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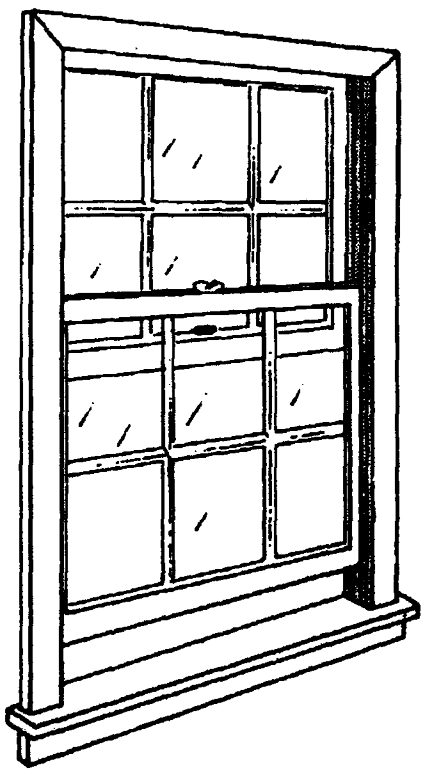
An Investigation Conducted by:
Brookhaven National Laboratory
Upton, New York



# USER DATA PACKAGE
# Energy-Efficient Windows and Window Coverings for Naval Housing





***ABSTRACT*** This User Data Package (UDP) identifies energy efficient windows and window coverings for housing applications. Procedures to determine the life cycle cost effectiveness and payback period for energy-efficient windows is provided. It is recommended that PVC, double-glazed, low-emissivity coated windows be used for all new housing construction in areas where heating and/or cooling is required. It is also recommended that energy-efficient windows be used when old windows are replaced in existing housing.

**NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043**

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13. ABSTRACT *(Maximum 200 words)*

This User Data Package ~~(UDP)~~ identifies energy-efficient windows and window coverings for housing applications. Procedures to determine the life cycle cost effectiveness and payback period for energy efficient windows is provided. It is recommended that PVC, double-glazed, low-emissivity coated windows be used for all new housing construction in areas where heating and/or cooling is required. It is also recommended that energy-efficient windows be used when old windows are replaced in existing housing. Keywords:

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## NOTE

A videotape describing available options is being prepared. This 30-minute videotape in VHS format will be available by October 1990. Please forward your comments on this UDP along with a request for the videotape to:

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Port Hueneme, CA 93043-5003

# FOREWORD

This User Data Package (UDP) was prepared by Brookhaven National Laboratory after a review and assessment of the vast amount of published literature, available technical research reports, and other material that concern the topic of energy-efficient windows and window coverings. Information was also obtained through communications with representatives of the window industry and window trade associations, whose input and assistance were of great value. This work effort was funded by the Naval Civil Engineering Laboratory, Port Hueneme, CA and was conducted under the auspices of the U.S. Department of Energy.

The UDP was developed to provide an information base on commercially available energy-efficient windows and window coverings, and is intended for use by Naval housing offices and maintenance personnel who are directly involved with the procurement, installation, and maintenance of windows in residential Naval housing. The purpose of the UDP is to supply users at the local activity level with the background necessary to make an informed decision on the selection of energy-efficient windows and window coverings for retrofit or for new construction of Navy housing.

A basic implementation process is described in Chapter 1 of the UDP, which outlines the procedure for selecting, procuring, installing, and operating thermally-efficient windows and window coverings. Chapter 2 provides some general information on the types of windows and window coverings considered for the purpose of this UDP. Chapter 3 discusses the window and window covering options that are currently available, and their suitability for Navy housing. Chapter 4 provides general guidance on the planning and selection of thermally-efficient windows and window coverings. In this chapter, a Field Survey sheet is also presented, along with Worksheet forms, which are to be used prior to conducting an economic analysis. The survey sheet facilitates the evaluation of the existing window stock in the building. The worksheets serve as a method of calculating the potential savings from a window retrofit option, in comparison to the windows already in place. An example is included in this chapter to illustrate how the sheets are used, and life-cycling costing techniques are also shown. In Chapter 5, a summary of recommendations for the selection of windows and window coverings for Navy housing is given, and suggested inputs to various Navy documents are outlined. Finally, Chapters 6 and 7 discuss general procedural guidelines for the installation, maintenance, and operation of energy-efficient window and window covering options.

The selection of energy-efficient windows and window coverings, supported by a cost/benefit analysis, can effectively reduce the energy consumption for space heating and cooling in residential-type Naval housing. Considering that an estimated 90,000 housing units in the Navy and Marine Corps inventory currently exists today, the potential for cost and energy savings can be significant. For more information on this report, please contact:

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# ACKNOWLEDGEMENTS

The preparation of this User Data Package was made possible with the help of several individuals at Brookhaven National Laboratory who have contributed to the development of this document. I would first like to thank Ruth T. Coughlan, BNL Staff Engineer, for the work she has done in writing and producing the UDP. I would also like to acknowledge Roger J. McDonald (BNL Deputy Division Head, Energy Efficiency and Conservation Division), Daniel Hagan (Engineering Studios), and Francine Donnelly (BNL) for their contributions in the preparation of this manuscript.

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# 1. GENERAL

## 1.1 INTRODUCTION

This User Data Package (UDP) was developed to provide an information base on commercially available energy efficient windows and window coverings and is intended for use by Naval housing offices and maintenance personnel who are directly involved with the procurement, installation, and maintenance of windows in residential Naval housing.

The purpose of the UDP is to supply users at the local activity level with the background necessary to make an informed decision on the selection of energy efficient windows and window coverings for retrofit and new construction of residential-type Navy housing. With this goal in mind, the UDP seeks to do the following:

- to provide Naval housing personnel with a general overview on basic window and window covering function and performance,
- to provide guidance for replacement of existing windows and window coverings,
- to assist Naval housing personnel in evaluating the energy-savings potential of selected window and window covering options, and guide them through a cost vs. benefit exercise, and
- to recommend modifications to various Navy Design Manuals with regard to selection of thermally-efficient windows and window coverings.

The UDP covers this information in several chapters. Chapter 1 introduces the Implementation Plan which outlines the procedure for selecting, procuring, installing, and operating thermally-efficient windows and window coverings. Chapter 2 provides information on all types of windows and window coverings considered for the purpose of this UDP. Chapter 3 discusses the window and window covering options that are currently available, and their suitability for Naval housing.

Chapter 4 provides general guidance on the planning and selection of thermally-efficient windows and window coverings. This chapter also presents a Field Survey Sheet as well as Worksheet forms which are to be used in evaluating the energy-savings potential associated with replacing existing windows with energy-efficient units. An example is included in Chapter 4 to illustrate how the sheets are used, and life-cycle costing techniques are also shown.

In Chapter 5, a summary of recommendations for the selection of windows and window coverings for Navy housing is given, and recommended modifications to various Navy documents (NAVFAC DM-35, NAVFAC DM-11.1, NAVFAC DM-33.02, NAVFAC DM-36.2, and NAVFAC P-455) are outlined. Finally, Chapters 6 and 7 discuss general procedural guidelines for the installation, maintenance, and operation of energy-efficient window and window covering options.

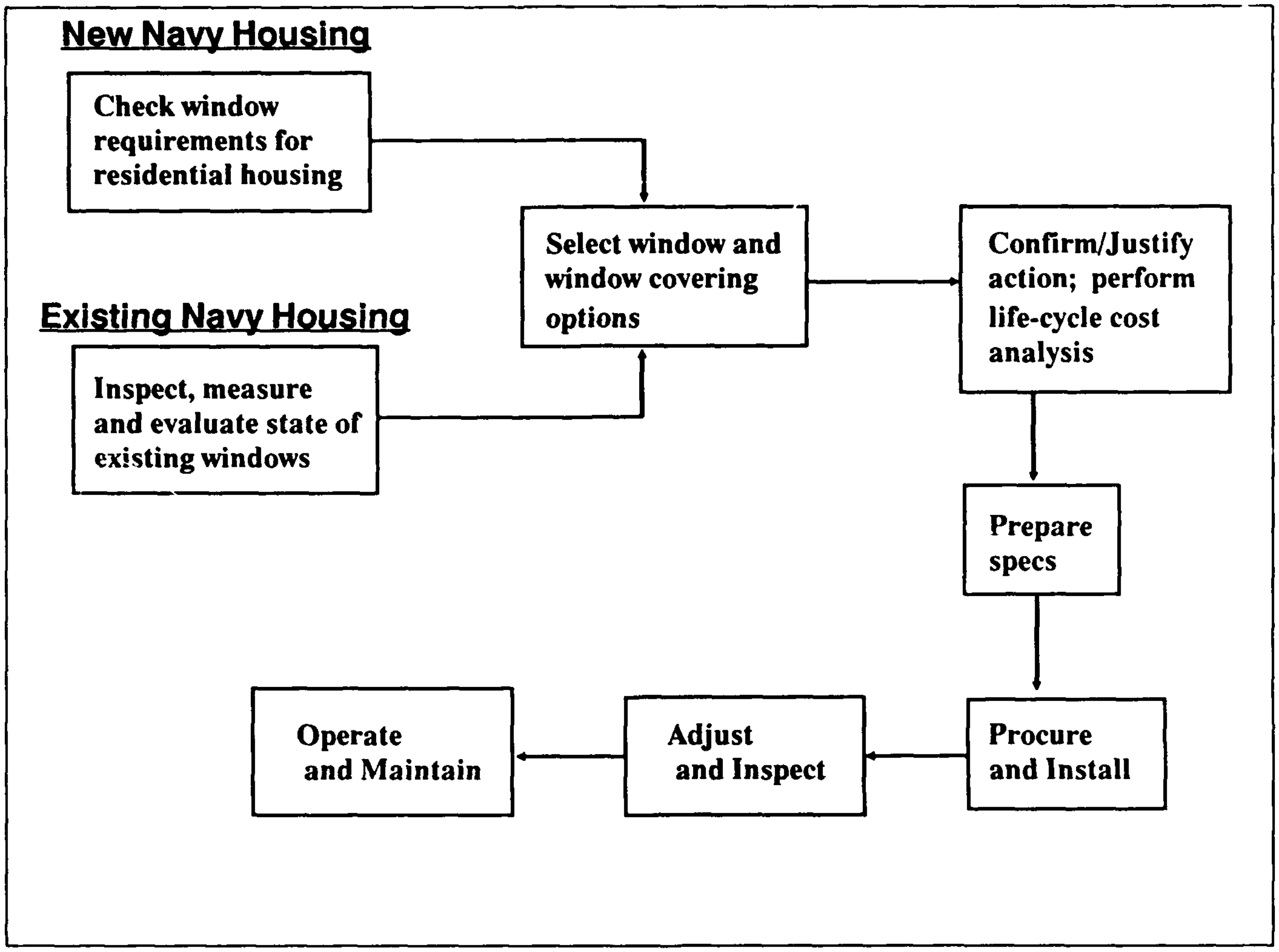



**Figure 1. Implementation Plan Flow Diagram**

## 1.2 IMPLEMENTATION PLAN

This section of the UDP is designed to support the implementation process for the selection of energy efficient window and window coverings for both retrofit and new construction applications for Naval residential housing. The implementation plan involves a multi-step process outlined in the flow diagram presented in *Figure 1*. The local activity housing office should direct and coordinate all phases of the implementation.

The replacement or retrofit of windows and window coverings in existing residential Naval housing should not be implemented without first assessing the condition of the currently installed window systems. Windows should also be inspected for type, sizes, age, condition of seals, and existing window treatments being utilized. Then the energy losses associated with the present windows and window coverings should be evaluated using tear-out survey and worksheet forms, included in Appendix A of the UDP. The work would be conducted by the public works maintenance staff (or contractor), and the results forwarded to the housing office for analysis and appropriate action.

In the case of new housing construction, the housing office, with appropriate support from the local activity public works engineering office and/or support contractors, would determine the proper orientation of planned windows and perform necessary calculations to decide the sizes of windows required as well as evaluate the various window options available. The resulting recommendations would again be directed to the housing office for analysis and appropriate action.

In new construction, or for existing housing requiring energy performance upgrade, various window options exist and should be compared to each other as well as to existing conditions in the retrofit case. The analysis would be based on energy savings potential, field data, and information provided in the UDP. The housing office should direct this analysis with support from the public works engineering office as required.

All available options in energy efficient windows and window coverings should be examined. Thermal performance, suitability to the required application, and to a lesser extent, cost, should be used as the basis for comparison for new housing construction. The specific window and window covering type would be selected and the various manufacturers would be determined. Life-cycle ccsts for replacing existing windows and window coverings is required for the retrofit case. The analysis is based on savings-vs.-investment economics, and the technique is presented in this UDP (Chapter 4.3 and Appendix B). If the replacement action predicts sufficient energy savings, as compared to costs, the recommendation would be made in favor of window system replacement and/or upgrade; if not, a no-action recommendation would result.

The next step would be to prepare window system specifications for purchase of the materials selected and their installation. This would again be coordinated by the housing office with technical support from public works engineering and maintenance offices. All materials, parts, and accessories must be checked for completeness, defects, and/or compliance to specifications prior to the installation procedure. The installation of the windows and/or window coverings would be conducted by either the public works maintenance staff (for replacement only) or contractors (for new construction and/or replacement) as required by the existing availability of staff and its allocation to various work projects by the local activity command. If the work is contracted out it would be coordinated through the public works maintenance and housing offices. The installed window system will then be inspected with regard to proper installation, work quality, and acceptability. Window coverings should be inspected and adjusted as needed.

Finally, the units would then be operated by the Navy occupants and their families, and future maintenance with regard to cleaning, repair, or associated upkeep will be the responsibility of the housing office and public works maintenance office on an "as-required" and/or scheduled basis.

# 2. FUNCTION AND PERFORMANCE OF WINDOWS AND WINDOW COVERINGS

Windows are an important element in building design, but they can also contribute significantly to energy loss in buildings. It has been estimated that approximately 5% of the total U.S. energy consumption or the equivalent of more than 1.7 million barrels of oil per day, is used to offset heat lost through poorly insulated windows.[1]

In Navy and Marine Corps residential housing, preliminary estimates show that the energy loss through windows can represent as much as a million barrels of oil a year. This is partially attributed to the fact that most of the Navy's existing residential windows are non-weatherstripped, uncoated, and single-paned, and thus, inefficient by today's standards. In addition, most existing windows are outdated, having reached or gone past their estimated lifetime, leading to imminent window failure and/or drastic performance inefficiencies due to loose or broken sash or frame components.

In order to minimize energy losses, as well as operating and maintenance costs associated with old and inefficient windows, existing units in residential Navy housing could be replaced and upgraded. New high performance windows have been made available in recent years, with up to 4-5 times greater thermal efficiencies than conventional single-paned windows. In addition to higher-performance windows, a variety of window treatment options such as insulated shades, drapes, and blinds are also available for reducing heat losses and for controlling heat gain. It is estimated that through the proper selection and use of energy-efficient windows and window covering products, the potential for substantial savings due to decreased energy costs can be realized by the Navy for both retrofit and new housing construction applications.

Prior to selecting energy efficient windows and window coverings, however, it is important to know what options there are, how they operate, and what they can do to minimize heat losses.

## 2.1 WINDOWS

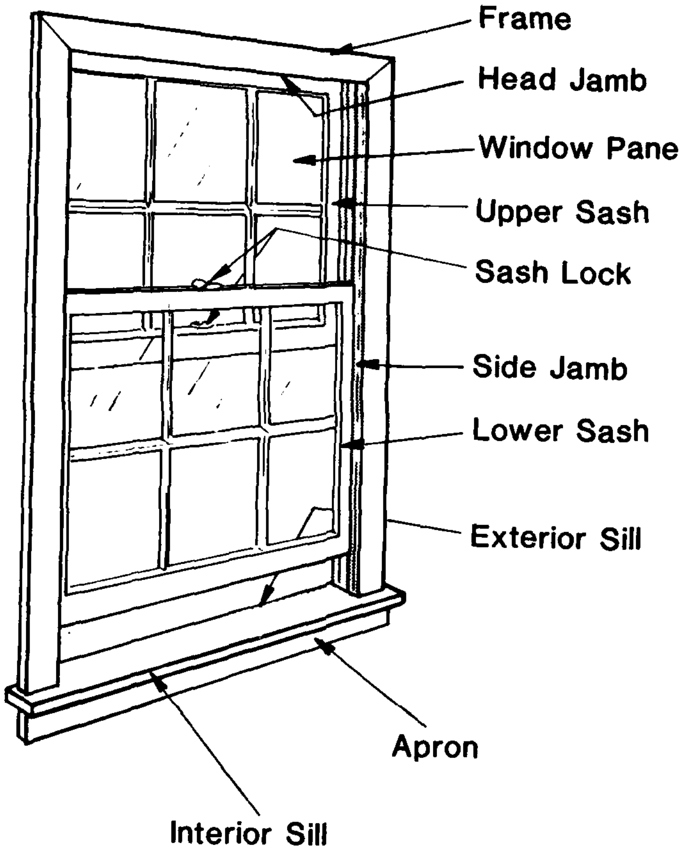
### 2.1.1 Function

The windows in a building serve many purposes. They admit daylight, permitting natural illumination into the home. They provide thermal comfort to occupants by keeping out the cold in winter, and allowing natural ventilation in summer. They also provide a view of the outdoors, as well as providing an exit in case of emergency.

Although there are practical advantages to having a window, there are certain disadvantages as well. Windows are not perfect seals against the cold since glass insulates very poorly; thus, they contribute greatly to heat loss. And while heat gain during the winter is welcomed, excessive heat gain during the summer is undesirable, as it causes overheating and can increase the air conditioning load.

**Figure 2.**

THE ANATOMY OF A WINDOW




### 2.1.2 Window Components

There are several different components that are used in assembling a window during its manufacture. Illustrated in Figure 2 are some of the various components that make up a typical window.[2] Descriptions of some of these window components are also listed below. These descriptions are common in the trade, and are provided here for reference purposes only.

- Frame - The part of a window unit which encloses the glazing and sash. The frame members are:

  Head Jamb - Top frame member
  Sill - Bottom frame member
  Side Jamb - Side or vertical frame member

- Window Pane - The glass portion of the window unit, also called "glazing"
- Sash - The operating part of a window unit; sash can be movable or fixed

### 2.1.3 Types of Windows

There are several different types of windows available. Shown below are some of the most common types of windows in residential buildings and a brief explanation of how they operate.

#### a. Double- or Single-Hung Window

Hung windows operate vertically *(Figure 3)*. They offer the advantage of a wide opening with no projection inward or outward when opened. However, for single-hung and double hung windows the opening will be less than 50% of the total window area. In double-hung types, both an upper and lower sash operate, permitting ventilation at the top, bottom, or both. Single-hung windows have a fixed top sash, so that only the bottom half of the window can be opened. Some hung windows are also available with a tilt-in sash, so external glass can be easily cleaned from the inside.

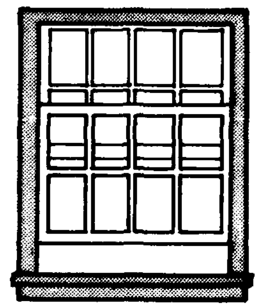


**Figure 3. Double-Hung Window**

#### b. Sliding Windows:

Sliding windows operate horizontally *(Figure 4)*. The simplest window unit is a single-slide, where one sash is fixed and the other slides. When both sash can slide open, the unit is classified as double-slide. Sliding windows, like hung windows, do not have sash that project in or out when opened. The maximum opening will be less than 50% of the total window area.

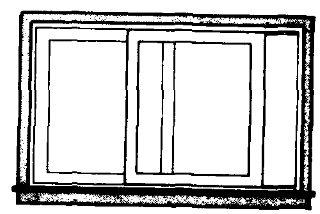


**Figure 4. Horizontal Slider**

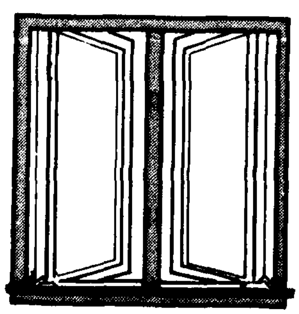


**Figure 5. Casement Window**

#### c. Casement Windows:

Casement windows consist of a single sash hinged at one side to swing vertically in or out *(Figure 5)*. Opening and closing may be done manually by a crank or a lever. Casement windows are commonly joined together to form larger windows with multiple hinged sash units or fixed sash (non operating components). Casements provide an opening nearly 100% of the total window area.

**d. Awning Windows:**

Awning windows consist of a single sash hinged at the top to open outward from the bottom, and is operated manually by a crank or a lever *(Figure 6).* Awnings can also have multiple ventilators arranged in a stack within a common frame. They provide an opening of nearly 100% of the total window area.

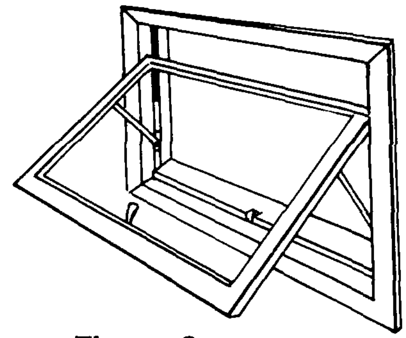


**Figure 6. Awning Window**

### 2.1.4 Window Heat Losses

Windows of all types are generally large sources of energy loss in buildings. The loss of heat follows many different pathways, such as through the glass panes, through the whole frame of the window, and through large cracks at the edges of the glass, sash, or frame. Heat is generally transmitted by several methods, namely by conduction, convection, radiation, and by air infiltration. *(Figure 7)*

When there is a temperature difference across a window, heat will flow through the window materials from the warm side to the cold side. The greater the temperature difference between the inside and outside, the faster heat will flow. The rate of heat flow through the window is determined by a combination of conduction, convective and radiative heat transfers, and overall heat transfer rate is referred to as the window's **U-value**. This is the heat transferred through one square foot of window area in one hour when the temperature difference across the window is one degree Fahrenheit.[3] In general, the lower the U-value, the better the insulating property of the window.

The reciprocal of the window's U-value, or 1/U, is called the window's **R-value**. The R-value refers to the thermal resistance of the glass and frame; thus, high R-values mean greater resistance to heat transfer. The higher the R-value, the better the insulating property of the window.

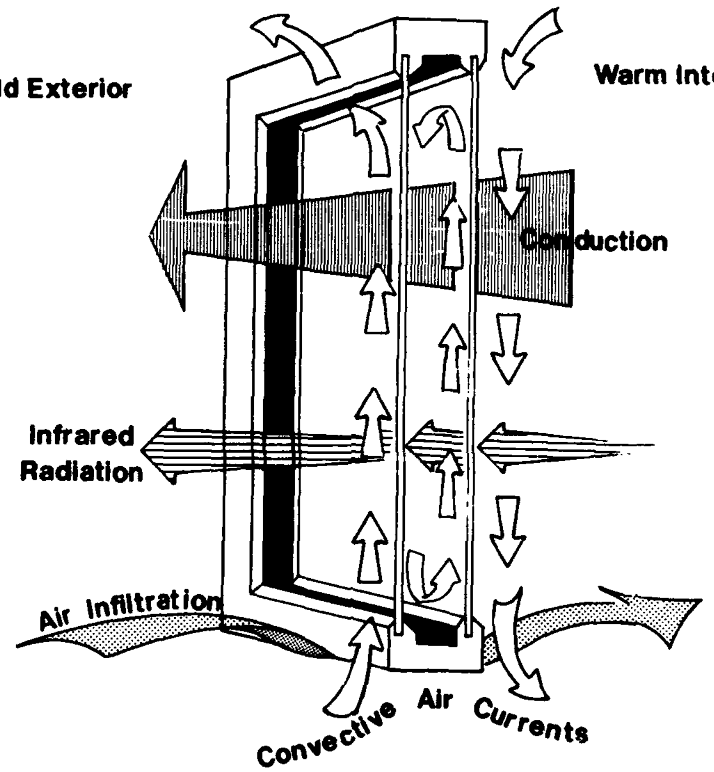
The total R-value of a window relies partly on the choice of material used for the frame. Metal, such as steel or aluminum, wood, and vinyl, all conduct heat at different rates; of these, metal frames have the propensity to lose the most heat. The R-value of a window is also dependent on the glass, its glazing thickness, the number of glazings, and the space between them. Since glass is a poor insulating material, it tends to conduct heat very quickly. To slow down heat flow, multiple glazings can be used to provide additional air spaces. Wider air space gaps also tend to increase a window's R-value, but only to a certain extent.

Heat is lost not only through the window frame and through the center of the glass area, but also through the glass edges. These "**edge effects**" are influenced mainly by the metal spacer which separates the glass panes in an insulating glass system.[4] Thus, the R-value at the edge of a sealed insulating glass unit is considerably lower than the R-value at the center of the glass. It is the R-value of the complete window that is the best indicator of total unit thermal performance.

It is important to note that the quality and performance of windows vary widely from manufacturer to manufacturer, and therefore, should be evaluated based on available test information to allow more realistic comparisons. In addition, manufacturers often list calculated R-values to demonstrate window thermal performance, which may not accurately reflect true field performance. Again, available test information with measured data of whole window performance would be of use.

**Figure 7.**

**WINDOW HEAT LOSS**




*In winter, windows lose heat by conduction, convection, air infiltration, and radiation. Warm indoor air loses some of its energy to the interior glass surface by conduction and convection. This energy is transmitted to the glass by conduction, and is subsequently transferred from the interior glass pane to the exterior glass pane by convective air currents moving between the two panes. This process is repeated at the exterior glass pane, as shown above.*

*Infiltration is the flow of air through gaps in the window unit. Infiltration can occur by loosening or fraying of old weatherstripping, lack of caulking, improper window fitting, or through loose or broken sash components.*

*Radiative heat loss occurs when interior objects give off energy in the form of infrared waves. Heat radiates from room objects to the window glass, is absorbed by and conducted through the glass, and then radiates to the cooler outdoors.*

Radiant energy is given off by warm bodies. When radiant energy strikes an object and is absorbed by it, the radiant energy heats the object. This process of heat transfer is referred to as **radiation.** Windows can gain heat through solar radiation. Solar energy is absorbed by the objects inside a room, which warm up and which then re-radiate the heat. Much of this re-radiated heat is at longer wavelengths and it remains trapped in the room, and is of great advantage during the winter months. However, excess heat gain during the summer can be a problem since it makes the room too hot for comfort and increases the need for more air-conditioning, thus increasing the building energy consumption.

Window coverings which help to shield the interior from summer solar heat gain can help significantly in reducing the cooling load in the building. Window coverings that provide the greatest shade will have a low shading coefficient value. The **shading coefficient, or S.C.**, is a measure of a product's ability to exclude the heat gain associated with solar radiation. S.C. is a number between 0 and 1.0, which is the fraction of solar heat gain compared to that admitted by clear single glazing. A clear single-paned window has an S.C. of 1.0, while a totally shaded window would have an S.C. of 0.

Winter heat loss through radiant heat transfer can be also be controlled by the use of **low-emissivity or "low-e"** coatings, a special coating on glass designed to reflect long wave heat radiation. The term **"emissivity"** refers to the ability of a surface to transmit radiation. A perfect radiator, called a blackbody, transmits all radiation and reflects none. On a scale of 0 to 1, its emissivity value would be 1. Ordinary window glass has an emissivity as high as 0.84. On the other hand, low-e glass can have emissivities between 0.05 and 0.40. This means that low-e glass will transmit much less heat radiation, because it reflects between 60 and 95 percent of the radiant heat back toward its source. Generally, the lower the emissivity of the glass, the higher the window's R-value.

**Air infiltration** is caused by the leakage of air through cracks around the glass, sash, or frame of a window, and is a major source of heat loss for windows that do not have good seals. For poorly-fitted windows, it is possible that, under certain conditions, the energy loss due to air leakage can exceed the energy loss due to conduction. The rate of air infiltration is largely dependent on the size of the crack and the direction and speed of the outside wind. It is normally expressed as cubic foot of air per minute per foot of crack length (cfm air/ft. crack), and is based on a nominal average wind speed. Air infiltration rates should always be minimized to avoid excessive heat loss, and can be controlled by proper window installation, weatherstripping, and caulking.

Planning the location of windows in new homes is also an area where energy savings can be obtained. The orientation of windows in relation to the summer and winter sun have a lot to do with how much heat gain and heat losses occur through the window area. In winter, the path and angle of the sun are lowest. In summer, the angle and path of the sun are highest. Southerly-facing windows receive the greatest amount of solar radiation during the winter months and a lesser amount during the summer. By concentrating living spaces and windows on southeast, south, and southwest facing walls, one can take practical advantage of the winter heat gain from the sun.[3] Beneficial use of the sun, by maximizing solar radiation in winter and minimizing solar radiation in summer, can affect both energy costs and comfort in a positive way.

(A further discussion of window heat loss is presented in Appendix C, along with derivations of expressions used to calculate annual energy losses through windows.)

## 2.2 WINDOW COVERINGS

### 2.2.1 Function

Window coverings are primarily used to control winter heat losses and summer heat gains. In winter, uncovered windows are responsible for much of the heat lost in a typical home. In summer, excessive heat gain can cause increased space-cooling requirements. Properly used interior window coverings can help to minimize the energy losses.

Window coverings also influence many other factors that contribute to the indoor environment. Shading devices provide privacy by controlling inward vision from the outside, and can alter visual comfort to the occupant by cutting down brightness or glare.

This ability to control the admission of heat and light through windows has frequently been called "window management". Several different kinds of window management devices have been in the market for years, and some novel, more energy-efficient products have recently been introduced that offer improvements in thermal performance. Devices with edge sealing have become a popular idea, as this provides a tight fit around the window perimeter, which serves to reduce air leakage, decrease convection, and cut down on condensation formation.

Window coverings can improve the thermal performance of windows year-round. However, in order for coverings to work properly, they must be opened and closed at the appropriate times during the day and all throughout the year to realize their full benefits. A system must fit into living patterns--it must be used diligently.[6] This implies a high degree of occupant responsibility.

Since energy-efficient window coverings are so user-intensive, *it must be stressed that the best types to choose are those that can most easily blend in with the occupant's habits and lifestyles. This will ensure a greater motivation on their part for frequent operation and proper use, which can in turn lead to higher energy savings for the Navy.*

Shown below are some common examples of window coverings currently available on the market , and a brief description of how they operate.

## 2.2.2 Types of Window Coverings

### a. Venetian Blinds

This type of window covering consists of parallel slats or louvers which function in two ways: 1)change angles to control sunlight, and 2)stack when drawn open or raised, and unstack when drawn closed or lowered. In the case of vertical blinds, blinds are drawn open and closed in sideways direction. Aluminum, steel, wood, plastic, and fabric blinds are commonly available. *(Figures 8a and 8b)*

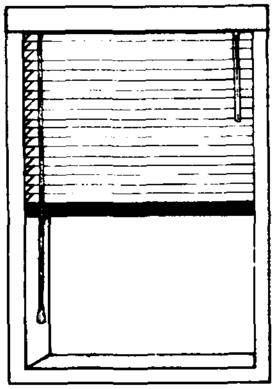


**Figure 8a.**
**Horizontal Blinds**

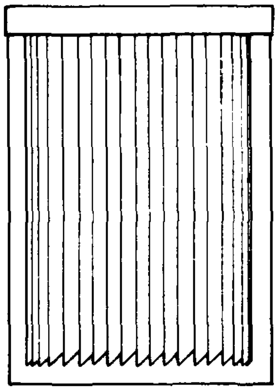


**Figure 8b.**
**Vertical Blinds**

### b. Drapes

Drapes are one of the most common types of window coverings used in most homes. These are usually mounted at the top of the window, and part in the middle when opened *(Figure 9)*. Drapery is generally made of fabric with varied weaves, with the most opaque drapes being those with the tighter weave.

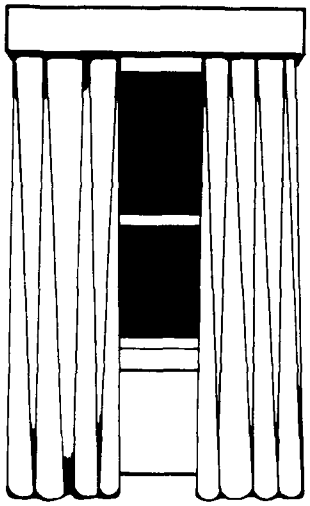


**Figure 9.**
**Drapes**

## c. Shades

Roller shades roll up or down on metal rollers mounted on top of the window *(Figure 10)*. The simplest version is a shade made from a single layer of non-permeable vinyl, although translucent or opaque fabrics, quilts, metallized films, and fiberglass shades have also been made available.

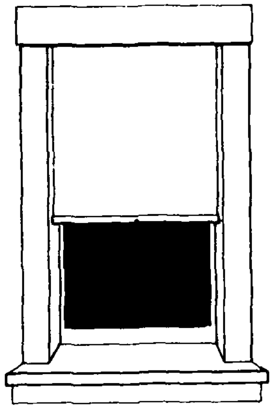


**Figure 10.**
**Window Shades**

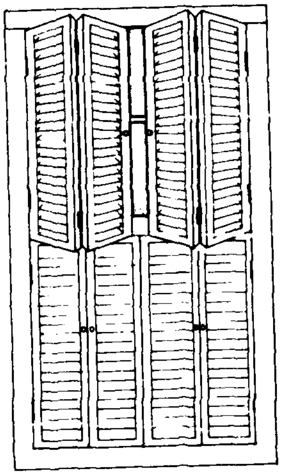


**Figure 11.**
**Louvered Shutters**

## d. Shutters

This type of window covering consists of louvers or slats that are mounted on a frame. Two frames are generally fastened on the sides of the window area with hinges, and can be opened or closed by parting the frames in the middle or pulling them back together. Indoor shutters are usually wooden fold-out types, with louvers that move for greater control of light or air. *(Figure 11)*

Another interior-type of shutter is the insulated shutter, which is constructed of insulation material, such as styrofoam, polyester batting, or fiberglass, sandwiched between two sheets of plywood, cardboard, or masonite. *(Figure 12)*

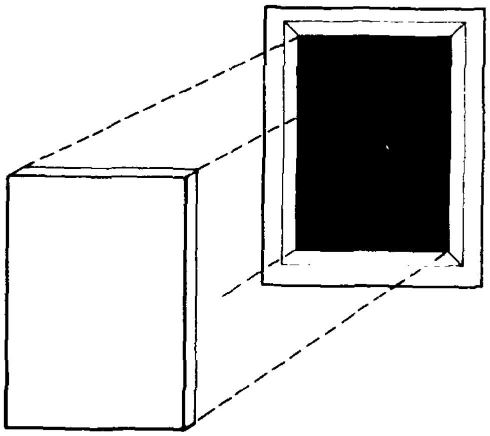


**Figure 12.**
**Insulated Shutter**

# 3. GUIDE TO ENERGY-EFFICIENT WINDOW AND WINDOW COVERING OPTIONS

## 3.1 ENERGY-EFFICIENT WINDOW OPTIONS

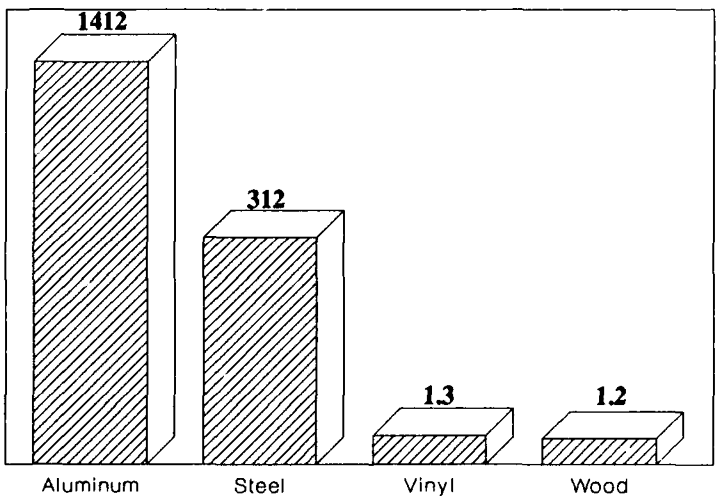
Windows can be a significant source of home energy loss if they are not thermally efficient or properly installed. In order to maximize energy savings, windows should be carefully selected based on frame and glass materials, their thermal performance (or R-values), their suitability for the local climate conditions, durability, and maintenance requirements. The following information is provided to facilitate selection of the most energy-efficient windows.

### 3.1.1 Frames

Several different types of window frame materials are used in residential building construction. Wood, aluminum, steel, and vinyl are all widely used, as well as "cladded" frames, which combine the look of two different materials in the interior and exterior parts of the window frame. All have different thermal performances, as illustrated in *Figure 13*. Figure 13 shows the relative rates of heat loss for four types of materials: wood, aluminum, vinyl, and steel. As seen from the figure, aluminum has the ability to lose the most heat, followed by steel, vinyl, and wood.

**Figure 13.**

Relative Rate of Heat Loss
(in BTUs per Hour)*




* *Heating, Ventilation & Air Conditioning Guide. American Society of Heating, Refrigerating and Air Conditioning Engineers; Test procedure ASTM C-177, American Society of Testing and Materials.*

Discussed in the following sections are some of the most common types of window frame materials available today, and a brief discussion of their relative advantages and disadvantages.

## a. Wood Frames

- **Advantages**

By far, the oldest and most common type of window framing material is wood. Wood is a natural insulator and has the lowest rate of conductive heat loss of all framing materials available. When comparing the thermal performance of frames, wood has one of the highest R-values. Looking back at Figure 13, the relative heat loss rate through wood is less than 0.1% of that through aluminum. Thus, interior wood surfaces feel relatively warm to the touch when it is cold outdoors, unlike metal surfaces, which are noticeably colder to the touch.

Years ago, wood windows were crafted to fit the opening of the wall, but they were subject to air leakage in the cracks around their edges, and their frames were not treated to resist deterioration. Wood windows have come a long way since then in being a more energy efficient window. Modern, quality-made wood windows have built-in weatherstripping to reduce air infiltration to a minimum. Factory-installed weatherstripping fits tightly around the window, provides protection against the cold, and seals in comfort.

The aesthetic value of wood windows have played a large role in affecting the interior and exterior looks of a home, as well as affecting the comfort of occupants. On the interior, wood lends a warm, natural look, and can be painted to match the room, or stained to accent the wood grain.

Considering original installations, wood windows are easiest to saw, mill, or fit. Wood windows are relatively light, and therefore, easy to handle and cheap to transport and install. They are also easy to procure due to their widespread availability.

- **Disadvantages**

Wood as a framing material for windows has certain inherent disadvantages. Although it is the most aesthetically pleasing material, it is a high-maintenance material, requiring a high measure of care to preserve its quality and integrity. Due to the nature of its interior cellular structure, wood tends to absorb moisture and swell, and is particularly a problem under high humidity conditions, which is not uncommon around Navy bases. Swelling can affect the window by causing it to stick when opening or closing, and may also affect the installation procedure. If the window is installed under warm, humid conditions, tight ones may leak in the winter. If they are installed in winter, they may be difficult to close during the summer.[7] The repeated expansion and contraction of wood due to moisture absorption, if it goes untreated, can become more of a problem as it may cause warping. This is an important factor especially in hot humid climates.

During the colder months, high indoor humidity will cause condensation to form on glass panes. There are instances where water literally runs off the windows and are said to "sweat". Moisture which drips onto painted wood frames and sills promotes premature cracking and peeling of the paint, requiring more frequent maintenance. Moisture on wood would also promote mildew, causing wood discoloration. Further, untreated wood is prone to attack by insects such as termites. Prolonged damage by either humidity or infestation will make wood susceptible to rotting and eventual deterioration.

Wood preservatives, water-repellent finishes, and paint are all adequate surface treatments; however, these must be applied diligently not just once, but periodically over the life of the wood frame. Failure to upkeep the surface of wood will surely promote some deterioration or damage to occur that will shorten the life of the frame, as well as compromise the performance of the window. Higher maintenance needs will imply additional costs, which must be considered when selecting a wood-framed window.

In addition to high maintenance, wood also takes up more space than aluminum -- about three times as much for most units. For a given opening, this means less glass for the same window area, and less solar gain.[8]

## b. Aluminum Frames (without Thermal Barrier)

- **Advantages**

Aluminum windows have maintained their popularity in the building industry, primarily because they are economical to build and install. Aluminum is an abundant material, cheap to extrude, and has had price stability in comparison to wood. Unlike wood, aluminum requires little or no maintenance because it doesn't absorb moisture; therefore, aluminum frames won't warp, rot, or swell.

Another advantage is aluminum's greater strength to withstand load stresses. Thus, for the same rough wall opening, about one-third less aluminum frame is needed for the window compared to wood. This means more glass in the aluminum window for providing a bigger view, and more of an opportunity for increased solar gain.

- **Disadvantages**

The main disadvantage of aluminum is its high thermal conductivity. Aluminum conducts heat faster than any other window material; compared to wood, it loses heat over 1000 times as fast. Therefore, its poor thermal performance renders it highly energy-inefficient, and a poor choice for Navy housing. Condensation is also a problem with aluminum frames. During winter months in northern regions, the wide temperature difference between outside and inside, coupled with relatively high humidity in the interior, causes moisture in the inside air to collect on glass and frames. A not uncommon result is water damage to the window sills, flooring material and draperies.[9]

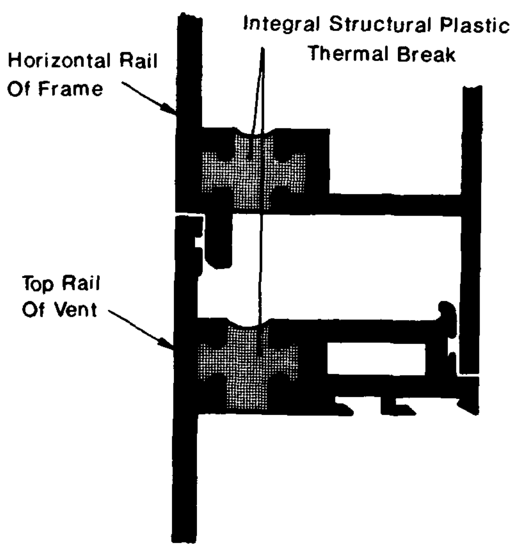
In addition, bare aluminum frames are subject to pitting and corrosion in coastal areas where they are constantly exposed to moist salt air, thus affecting their long-term durability. Since Navy bases are often located on coastal locales, aluminum windows would not be practical to use. Measures can be taken to improve the aluminum surface, such as electrostatic application of an acrylic polyester enamel paint or application of an anodized finish; however, this increases the maintenance requirements of the window, and adds to its original cost.

### c. Aluminum Frames (with Thermal Barrier)

- **Advantages**

Modern aluminum windows have been made more energy-efficient by blocking the path of heat flow through the interior and exterior parts of the aluminum frame. This is accomplished by adding a "thermal barrier" --such as rigid vinyl or polyurethane -- which is added in to eliminate any metal-to-metal contact.[10] The thermal barrier maintains the frame's strength and stability, while improving the window's thermal performance. Thermal barriers are also referred to as "thermal breaks", and aluminum frames which incorporate thermal breaks are referred to as "thermalized" or "thermally-broken" windows *(Figure 14).*

The big advantage of thermally-broken aluminum windows is their increased thermal resistance as compared to non-thermally broken aluminum window units. Thermally-broken frames will reduce the heat loss through the frame and lessen the likelihood of condensation problems.




CROSS SECTION OF A TYPICAL THERMAL BREAK

**Figure 14.**

- **Disadvantages**

Aluminum frames with thermal barriers are generally more expensive than conventional aluminum-frame windows and although their thermal resistance is higher than non-thermally broken aluminum frames, they still conduct more heat through the sash than wood or vinyl-framed units.

Another big disadvantage is that the location of most thermal barrier connections occur in the same plane as the wall cavity of most wall construction. Thus, water leakage into these areas can damage the thermal break and can be very difficult to detect.[11]

As with conventional aluminum frames, the aluminum surface of thermally-improved windows is still subject to pitting and corrosion upon prolonged exposure to salty sea air. This implies that aluminum windows will not endure in coastal areas, and for this reason, would not be practical for use in Navy installations.

## d. Vinyl Frames

- **Advantages**

Vinyl windows have been commercially available in the U.S. since the mid-1960's. Vinyl used in window manufacture contains additives to give elastic and stuctural strength to take the strain of expansion and impact. They are also modified to control the effect of ultraviolet light.

Also referred to as PVC (polyvinyl chloride), vinyl offers several compelling advantages over aluminum and wood windows. The main advantage of vinyl is that *it is a low-maintenance product with excellent thermal properties*. The thermal conductivity of vinyl is nearly as good as wood. As shown in Figure 14, the R-value of vinyl closely approaches the R-value of wood. Similar to wood, vinyl frames conduct less heat out of the house and prevent condensation from forming on the inner frame.

The extreme durability of vinyl windows for outdoor weathering has become well-established through many years of successful application.[12] It is strong, abrasion-resistant, and chemically inert. Its surfaces will not chip, flake, rust, blister, or peel. It also does not swell, shrink, warp. Vinyl also does not stick like wood windows can, as their moving parts slide together with ease.[13]

Perhaps the biggest advantage with using vinyl is that it is virtually maintenance-free. While wood requires painting and may lend itself to damage by termites or wood rot, vinyl is immune to rotting, is not prone to insect damage, nor does it ever require painting. Vinyl *never* needs to be painted because it is self-colored, meaning that the color is locked in the material. In addition, a vinyl surface wipes clean with ordinary soap and water.

Vinyl also stands up better than aluminum. In comparing their thermal performance, vinyl is over 1,000 times better than aluminum in reducing heat losses. Furthermore, while bare aluminum can pit, corrode, and is subject to degradation along the sea coast, vinyl windows are unaffected by exposure to moisture, nor will salty sea air cause any corrosion to occur.

In an all-vinyl type window construction, the frame and sash are fabricated from rigid PVC extrusions, or lineals. Extruded profiles contain "chambers" that act as multiple dead-air spaces, which serve to block heat transfer and enhance the insulating qualities of the window. The chambered profiles also serve to drain water away from the edges of the sealed insulated glass unit and into the weep hole, decreasing the likelihood of condensation formation due to seal failure. In some instances, manufacturers employ a metal-reinforced vinyl instead of all-vinyl for larger-sized windows. Usually, a vinyl window whose width is above 36 or 38 inches will need to be reinforced in the sash rail with steel or aluminum for added strength and support.

Vinyl window corners can now be completely welded instead of mechanically fastened. Welded corners won't separate like the corners of wood or aluminum frames which are held together by screws or nails, and they add strength and ensure squareness of the installation. Because the extruded profile shapes do not vary from one to the other, parts to be welded mate virtually perfectly, making a weld that is neat, clean, strong, air and water tight, and can also withstand thermal movement.[14] A welded corner also provides enough stability to the frame such that in certain sizes of windows, the need for metal reinforcement is eliminated.

Finally, vinyl has the advantage of being a self-extinguishing material, such that in the event of a fire, the frame does not spread the path of the flame, and does not sustain burning, as wood frames will.

- **Disadvantages**

Vinyl has several virtues and attributes; however, as with all things, it also has some disadvantageous features. One consideration is the inability to find a wide color selection for vinyl window frames. Frequently, white and beige (or tan) are the chief colors offered by major manufacturers. The reason stems from the way in which the vinyl, or PVC, is formulated.

Current PVC formulations are quite sophisticated and employ various ingredients which enables the material to withstand effects of weather. One of the most important ingredients of PVC is titanium dioxide ($TiO_2$) which acts as a whitener and an absorber of ultraviolet (UV) light, the primary cause of weathering of PVC. Since PVC must be protected against the damaging UV rays, base levels of $TiO_2$ must remain high; therefore the most weather-resistant type of PVC has a white color from the $TiO_2$.

Limited quantities of tan and gray PVC are beginning to be employed in window products by adding weatherable pigments to standard high $TiO_2$ levels during the compounding. But for darker colors like brown, it is virtually impossible to overcome the whitening effect of the $TiO_2$ without adding excessive amounts of very costly weatherable brown pigments.[15] Manufacturers frequently coat the PVC lineal with a thin layer of weatherable brown PVC capstock instead. Even with this approach, the capping material must be specially formulated to have minimal heat buildup. Since darker colors tend to absorb more heat, care must be taken to ensure that heat buildup is minimized. If not, the resulting effect could mean that expansion or deflection of the vinyl frame is possible under extreme conditions.

Because of the lack of clear evidence that brown-colored PVC can maintain long life, or that it can be successfully used for windows in areas with hot climates, brown is <u>not</u> recommended as a viable color selection for windows in Navy housing at this time. White and beige vinyl windows appear to have a more successful track record in field applications, and therefore should be the colors of choice.

Manufacturer brochures should be examined with care as several companies identify colored vinyl products with their own particular brand names. Colors similar to brown may be referred in other ways (i.e., "Cocoa"," Terracotta","Bronze", etc.), thus it would be wise to look at the actual color of the product, or directly inquire the manufacturer for details.

### e. Vinyl-Clad Wood Frames

- **Advantages**

The interior surface of this type of frame has all the advantages of having an all-wood frame, such as natural beauty and an aesthetically pleasing appearance. The wood is generally constructed of clear pine and is factory treated with water-repellent and other preservatives. The vinyl sheathing gives the exterior surface protection from the environment and provides added durability. In addition, the frame typically has a high R-value comparable to wood and vinyl which suggests that its thermal properties are good; thus heat conduction is low.

- **Disadvantages**

The interior wood surface is subject to the same disadvantages likely for an all-wood window. It must be repeatedly and diligently maintained, either by painting or other preservatives, in order to keep it protected from the damaging effects of moisture and humidity. The exterior vinyl sheathing is also subject to the same disadvantageous features of vinyl, namely limited color availability.

### f. Aluminum-Clad Wood Frames

- **Advantages**

This type of window frame is composed of a wood interior with an aluminum-clad wood exterior. The interior wood member offers the natural beauty of wood, and the exterior surface is clad with heavy extruded aluminum for protection from weather and aging. The thermal resistance of this type of window frame approximates that of wood.

- **Disadvantages**

The primary disadvantage with aluminum-clad wood frames is the maintenance involved with the interior frame, and the susceptibility of the exterior to damage in coastal locales.

All interior wood surfaces will require higher maintenance due to the periodic painting or varnishing needed to protect the wood from damage caused by moisture or humidity. The exterior aluminum cladding, like an all-aluminum window, will be subject to limited life due to pitting and corrosion especially in seacoast areas where salty sea air is present.

### g. Vinyl-Clad Aluminum

- **Advantages**

This type of frame consists of an aluminum frame whose exterior is covered with a rigid vinyl sheath. The advantage of this type of frame is that the thermal properties are slightly improved due to the vinyl exterior where heat loss is minimized. The inner aluminum core provides structural strength and dimensional stability, as with an all-aluminum window frame.

- **Disadvantages**

Although thermal performance is improved over an all-aluminum frame, this type of a frame without a thermal barrier would still have unsatisfactorily low R-values as compared to vinyl or wood units. The vinyl exterior would have the same disadvantages as discussed earlier, and the aluminum interior would have the same disadvantages as for an all aluminum frame.

### h. Steel Frames

Steel-framed windows are the strongest of all available window materials; however, it has high conductive heat losses (over 200 times greater than vinyl). It is also very heavy and cumbersome to use, making it suitable only for limited applications. Steel is subject to rust if bare surfaces are exposed to the elements, and therefore, require frequent maintenance. Steel frames are inappropriate for residential Navy housing, and are not recommended.

### i. Fiberglass Frames

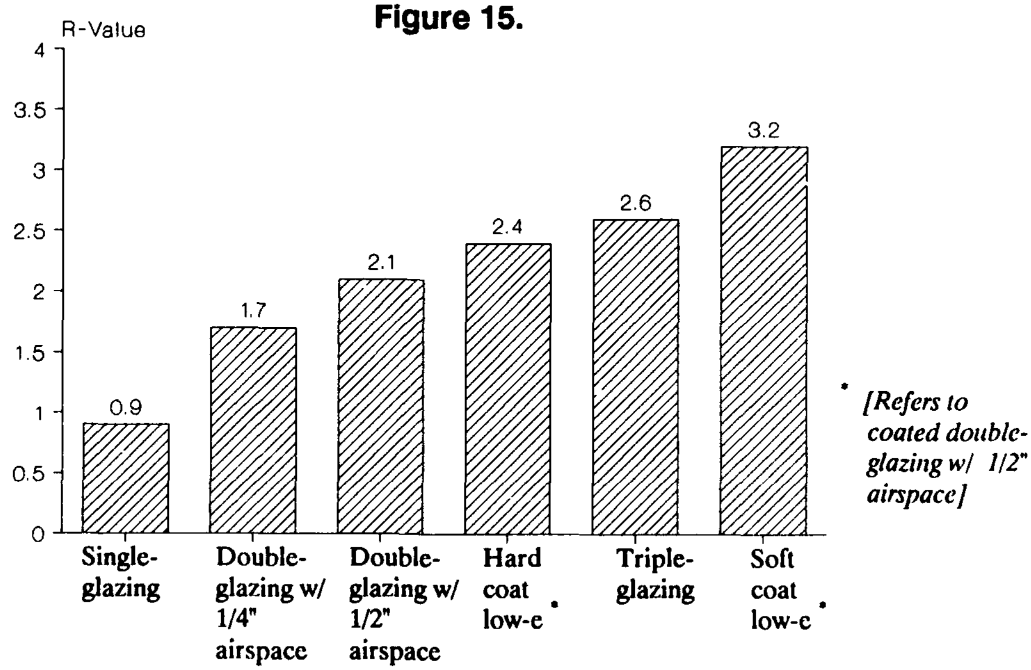
Window frames made of fiberglass are a recent introduction in the window marketplace. Fiberglass is a strong material, has a lower thermal expansion coefficient than vinyl, and comes in a variety of colors. However, since it is a completely different material, it requires innovative ideas for a successful window design. Some companies are now launching into developmental work in making fiberglass the next generation of replacement windows.[16] Forecasters agree that a few years will be required for fiberglass window frames to penetrate the residential sector, and for market acceptance to take place. Since fiberglass windows are relatively new and still currently under development, no recommendation for their use in Navy housing can be made at this time.

## 3.1.2 WINDOW GLAZINGS

The main functions of window glass are to provide daylighting, natural ventilation, and a view of the outdoors, all this while also trying to keep out the cold during winter and the heat in the summer. However, this is not an easy job for glass since it is such a ready conductor of heat; therefore, ways have been sought to try to impove the glass in order to minimize the potential for heat losses and heat gains. Several types of window glazings are available, and newer, more thermally-efficient glazing systems have been introduced recently. *Figure 15* illustrates the different types of glazing systems available and their nominal R-values. These systems will be discussed in the sections to follow.

COMPARING GLAZING R-VALUES

**Figure 15.**

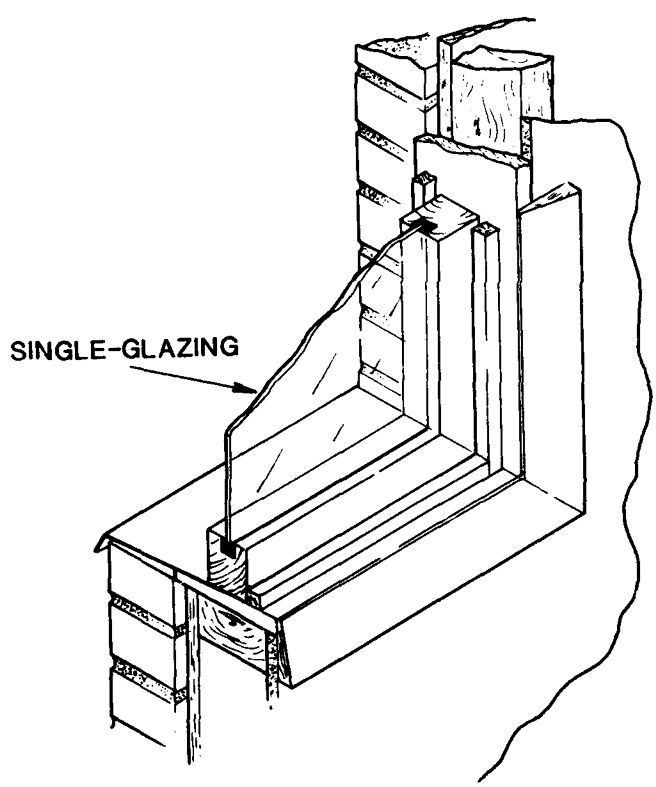


Glass that is used for windows is usually "annealed", having gone through a process that gives the glass added strength. In the annealing process, glass is cooled slowly as it exits the float line to minimize residual internal stresses. The glass is available in several thicknesses , i.e. 1/16- , 3/32-, 1/8-, 3/16-, and 1/4-inch thick. If the glass is less than 1/8-inch thickness, it is referred to as "single-strength" glass. If it is at least 1/8-inch thick or more, it is referred to as "double-strength". Windows that are within 12 inches away from a door or within 18 inches off the floor require the use of "tempered" glass, as specified by building and safety codes. Tempered glass is 3-5 times stronger than annealed glass and does not fragment into large sharp-edged shards when broken upon impact. Safety glass such as tempered glass is also a more expensive option, and must be specially ordered.

### a. Single-Glazing

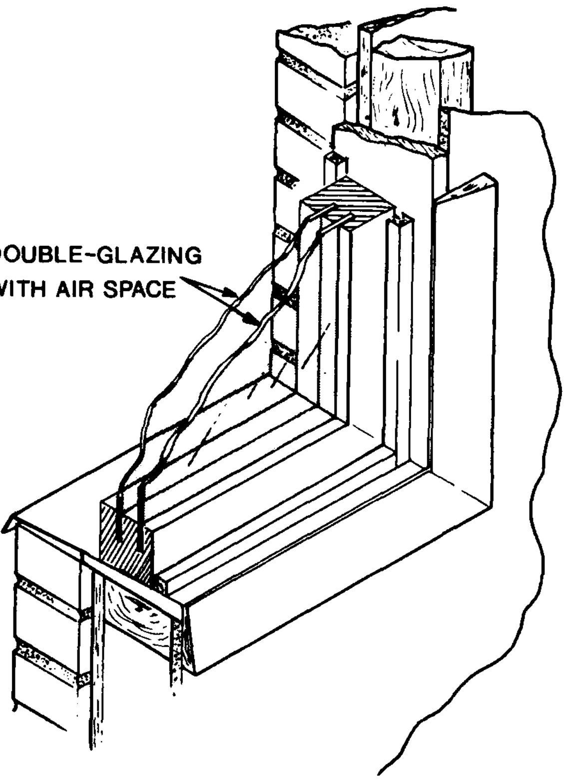
Single-glazing is defined as a window unit incorporating a single pane of glass *(Figure 16)*. If the glass is designated as single-strength, it usually is about 3/32-inch thick. If the glass is designated as double-strength, it has a thickness of 1/8-inch or more. Since the pane is only of a single thickness, it is recommended that double-strength glass be used for Navy housing rather than single-strength as a safety precaution against breakage.

**Figure 16.
Single-glazed Window Unit**




Single-glazed windows are clearer and more transparent than other glass systems because only one layer of glass exists, however there is a large energy penalty in that it loses the most heat. A single pane of window glass has an R-value of about 1.0, and therefore would conduct heat at a very fast rate. In cold weather, a person near the window would feel cold due to the window's high heat loss. Condensation is also often a problem during cold weather. Since the temperature of the interior glass side will be much lower than the room temperature, moisture in the warm room air will quickly condense on the glass panes. Condensation will not only affect outward vision, but can potentially damage frames, sills, drapery, or carpeting.

**Figure 17.**
**Double-glazed Window Unit**




## b. Double-glazing

Double-glazed windows incorporate two panes of glass in the window and is often also referred to as an "*insulating glass*" unit. The insulation provided by an insulating glass unit is not because of the glass, but due to the air space which exists between the two separate panes *(Figure 17)*.

Insulating glass is frequently the glass of choice for new housing construction and in the replacement window market. Since its R-value is about twice that of the single-glazing, the rate of heat loss is about half, and the temperature of the interior glass stays closer to the room temperature. This means greater occupant comfort, and also less condensation can form on the glass surface. In addition to better thermal performance, insulating glass also precludes the need for storm windows because the extra layer of glass is already built-in. This helps to eliminate any maintenance requirements or hazards involved with installing or removing the storm sash. Sound transmission is reduced through double-glazing, as well reducing the transmission of ultraviolet light which is responsible for fabric fading.

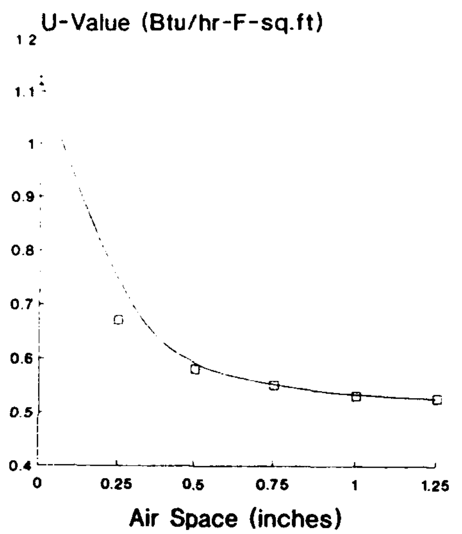
Insulating glass is factory-sealed around the edges to prevent moisture from getting in. Moisture, again, can be a serious problem since the space between glazings is inaccessible, and moisture can condense and block vision through the window. To prevent moisture entry, the insulating glass is usually sealed in one of two ways. One method is by permanently sealing the insulating glass by welding. Since the unit is made entirely of glass, moisture will never penetrate the seal unless the glass is broken.

The other method is, by far, the most common method among glass manufacturers. This process employs a metal (aluminum) spacer around the glass which is filled with a dessicant to absorb moisture, and then uses special sealants such as polyurethane, polysulfide. or polyisobutylene to seal the edge. Lower-priced units may employ a single seal, while better units may employ a dual-seal which incorporates a primary and secondary sealant.

Any water that gets in and around the frame should be drained appropriately with weep holes to prevent moisture from building up around the insulating glass unit. Water that comes into contact with the sealant is likely to cause damage to the seal, and can possibly promote its failure. When an insulating glass unit fails, this generally means that the seal is no longer air-tight; thus, the first sign of a failed insulating glass unit is fogging or condensation from within the glass caused by moisture which has found its way in. The durability of the edge seal is critical for the life of the insulating glass. Use of a dual seal is more effective than a single seal, and should be considered.

**Figure 18.**

U-Value vs. Air Space




It is very important to note that manufacturers differ in the amount of time they warranty the insulating glass unit against failure. Manufacturers who offer longer-term warranties are generally more confident of the quality and the expected lifetimes of the insulating glass unit. Such information should be obtained from individual window manufacturers and compared.

Typical double-glazed units have an R-value of about 2. The R-values tend to increase slightly with increasing air space widths, but the benefits in thermal performance approach a limit when wider air spaces are used. *(Figure 18)*

### c. Triple-Glazing

Triple-glazed windows incorporate three panes of glass in a window unit, with typical R-values of about 3. In this case, there is an extra layer of glass between two air spaces which separate the interior and exterior glass panes.

Triple-glazing insulates slightly better than double-glazing. As one goes from double to triple glazing, heat loss is reduced by 33%. The amount of beneficial heat gain during wintertime, however, would also be reduced because each layer of glass reduces the incoming sunlight by about 15 percent. What's more, the additional pane of glass adds much more weight to the window, thereby making it difficult to operate. A wider jamb may also be required since triple glazing is much thicker than a double-glazed insulating glass unit.

Triple-glazed windows are obviously more expensive than their double-glazed counterparts. Benefits that can be gained by going to triple-glazing must be weighed against its drawbacks. With the advent of newer, more thermally efficient insulating glass units such as low-e glass (see the following section), the need for triple glazing may not be warranted.

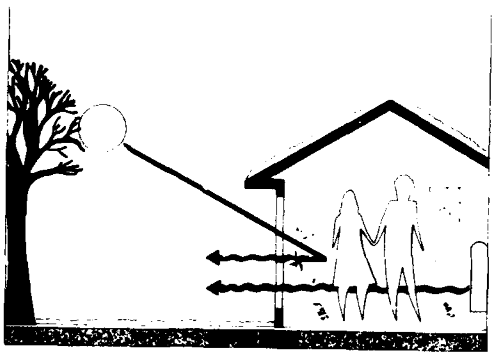
## d. Low-Emissivity Glass

Low-emissivity ("low-e") glass is a product which was introduced about 10 years ago and has since made headway in the replacement window and new home construction market. Low-e coatings have made it possible for insulating glass systems to achieve improved energy efficiencies over regular double-glazing (with R-values as high as 4), while still maintaining the clear look of ordinary glass.

Radiation accounts for a large portion of the heat lost through conventional glass in a window unit during winter. Low-e coatings increase the thermal performance of glass by reducing the radiant portion of the heat loss *(see Figure 19)*. As explained in the earlier section, all objects radiate heat energy. Anyone who ever sat in front of a fireplace or wood stove has felt radiation warming his hands, face, and clothing. This is known as room-temperature infrared (longwave) radiation. The sun also radiates heat, primarily in the ultraviolet (short-wave) and visible (medium-wave) parts of the spectrum. Because glass transmits about 85% of the ultra-violet and visible light, this solar radiant energy enters the room and is absorbed by interior objects, such as furniture, walls and carpeting. These warm interior objects re-radiate energy in the form of long wave radiation.

Some of these long wavelengths reach the window glass. But, although glass is highly transparent to the sun's short wavelength radiation, it is less transparent to the room-temperature infrared, or longwave radiation. Still, some of this longwave radiation is absorbed by the glass, which conducts and re- radiates the heat to the outside. This accounts for over half the heat loss through normal double-pane windows.[17]

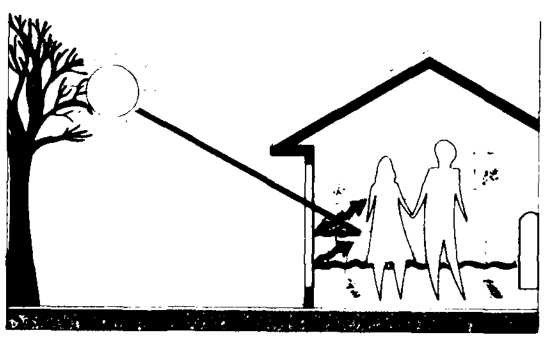
**Figure 19.**
**How Low-emissivity Glass Works**



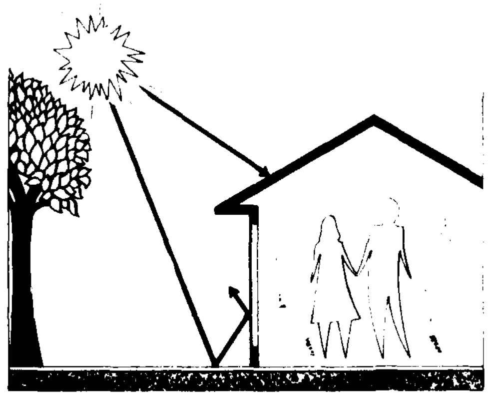
CONVENTIONAL GLASS IN WINTER

*Conventional window glass loses heat in winter. (left photo)*

*Low-emissivity glass can save energy in the winter by blocking reradiated heat which is generated by a furnace or results from solar heat being absorbed by people and objects in the room (bottom left). During the summer, low-emissivity glass helps to block reradiated heat generated by outdoor objects, hot driveways, pavements, etc. (bottom right).*



LOW-E GLASS IN WINTER

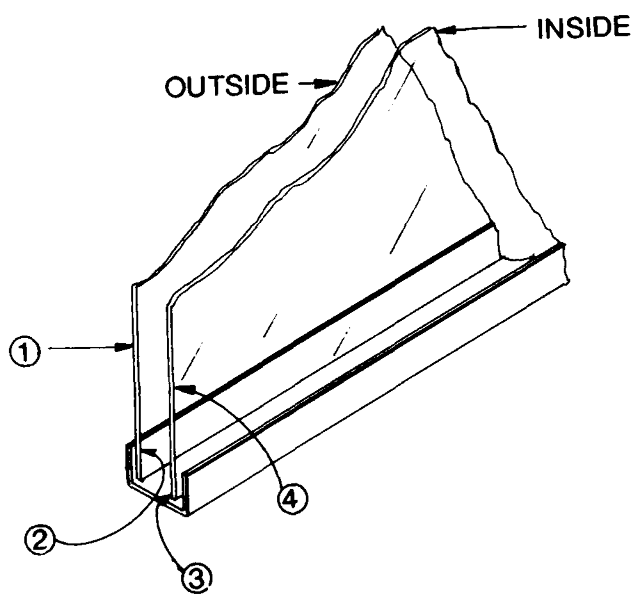


LOW-E GLASS IN SUMMER

Low-e coatings lower the emissivity value of glass so that radiant heat does not pass through as easily. By lowering the emissivity, radiant heat is blocked and then is reflected back towards its source. This means that in wintertime, the thermal energy from the fireplace and woodstove and other objects in the room is prevented from escaping through the glass. In the summer, hot pavements, driveways, cars, and other outdoor objects which heat up cannot radiate their heat through the glass because the low-e coating will reflect it back to the outside.

Windows that have a coating with an emissivity value of 0.40 or less on one pane are classified by manufacturers as low-e The lower the emittance, the higher the window's R-value; thus, it will be a better thermal insulator. The low-e coating faces the airspace of an insulating glass unit, and depending on which surface is coated, performance can differ. *(Figure 20)*

**Figure 20.**
**Low-emissivity coating faces the airspace in an insulating glass unit**




*Low-e coating performance can differ depending on coating placement.*

*By numbering the glass panes from the outside to the inside, surface 1 is the outer surface of the external pane, surface 2 is the inner surface of the external pane; surface 3 is the outer surface of the internal pane, and surface 4 is the inner surface of the internal pane.*

*For hot climates, surface 2 is the preferred surface for low-e coatings. For colder climates, surface 3 is preferred.*

Low-e glass holds several advantages over clear, uncoated glass. For one, low-e glass means greater thermal comfort. The inside pane of a low-e insulating glass window will be up to 16°F warmer than an uncoated one, reducing the chilling effect people feel as they stand close to the glass.

Low-e glass also provides the added benefit of reducing condensation on windows. Since the low-e coated insulating glass insulates so well, windows are warmer and condensation is much less likely to occur. In addition, low-e glass helps to block the sun's damaging ultraviolet rays which can cause fading of fabrics on drapery, upholstery, and carpeting. By using low-e coated insulating glass, the energy performance is comparable to that of triple-glazed units, but at one-third less weight.

There are currently two techniques of producing a low-e coating. One method uses a "sputter coating" process to make a soft-coat low-e, and the other uses a "pyrolitic" process to make what's known as a hard-coat low-e glass. Features of these two types of coatings are described below.

- **Hard-coat Low-emissivity glass**

  In the pyrolitic method, a metal oxide layer is applied to the glass while it is hot, and is baked into the surface as the glass is being made. The coating is relatively thick and is made commercially with inexpensive materials such as tin oxide.

  The low-e coating is called a "hard-coat" because of its durable finish. Having been incorporated into the glass itself, the low-e coating is unaffected by touch, and can be handled, washed, and cut like ordinary glass. The hard-coat low-e will retain its emissivity with age, and therefore, has an unlimited shelf life.

  Hard-coat low-e glass typically have emissivities in the 0.3-0.4 range, which is an improvement over normal glass with an emissivity of about 0.85 (note that the lower the emissivity, the better the ability to reflect radiant heat). This means that it can reflect up to 70% of radiant heat energy, thus enhancing a window's overall thermal performance. Typical R-values for hard-coat low-e insulating glass is about 2.5.[18]

  Some glass manufacturers who employ the pryolitic process and the corresponding trademark names of their low-e glass are: AFG Industries' "Comfort-E", Ford Motor Co.'s Sunglas HR, and PPG Industries' Sungate 300 (formerly called Sungate 200). Some window manufacturers also import hard-coat low-e glass from a glass company in Belgium called Glaverbel. This imported hard-coat low-e glass has exceptionally good performance, having the lowest emissivity value (0.15) of all the other hard-coated glass.

- **Soft-coat Low-emissivity Glass**

  In the sputter process, a soft-coat low-e glass is obtained by a slow and expensive vacuum process which deposits a thin layer of precious metal (such as silver), and then cover this with a layer of metal oxide. Typical R- values for soft-coats are around 3, about the same as that for triple-glazing.

  Before manufacturers employed the sputtering technique on glass, it was first introduced by one company as a soft-coated low-e film. The film is coated with a very thin metallic coating only hundreds of atoms thick, and is suspended tautly between the airspaces of the two panes in an insulating glass unit. This unique product has been patented and developed by Southwall Technologies, Inc., and is known by the trademark name of "Heat Mirror." Part of the improved performance is because the polyester film creates an additional airspace. Much of the improvement, however, is due to the coating which serves as a selective filter of radiation. The overall glazing performance due to these combined features is therefore higher than soft-coated insulating glass, with an R-value of about 4. The Heat Mirror product, however, commands a higher price than most of the other low-e coated insulating glass.

Although soft-coat low-e glass has better thermal performance than hard-coats, it requires special handling during its manufacture to protect the soft-coat finish. The soft-coating on low-e glass is extremely fragile; it can degrade if scratched, touched, exposed to moisture, or left open to the air for long periods of time. Due to its sensitivity, the low-e glass coating has very limited shelf life at the factory. Therefore, it must be handled with care and sealed in an insulating glass unit soon after it is manufactured.

Glass manufacturers who use the sputtering process on glass and their corresponding low-e trademark names are: Guardian Industries' Low-e glass, PPG Industries' Sungate 100, Interpane Coatings' IPlus Neutral R, and Cardinal Glass Co.(sole supplier of Andersen's High Performance and High Performance Sun glass).

- **Soft-coat versus Hard-coat**

Both hard and soft low-e coatings have their pros and cons. When one compares their relative merits, two factors must be considered: thermal performance and overall cost.

Clearly, the soft-coats outperform the hard-coats as far as thermal efficiency is concerned. Soft-coated low-e glass has lower emissivities, and therefore, higher R-values than hard-coat low-e. However, the soft-coat process implies higher initial first costs due to the fragile nature of the soft coating, as additional steps are needed to protect the glass during its manufacture and shipping.

Hard-coated low-e glass, on the other hand, has a higher emissivity value than the soft-coat. Thus, while its R-value is better than double-glazing, it is not quite as good as the soft-coat low-e (with the exception of the European version). No special handling is required with the hard-coatings due to its extreme durability, and therefore, can be mass-produced by companies for lowest first costs. Also, hard-coats can be versatile, finding other applications such as in storm windows and add-on glazings.

Current technology has been moving at such a quick pace, that in the near future, both hard- and soft-coats will experience even more improvements. The trend, according to one manufacturer, is for hard-coat low-e glass to have thermal performances approaching that of soft-coat low-e. Likewise, the sputtering process which makes soft-coat low-E is being improved upon such that the coating becomes as durable as the hard-coat. Such advances can be expected sometime soon, although there is no definite way to predict when they can be commercially available.

It should be stressed that the life of the low-e coating, whether it is a soft- or hard-coat, is only as good as the life of the insulating glass unit itself. *The unit must be protected from seal failure, and the longer the guarantee on the seal, the better.* Warranty periods for insulating glass units must be checked and compared as they can vary widely from manufacturer to manufacturer.

### e. Low-e glass with Argon

The concept of gas-filled windows has recently been introduced into the marketplace, and is now commercially available from several window manufacturers. The premise behind displacing air in an insulating glass unit with an inert gas, such as argon, is that the heavier argon gas will be less conductive than air. Thus, the thermal performance of the unit, particularly if low-e glass is used, will be enhanced.

Since argon is inert, and being that it only costs pennies per window to fill, companies are beginning to take advantage of the benefits of argon gas. Some companies, such as Andersen Corporation, have begun this year to fill all their low-e glass windows with argon and is now marketing this as their standard low-e stock item. Still more companies are likely to follow suit.

Though now offered by some as a standard stock item, it is still not known exactly how much argon gas is expected to leak out over time in gas-filled units. The long-term containment of argon gas within an insulating glass unit remains the subject of some controversy. Tests of sealant permeability and accumulating data, however, suggest that argon leakage may be minimal throughout the normal life of an insulating glass unit. One would expect future improvements in glass-sealing technology to further increase the opportunities for low-conductance gases (such as argon).[19]

Gas-filled windows show a lot of potential in enhancing the insulating capability of glass, and look promising for increased energy savings over conventional low-e uits. However, it must be remembered that the technology is still very new, and therefore, cannot be recommended as a clear choice for windows in Navy housing at this point in time.

### f. Tinted glass

Tinted glass reduces sunlight and glare by reflecting and absorbing some of the sun's rays. The tinting material is not a coating, but a metallic oxide that is mixed into the ingredients. Iron-oxide produces a bluish-green tint. Nickel oxide or copper oxide produces a bronze or gray tint. Tinted glass is mostly used in warm climates where minimized heat gain is desired. However, while its shading capacity is great, the transmission of daylight is reduced. When comparing tinted glass products, consider the shading coefficient (lower S.C. is best), and visible light transmittance (higher % is best).

### g. Reflective films

Films can be adhered to the inside of windows to reflect and absorb some of the sun's heat. These films usually have a metal-like or mirror-like appearance, and are generally used in spaces subject to overheating. Both reflective films and tinted glass are retrofit options that are most useful during summertime use, or in predominantly hot climates.

### h. Future Advancements in Energy-Efficient Glazing Systems

Many innovative designs for insulating windows are currently underway and in various stages of development. One is the electrochromic window, also called "switchable" glazing. This type of glazing acts as an automatic optical shutter, which becomes lighter or darker in reaction to an applied current or electric field. Another design uses silica aerogel-filled insulating glass units. With air, the aerogel window could have an R-value of as much as an 7; with air removed, the R-value may be as high as 20. Another alternative to argon gas-filled windows is the use of krypton gas, which can slow down the conduction of heat even more than argon.

Others have also looked at evacuated glazings, where a vacuum is imposed upon a sealed glass unit which has spacers to maintain glass-to-glass separation. As with the gas-filled glass units, provision of a long-term hermetic seal that is also cost-effective is the primary stumbling block for such a system.

Another new design is the "Superwindow" developed by Southwall Technologies, the manufacturer of Heat Mirror products. This new system is a variation of the Heat Mirror window unit described earlier, but contains two Heat Mirror films rather than just one. The two films are suspended between the glass panes in a double-glazed unit, and are separated from one another by a newly-designed insulating spacer. The multiple airspaces created by this configuration serve to set up additional barriers to the transfer of heat. The airspaces are also filled with a mixture of inert gases to further inhibit heat transfer. This product, which reportedly has an R-value of about 8.0, is expected to be marketed in the near future. At the time of this writing, no further information on product cost has been made available.

All new window designs and concepts have a common goal: to slow down the transfer of heat without sacrificing the beneficial characteristics of the window. Most of these designs, however, are still in the developmental stage, and are currently associated with a high degree of complexity and cost. As such, they are presently not recommended for applications in residential Navy housing.

## 3.2 ENERGY-EFFICIENT WINDOW COVERING OPTIONS

In order to minimize the energy costs associated with windows, it is generally desirable to minimize winter thermal losses and reduce summer heat gains. Though options for thermally improved frames and glazings exist commercially, other options, such as window covering devices, can be used alone or together with windows to enhance their thermal performance during both winter and summer.

There are several different types of window covering options to choose from and some are more energy-efficient than others. New, insulating window treatments have edge-seals which fit tightly around the window, enhancing the window's thermal performance. Many types and materials are also available.[20] Reflective materials lined onto shades or drapes help to provide solar control in hotter climates.

Below are a few examples of frequently-used window treatments, and their potential advantages and disadvantages.

### 3.2.1 Drapes

- **Advantages**
  Drapery is a commonly used window covering. It comes in a variety of fabrics and colors to suit individual tastes, and is widely available commercially. In general, drapes are hung from a mount at the top of the window frame and hang to the bottom sill or the floor. They operate by parting in the middle when opened, using a cord-and-pulley system if mounted on a traverse rod. If a stationary rod is used, the drapes are hung on rings and are manually moved.

  The variety of fabrics and materials used in energy-efficient window treatments provide an array of choice, and can be selected based on purpose and need. During the summer, to reduce the amount of direct sunight and heat coming into the room through the window glass, use a light-colored or tightly-woven drapery fabric. To be most energy-efficient, the light colored surface should face the glass.

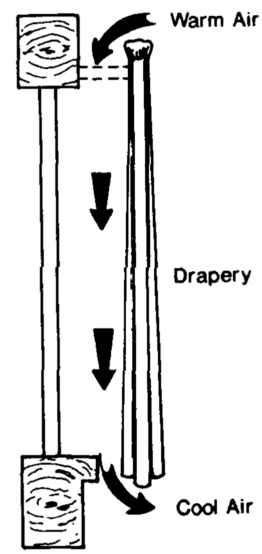
  The color of a fabric influences the ability of the fabric to absorb or reflect radiant heat. White or light colored fabrics reflect more solar heat than black or dark-colored fabrics. The ability of fabrics to reflect radiant heat is also affected by the weave of the fabric. Fabrics of very loose and open texture will allow the radiant heat to penetrate through the fabric and will warm the room. A tightly woven fabric will give better protection from the sun because it will reduce sun penetration. Radiant heat is absored more by rough, fuzzy or textured surfaces than smooth or shiny surfaces. Generally, materials that are thick tend to insulate better in the wintertime than thin fabrics. This is because thick fabrics have more space to trap air between the fibers.

Drapery liners serve to boost energy savings because they provide additional barriers to the sun's rays in the summer and protects the drapery from premature fading. The addition of a lining, whether separate from the drape or adhered to the back of the drape, provides better insulation than unlined drapes to help reduce heat losses in the winter. Also, the lining acts as an extra vapor barrier to ward off the migration of water vapor through the porous drapery fabric. Drapery liners can be made of polyethylene, woven acetate, or other insulative types of fabric.

Double drapes are also available on the market. These incorporate two layers of drapery separated by an airspace. Double drapes can improve the thermal performance of the window. However, this depends heavily on how the drapes are mounted. Drapery can be an energy-efficient option, as long as it is installed correctly by sealing the tops, bottom, and sides.

- **Disadvantages**

Drapes that are simply hung on a rod does little to prevent heat loss during winter. This type of installation allows wide air gaps between the frame and the material so that warm air from the room is cooled as it passes behind the drapery.[21] As warm air enters the top of the drapery system, it becomes cooled down as it falls between the glass and the drapes. It then exits back to the room from the bottom of the drapes as cold air. This movement of air is called a "reverse chimney effect" *(Figure 21)*.




REVERSE CHIMNEY EFFECT

**Figure 21.**

Because window insulation reduces the temperature of the inner glass surface, good edge seals are important for minimizing condensation within the cavity. High R-value window insulation, single-glazing, and high indoor relative humidities make the condensation problem worse. On very cold days, the glass can frost heavily as a result. Once the frost melts, water can leak between the sash and frame. Water damage can also harm drapery fabrics, as well as wooden sills, and floors.

If drapes are to be made more energy-efficient, proper mounting is essential in order to stop this reverse chimney effect. Unfortunately, edge-sealed drapery is not an off-the-shelf commercial item; thus, the edges of the drapes have to be sealed by other methods. The top of the drapery system should be sealed using a closed valance(wooden- or fabric-framed box) or the drapes should be extended to the ceiling to prevent warm air from entering the top. Also, bottom and sides should be sealed to educe convection currents. If baseboard heating exists under the drapery system, a deflector should be installed to direct heat back into the room.

Although tightly-woven fabrics do best in reducing summer heat gain, outward vision is subsequently sacrificed. Open-weave fabrics are not as effective in reducing heat gain, but allow for greater light transmission.

Traverse rods that are used to hang drapes have moving parts as compared to stationary rods, and therefore can tend to develop mechanical problems involving the slide and pulley system.

### 3.2.2 Shades

- **Advantages**

The familiar roller shade is a frequently used window treatment. It is usually mounted on a wooden or metal roller, and the shade material is made of non-permeable vinyl or cloth. Roller shades are uncomplicated devices and are easy and convenient to use. In the summer, heat gain into the house from direct sunlight can be reduced by lowering the shade. In the winter, shades that are fitted with edge-seals can cut back significantly on nighttime heat losses.

The color of the shade cloth and its ability to let light through also affects its performance to a certain extent by the amount of radiant heat it absorbs or reflects. Light-colored shades reflect more heat than dark-colored shades, lessening the amount of radiant heat gain. Opaque shades also reflect more than translucent shades, because translucent materials tend to transmit more solar energy into the room. Typically, a white, opaque roller shade will reduce solar heat gain through clear glass by about 50%.

Shades are commonly made of vinyl, although this provides only a minimal increase in the window's R-value for wintertime use. Shades made of insulating fabric are now commercially available and promise increased R-values. Popular styles include heavily quilted shades which sandwich fiber insulation and a reflective vapor barrier between decorative face fabrics. Appropriate Technology Corporation's "Window Quilt" uses five layers of insulative fabric and is edge-sealed using vertical tracks. Other successful types are multilayered shades, which combine two or more layers of reflective film in combination with opaque vinyl. Dirt Road Company's " Comfort Shade" is a double loop roller shade that has 4 layers of material, creating air spaces that increase insulation. The exterior layers are white vinyl, and its interior layers are aluminized mylar foil.

For summer use, shades made of heat reflective film are also available for sun control. These films are actually metallized polyester, and can reflect over 85% of the total solary energy, reducing airconditioning needs and costs. In addition, they protect the interior from glare and block over 90% of ultraviolet radiation that can cause fading of fabrics on furnishings. Reflective films offer daytime privacy since outsiders cannot see in, while occupants can still have a view out.

- **Disadvantages**

Shades, like drapes, must be mounted properly to obtain any significant energy savings. Again, seals around the top, bottom, and sides are necessary for good performance during winter. Edge seals can be obtained by hook and loop seals, magnetic seals, or mechanical seals that slide on vertical tracks.

It is also important to have the shade cover the window glass from top to bottom, and when fully closed, the bottom edge should rest firmly on the window sill.

Shades, whether made of translucent or opaque material, provides no inward or outward vision whatsoever when fully drawn. Shades made of reflective film provide some vision outward, though from the exterior, the shade will take on a mirror-like appearance during the day. At night, the shade will appear clear from the outside, and can eliminate any privacy for the homeowner.

Automated shades that use control mechanisms for opening or closing should be avoided, as it only serves to complicate a simple device and can add to maintenance costs if something should go wrong. In addition, failure of the control mechanism while shades are in the closed position can hamper escape through the window in the event of an emergency.

### 3.2.3 Blinds

- **Advantages**

Venetian blinds are another common type of window covering, and are readily available in either horizontal or vertical-closing modes. They are usually made of aluminum, vinyl, fabric, or soft wood. In the summer, venetian blinds are effective in controlling the quantity and direction of light and heat entering the room. The slats can be tilted to provide reflection of direct sunlight back out the window, reducing some solar heat gain (depending on the angle and color of the slats).

Due to the angle of the slats in relationship to the sun, horizontal blinds absorb more sunlight than the vertical blinds. In addition, light colors tend to reflect more sun than dark-colored blinds. Now commercially available are window blinds with low-emissivity coatings applied to the slats for greater control of summer heat gain. These operate in the same manner as normal blinds but are claimed to be more effective in blocking out light. Other companies such as Pella Rolscreen Co. have been marketing their "Slimshade" line of blinds for some time. These blinds are enclosed within the double glazing panels and are operated from the glass exterior. The benefit lies in that cleaning and maintenance of the blinds are reduced, as the system is safe from dust

- **Disadvantages**

Because of the space between the louvers in venetian blinds, air moves between the slats even when the louvers are closed. This means that warm air can escape from the room to the cold window in wintertime. Blinds that are made of metal louvers are not very effective in cold areas since they conduct heat quite readily. Blinds are most effective in the summer to reduce solar heat gain and are less effective in winter. This is because the potential is great for air leakage between the slats, and no sealing aroung the top, bottom, or edges of the blinds are possible.

Newer, more advanced types of blinds offer improvements in energy efficiency, but are priced very high. Blinds enclosed between glass panels are not only expensive, but cannot be rolled up, so the view through the windows is always limited. The cord and pulley system of blinds can occasionally be damaged and may require increased maintenance. Dust and dirt can accumulate over slats and will also require periodic cleaning.

### 3.2.4 Interior Shutters

- **Advantages**

Louvered shutters are typically made of wood and will block some of the summer sunlight from entering the house. Traditional louvered shutters have small slats that can be moved, allowing air to move between the louvers for ventilation in the summertime. In order to be energy-efficient, the louvered shutter frame should fit snugly to the window area. If the louvers are moveable, they should be closed as tightly as possible on cloudy winter days to reduce the amount of heat lost through the windows.

Another type of interior shutter is the insulated shutter, made out of insulation material sandwiched between two sheets of plywood, cardboard, or masonite. The insulation material can be styrofoam, polyester batting, or fiberglass batting. They serve well for all-winter coverage of non-south windows that are not needed for daylight or views.[22] This type of covering can have a high R-value when mounted correctly, as air is trapped between the glass and the panel.

- **Disadvantages**
  Similarly to blinds, air leaks between the louvers and the frame are difficult to prevent; this is a major drawback for winter use. Louvers can also tend to collect dust on the slats, which must be cleaned off periodically to prevent buildup.

  Insulated shutters must be positioned to fit tightly around the window glazing to prevent the occurence of air movement. However, it must be sealed on all four sides in order to minimize condensation. Proper installation is essential. During summertime, insulated shutters will not be of use and must be removed and stored for winter. They also need ample storage space and require a lot of maintenance.

Window covering devices are an excellent way of enhancing a window's thermal performance and can help to supplement energy and cost savings. Ideally, they should be opened and closed at the appropriate times during the day and night on a consistent basis year-round in order to obtain their full benefits. However, *the use of window coverings implies a tremendous degree of occupant responsibility.* If an energy-efficient window covering option is installed and operated only on an occasional basis, or not at all, then no appreciable energy or cost savings will be accumulated; furthermore, the energy-efficient window covering will be a pointless investment.

From the Navy standpoint, the path to follow in deciding the most energy-efficient window system must first lead to improving the window itself. Thus, for new housing construction, or for existing housing where window replacement is economically justified, a new thermally-efficient window will result in greatest energy and cost savings. Once the window is in place, a thermally-efficient window covering becomes unnecessary. This is because the incremental increase in efficiency offered by the thermally-efficient window covering will be minimal and the payback period to recoup the cost of the covering will be very long. If a window covering is desirable for privacy or for shade, the least-cost window covering option should be considered. Conventional blinds, shades, or drapes would be equally suitable.

Energy-efficient window coverings serve to enhance a window's thermal performance, and therefore, are most useful for existing windows that have not been upgraded. Thus, in situations where window replacement is not a viable option, only then should energy-efficient window coverings be considered.

Prior to selecting a window covering, however, it is first recommended that the condition of the window be checked to see what protection already exists. The window should be appropriately caulked and weatherstripped to eliminate potential air leaks. The heat lost in winter and gained in summer through drafts and faulty window frames could easily offset the benefits of installing energy-efficient window covering devices.

The main issues in choosing a window covering product will primarily depend on its intended use, whether it be as a thermal insulator, shading device, or both. If the window covering is to be used for offsetting window heat losses, then the most effective coverings to look for should have high thermal resistance (high R-value). Window covering products that incorporate edge seals, such as insulated roller shades, are also recommended because the edge seals minimize convection effects.

If the window covering will be used mainly as a shading device to keep solar heat gain at a minimum (and reduce space-cooling costs), then the most effective coverings to look for should have low shading coefficients. This means that the material used for shading would reflect and block solar heat.

If the window covering will be used to enhance the thermal performance of existing windows in an area where heating and cooling costs are of equal concern, then it is recommended that a high R-value insulating device incorporating edge seals and lined with an external reflecting material be used. Thermal shades layered with insulating fabric and which slide on vertical tracks are one good example of such an insulating device.

It is important to note that if window coverings are sealed tightly against the window and are kept in place for prolonged periods of time, overheating of the window may occur. This can be avoided by operating the covering intermittently during the day in order to vent the space between the window and the window covering.

It should also be remembered that energy-efficient window coverings can only work effectively if they are diligently used by the building occupant. Therefore, since use of the covering relies solely on the occupant, it must link closely with the occupant's daily routines to achieve maximum energy savings. Window coverings that are easy to operate, easy to maintain, and are both reliable and durable, should be considered.

# 4. PLANNING, SELECTION, AND LIFE-CYCLE COST ANALYSIS OF WINDOW AND WINDOW COVERING OPTIONS

## 4.1. PLANNING

In planning the types of windows and window coverings that will be suitable for new Navy housing, or for replacement of older units in existing housing, several factors should be considered prior to selecting a particular option. Initially, one must first decide which windows are to be replaced, or if they should be replaced at all.

For new Navy housing, the items to check will pertain to window type, size, and placement or orientation. This should be done in accordance to architectural/contractual specifications on window requirements for new construction. The final window selection will then depend largely on the climate (or number of heating-degree days) at that Naval installation.

For existing Navy residential housing with old window units, an assessment should be made of their present condition and need for replacement. If the units are single-glazed, and/or if the frame has suffered from rot, warping, corrosion, or other structural damage that is not correctable, then replacement may be a necessary step. If the existing window unit is not in an obvious state of disrepair, it can still be a liability if it is a large source of energy loss. This can be validated by evaluating its thermal performance in comparison to a new, energy-efficient option.

It is possible that, for existing windows in very good condition, local base officials may prefer to save energy through the use of shades, assuming the shades are found to be cost effective. The procedure for determing the cost-effectiveness of various options is described later in this chapter.

## 4.2. SELECTION CRITERIA

The selection of energy-efficient window and window covering options will rely on applicability to local climate, thermal performance and energy-savings potential, maintainability, and durability. Other factors, such as cost, warranty periods, and ease of installation and operation, are also equally important. In both cases, the selection process for determining which energy-efficient window and window covering to use will be the same and largely based upon life-cycle cost. The following criteria should be considered:

### 4.2.1. Selection of Energy-Efficient Windows

#### a. Energy Savings Potential

- Choose a window frame material that has effective insulation properties in order to save heating and/or cooling energy costs. Of all framing materials discussed, **vinyl is most strongly recommended for Navy housing** because of its high resistance to the transfer of heat (high R-value). Like wood, it is a natural insulator, but exempt from the maintenance problems that continually plague wood frames. Metal frames are also poor choices for Navy housing because of their high heat transfer rates. Even metal windows which incorporate thermal breaks are not as thermally-efficient or as durable as rigid vinyl.

- Choose the window glazing that will work best to suit local climate conditions. For predominantly cold climates where heating is a major concern, a minimum of double-glazing is required. However, in order to maximize energy savings, **the use of low-emissivity insulating glass is strongly recommended.** Low-e should help to keep heat indoors during cold weather by reflecting radiant heat back into the home, cutting back on the required heating energy and subsequently reducing heating fuel costs. For heating applications, the low-e coating should be placed on surface 3 of the insulating glass unit.

  For predominantly hot climates where cooling is a major concern, low-e glass can also be helpful to reduce air conditioning loads, so long as the coating is on surface 2 of the insulating glass unit. Glazings with low shading coefficients should also be considered for maximum benefits.

- When comparing the thermal performance of whole window units, use the U-value or R-value as a measure of energy-conserving potential. The lower the U-value, or the higher the R-value, the better will be the thermal performance of the window. Look for actual standard laboratory-tested thermal performance numbers rather than calculated performance numbers. This will ensure that an unbiased party has given an accurate appraisal of the window's true thermal performance.

- Air infiltration is also an important characteristic in determining a window's thermal performance. Check that air infiltration test results are available, and that the window does not exceed the maximum air infiltration rating, based on AAMA (American Architectural Manufacturers Association) or ASTM (American Society of Testing and Materials) specifications.

### b. Maintainability

- In comparing the maintenance requirements associated with the framing materials presented in the preceding sections, vinyl is considered to be the material with the lowest maintenance requirements. This is a key feature in support of using vinyl-framed windows from the maintainability standpoint, as there are practically no labor or material costs involved. Vinyl never needs painting, and will not chip, flake, rust, rot, blister, or peel. Furthermore, vinyl is self-lubricating so that parts slide with ease. To clean the vinyl frame, one simply needs to wipe the surface with soap and water.

- Wooden frames are hard to maintain since they must be weather-protected and painted on a regular basis, and requires constant attention should they be damaged to the extent that their performance is compromised.

### c. Durability

- Rigid vinyl is resistant to rain, humidity, atmospheric pollutants, and corrosion, and thus, has longer life as compared to either wood, aluminum, or steel frames. **Vinyl should be selected in white or beige colors** because these have been proven to be more durable than darker colors, such as brown, which may be prone to fading or overheating under extremely hot conditions.

- Hard-coat low-e glass is substantially more durable than soft-coated low-e glass due to the fact that the metallic coatings, which allow it to reflect the radiant portion of the sun's rays, are baked right into the glass. Soft-coat low-e glass, on the other hand, uses a different procedure which renders the coating susceptible to damage from scratches, humidity, exposure, etc. Therefore, it is inherently more fragile than the hard-coat variety. The differences between hard-coated and soft-coated low-e glass are typically borne by the warranty periods offered by the low-e glass manufacturers and the manufacturing costs associated with each type of low-e glass, which are subsequently passed on to the buyer.

- It must be remembered that low-e insulating glass units, or any other insulating glass unit, is only as good as the seal which protects the interior portion of the glass. Therefore, durability, whether hard-coat low-e or soft-coat low-e insulating glass, is dictated primarily by the strength and quality of the edge-sealing material used to seal the glass.

### d. Warranty periods

- In comparing the warranty periods of vinyl frames, look for manufacturers who offer **long-term warranties** on their white or beige vinyl products. This will usually be an indication of quality workmanship and an expression of manufacturer's confidence in the product line.

- Most importantly, low-e insulating glass units must also be compared for **long-term warranties** because once it fails, it is irreversibly damaged and performance will not be the same. When checking the insulating glass unit portion of the window, make sure that the glass edges are dual-sealed for maximum protection against moisture. Dual-sealed units typically have longer warranty periods.

### e. Cost

- Cost considerations are important, although this should not be used as the primary reason for selecting one window versus another. Vinyl has several significant attributes, among them being that it is less costly than wood or thermalized aluminum windows.

- In comparing the costs of low-e glass, hard coat low-e glass is less costly than the soft-coat version because of the difference in handling requirements which drives the price of the soft-coat low-e glass up higher. As low- e coating technology grows further and methods are improved, this current situation is likely to change. However, at the moment, **hard-coat low-e glass is recommended** based on its durability, thermal performance, and cost.

### 4.2.2. Selection of Window Coverings

As discussed in the earlier chapters, the path to deciding the most energy- efficient window and window covering combination should first lead to improving the window. If this is found to be economically justifiable then addition of an energy efficient window covering becomes unneccessary. If a window covering is desired, the least-cost option will suffice. However, if it is decided that the existing window need not be upgraded, then an energy-efficient window covering option should be considered.

In order for a window covering device to be energy-efficient, it must be opened and closed at the appropriate times during the day and throughout the year to realize true energy savings. This is a very important consideration in selecting window coverings for Navy housing because their operation is very user-intensive. Since housing occupants do not take responsibility for paying fuel costs associated with heating and cooling, it is unlikely that they will be concerned with the energy-savings capability of a window covering device. Rather, how it appears, provides privacy and thermal comfort, and operational ease are assumed to be more of the occupant's concern.

There are several energy-efficient options to consider; however, one must keep in mind that *usage* of window coverings are the sole responsibility of the occupant, and therefore, must be closely tied in with his habits and lifestyle for maximum effectiveness.

#### a. Maintainability

- Maintainability is one of the biggest factors in the selection of window covering devices. In selecting window coverings for Navy housing, it must be stressed that window coverings do not work on their own, and therefore, rely heavily on the occupant's diligence in operating them during the course of the day. Thus, if potential savings are to be fully realized, **these devices must be closed and opened conscientiously.** The degree of user responsibility is critical if a window covering device is to perform in an energy-efficient manner.

- Coverings that require little mental effort to operate and that have simple functions are good choices for Navy housing.

**b. Energy Savings Potential**

- The energy savings potential of a window covering device is also closely coupled with the occupant's diligence in maintaining the proper operation of the device during the day. If a highly-insulating window covering is installed and operated only occasionally, or not at all, then it will not work energy-efficiently.

- If energy-efficient options are to be recommended, then choose window coverings that have the highest insulating potential. High R-value materials are best for winter use in preventing excessive nighttime heat losses. **Covering designs which provide seals at the tops, sides and bottom** are necessary to achieve energy-savings, and are strongly recommended. An example of this type of window covering is edge-sealed roller shades.

- Window blinds are not as effective for cold-weather use, and therefore are *not recommended* for Navy housing. Interior wooden shutters have very similar drawbacks to venetian blinds, and the insulated pop-in shutters are not as convenient to use because they do not allow daylight throught and must be removed when n^t in use. These coverings, too, are inadequate for residential Navy housing, and are *not recommended.*

- For summertime use, materials with low shading coefficients do best to shield the interior from excessive solar radiation heat gain. Light-colored, opaque materials reflect more heat than dark-colored or translucent materials, and should be considered when selecting shades or drapes.

**c. Cost**

- Cost considerations for window coverings are extremely important. It stands to reason that the more advanced and energy-efficient the window covering device, the more it will cost. Again, however, if the device is not used in an energy-efficient manner, then there will be no energy saved, and the initial investment will not be recovered through energy savings.

**d. Durability**

- Choose window coverings that are durable. In selecting fabrics for drapes or shades, avoid delicate materials that can tear easily. Materials that are easily cleaned and maintained are also good choices.

**e. Warranty periods**

- Check manufacturer warranty periods. Long warranty periods are desirable for protection in the event that the product fails, is defective, or does not perform adequately.

## 4.3 LIFE-CYCLE COST ANALYSIS

In order to justify whether or not windows should be replaced, a preliminary assessment must be made as to whether replacement of an existing window will conserve energy and result in a long-term cost savings. To facilitate this assessment, a Field Data Sheet, given on page 91 in Appendix A, was developed for the user to survey windows in Navy housing as a first step in evaluating the existing window stock.

Worksheets have also been developed, given in Appendix A, to aid the user in evaluating the energy savings that can be obtained from a retrofit option in comparison to the windows already in place. Two worksheets are presented: a short version and a long version. Both are offered to provide the user with a choice.

Life-cycle cost analysis is also necessary in order to confirm whether or not a window replacement action will result in a long-term cost savings. Basic procedures used to evaluate life-cycle costing, as well as descriptions of the Field Data Sheet and Worksheets I and II, are described below.

### 4.3.1 Field Data Sheet - (Window Survey)

The first step in a retrofit is to determine the condition of existing windows. For this purpose, the Field Data Sheet is provided to survey and document the types of windows in a residential housing unit, their average size, their present condition, as well as other characteristics of the window and building.

The actual survey of existing windows using the Field Data Sheet can be performed in two ways. The first method is to conduct separate surveys (as well as separate worksheets) for each group of windows of a particular type and size. This method is most useful for surveying housing units where large window variations exist. While this method would provide a more exact survey of the housing unit's window stock, it also commands substantially more effort and time. Therefore, it is not a recommended method to follow.

The second method is a more generalized approach and considers the situation where a multiplicity of similar windows are present in the building. For simplicity, the characteristics of all windows should be pooled, such that the survey sheet reflects an average representation of all windows in the building. This method is most useful for surveying housing units where most of the windows are of a standard size. The survey performed for one housing unit can then also be used to represent identical housing units in each housing category, assuming that all windows are situated in a similar orientation. This latter method is the preferred method for completing the Field Data Sheet.

### 4.3.2 Worksheet I - (Short version)

Worksheet I is designed to use the information obtained from the Field Data Sheet by translating it in a way that will allow one to estimate annual energy loss through the existing windows, as well as the energy loss through the retrofit window option. The annual energy savings due to the retrofit option can then be obtained by difference.

Worksheet I considers only the energy costs associated with heating, and does not consider window exposure direction, which adds a fair degree of complexity to the analysis procedure. However, it is a quick and easy method for evaluating window performance. *This worksheet is the preferred form for preliminary evaluations because of its simplicity.*

### 4.3.3 Worksheet II - (Long Version)

Worksheet II is intended as a more detailed procedure for evaluating window performance. It considers orientation of all windows and provides a more exact picture of true winter heat losses and summer heat gains. Worksheet II is a lengthy form and requires substantially more effort to complete. It is recommended for those who desire a more accurate evaluation.

*(Tear-out copies of the Field Data Sheet, Worksheet I, and Worksheet II are included in Appendix A.)*

### 4.3.4 Example of Field Data Sheet and Worksheet I

An example of a completed Field Data Sheet (Window Survey) and Worksheet I are presented in pages 49-53 in order to help the user better understand how to use the sheets. Some Pertinent equations used in the worksheet to evaluate annual energy losses and associated heating costs are provided in Appendix C.

For convenience, the equations used in Worksheet I are briefly summarized below:

a) An expression for the annual heat loss through windows is derived in Appendix C. This equation is used to calculate the annual heat loss due to existing windows (before retrofit) and the heat loss after window replacement (after retrofit) as shown in Section 4 of Worksheet I.

$$Q = (U \times A \times D \times 24) + (C_p \times I \times L_c \times \rho \times D \times 24 \times 60)$$

where:

| | | | | | |
|---|---|---|---|---|---|
| Q | = heat loss through window, in Btu/yr | | $C_p$ | = specific heat of air, 0.245 Btu/lb-F |
| U | = overall coefficient of heat transfer, in Btu/hr-ft$^2$-F | | I | = air infiltration rate, in ft$^3$/min.-ft. |
| A | = area of window, in ft$^2$ | | $L_c$ | = crack length, ft. |
| D | = # of heating degree days >65F, in F-day/yr | | $\rho$ | = density of air at standard conditions, 0.075 lb/ft$^3$ |
| 24 | = multiplier, 24hr/day | | 60 | = multiplier, 60 min./hr |

Therefore: $Q = (24 \times U \times A \times D) + (0.245 \times I \times L_c \times 0.075 \times D \times 24 \times 60)$

or: $Q = (24 \times U \times A \times D) + (26.46 \times I \times L_c \times D)$.

b) The annual heating cost required to cover the window losses before retrofit and after retrofit (shown in Section 5 of Worksheet I) is as follows:

$$P = Q \times C \times 100 / r$$

where:
P = annual heating cost, $/yr
Q = annual heat loss through windows, Btu/yr
C = cost of heating fuel, $/Btu
r = heating system efficiency, %
100 = to convert from % to a decimal
By knowing the annual heating cost before retrofit and the annual heating cost after retrofit, the first year heating cost savings is then obtained by difference.

c) For windows that have a window covering, the U-value of the window should be adjusted as follows:

$$U_{adj.} = [(U_{wc} \times t) + (U \times (24 - t)] / 24$$

where:
$U_{wc}$ = U-value of window covering plus glazing
U = U-value of window (including frame and edge effects)
t = avg. # of hrs. that the covering is used during the day
24 = 24 hrs/day

This adjustment is then subtracted from the overall U-value of the window to get the corrected U-value, as shown in the equation below. It is this adjusted value that is used for calculating annual energy losses.

$$\text{Corrected U-value} = (U - U_{adj.})$$

The overall window U-value used in Worksheet I includes frame and edge effects; Worksheet II supplies a more detailed analysis and includes, in some sections, a calculation of the effects of frame and edge-of-glass on overall U-value.

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In the next few pages, an example is given to show how the window survey and Worksheet I should be completed. All tables which are referenced in Worksheet I can be found at the end of this UDP. *(Other figures pertinent to Worksheet II can also be found at the end of the UDP).*

The example illustrated compares the energy losses through ten existing windows of a house versus the energy losses due to the replacement windows. Existing windows are assumed to be single-glazed wood-framed windows. Replacement windows are assumed to be low-e coated insulating glass (with 3/8" air space) vinyl windows.

# FIELD DATA SHEET
## WINDOW SURVEY

**FACILITY:** XYZ BASE **BUILDING:** #500
**LOCATION:** NORFOLK, VA. **PERFORMED BY:** M. SMITH

*Directions:*
*Inspect the existing windows in the building. For each question below, circle one of the items which best describes the windows and fill in the blanks, where indicated.*

1. **WINDOW TYPE:** *(circle one)* Double-Hung / Casement / Horizontal Slider / Awning

2. **AVERAGE WINDOW SIZE:** Height (in.): 48
Width (in.): 36

3. **NUMBER OF WINDOWS: @ EACH EXPOSURE:** North 1 South 3 East 4 West 2 **TOTAL # of WINDOWS** 10

4. **WINDOW FRAME MATERIAL:** *(circle one)* Wood / Vinyl / Aluminum / Aluminum w/ thermal break

5. **GLAZING TYPE:** *(circle one)* Single-Glazing / Double-Glazing

6. **ARE THE WINDOWS WEATHERSTRIPPED?** *(circle one)* Yes / No

7. **CONDITION OF WINDOW FIT:** *(circle one)* Poor / Average / Excellent

8. **INDICATE THE TYPE OF WINDOW COVERING USED , IF ANY:**

*(Select one type only)*
A - No covering used
B - Medium-colored blinds
C - Light-colored blinds
D - Opaque white shades
E - Open-weave dark drapery
F - Close-weave dark drapery

**Window Covering Type** OPEN-WEAVE DRAPERY

9. **HEATING FUEL TYPE:** *(circle one)* Oil / Gas / None

10. **HEATING SYSTEM EFFICIENCY:** 65 %
*(If unknown, select a nominal system efficiency from the table provided)*

| *Nominal Heating System Efficiencies* | | |
|---|---|---|
| *Condition* | *Oil-Fired* | *Gas-Fired* |
| *Poor* | *50%* | *45%* |
| *Fair* | *65%* | *60%* |
| *Good* | *85%* | *80%* |

11. **IS THE BUILDING AIR-CONDITIONED?** *(circle one)* Yes / No

12. **COOLING SYSTEM ENERGY EFFICIENCY RATIO (EER):** — EER
*(If unknown, select a nominal system EER rating from the table provided)*

| *Nominal Cooling System Energy Efficieny Ratios* | |
|---|---|
| *Condition* | *EER* |
| *Poor* | *6.0 to 7.0* |
| *Fair* | *7.0 to 9.0* |
| *Good* | *9.0 to 11.0* |

# WORKSHEET I
## Short Version

*Worksheet I provides a quick procedure for estimating the annual energy savings from retrofitting existing windows with new vinyl -framed, hard-coat low-e insulating glass windows. Worksheet I considers the energy losses due to heating only, and does not take into account beneficial winter heat gain.*

*Directions:*
*For each question below, circle one of the items which best describes the windows and fill in the blanks, where indicated, using information from the right-hand column marked "Source".*

| **1. SITE INFORMATION** | **Input** | **Source** |
|---|---|---|
| **a. Annual Heating Degree Days:** | 3421 F-day/yr | *Table 1* |
| **b. Heating Fuel Type:** *(circle one)* | Oil / Gas / None | *Field Data* |
| **c. Heating System Efficiency:** | 65 % | *Field Data* |
| **d. Cost of Heating Fuel:** *(select one)* | Oil 0.94 $/gallon<br>Gas – $/therm | *Local Price* |

**2. WINDOW INFORMATION**

| | Input | Source |
|---|---|---|
| **a. Window type:** *(circle one)* | Double-Hung / Casement / Slider / Awning | *Field Data* |
| **b. Average window size:** | Height: 48 in. Width: 36 in. | *Field Data* |
| **c. Total Number of windows:** | Total # 10 | *Field Data* |
| **d. Window covering type most used:** | Window Covering type OPEN - WEAVE DRAPERY | *Field Data* |

| | **(BEFORE RETROFIT)** | **(AFTER RETROFIT)** | |
|---|---|---|---|
| **e. Window Frame Material:** *(circle one)* | Wood / Alum./Alum. w/Th.Br. | *Vinyl* | *Field Data* |
| **f. Window Frame U-value:** | 0.40 Btu/hr-ft$^2$-F | 0.40 *Btu/hr-ft$^2$-F* | *Table 2* |
| **g. Glazing Type:** *(circle one)* | Single / Double | *Double w/Low-e* | *Field Data* |
| **h. Overall glazing and frame U-value:** | 0.90 Btu/hr-ft$^2$-F | 0.45 *Btu/hr-ft$^2$-F* | *Table 2* |
| **i. Are window weatherstripped?** *(circle one)* | Yes / No | *Yes* | *Field Data* |
| **j. Condition of fit:** *(circle one)* | Poor / Average / Excellent | *Excellent* | *Field Data* |
| **k. Air Infiltration Rate:** | 1.67 cfm/ft. | 0.16 *cfm/ft* | *Table 3* |
| **l. Combined glazing and covering U-Value:** | 0.83 Btu/hr-ft$^2$-F | 0.43 *Btu/hr-ft$^2$-F* | *Table 4* |

## 3. GENERAL CALCULATIONS

**Source**

**a. Calculate cost of fuel in \$ / MBtu:** Oil: [(0.94 \$ / gallon) / 139,600 Btu/gallon ] x $10^6$ = 6.73 \$ / MBtu — *Line 1d*

or Gas: [(– \$ / therm) / 100,000 Btu/therm ] x $10^6$ = – \$ / MBtu

**b. Calculate area of representative window:**

Area = (48 in. x 36 in.) / 144 = 12 $ft^2$ — *Line 2b*

(Height) (Width)

**c. Calculate total window area in building:**

Total Area = 10 x 12 = 120 $ft^2$ — *Line 2c*

(Total # of Windows) (Line 3b)

**d. Calculate crack length, $L_c$, for representative window type:** — *Line 2a and Line 2b*

$L_c$: (Double-Hung) = [(2 x 48 in.) + (3 x 36 in.)] / 12 = 17 ft.
(Height) (Width)

$L_c$: (Casement) = [(2 x ____ in.) + (2 x ____ in.)] / 12 = – ft.
(Height) (Width)

$L_c$: (Slider) = [(3 x ____ in.) + (2 x ____ in.)] / 12 = – ft.
(Height) (Width)

$L_c$: (Awning) = [(2 x ____ in.) + (2 x ____ in.)] / 12 = – ft.
(Height) (Width)

**e. Calculate total crack length for all windows in the building:** — *Line 2c and Line 3d*

**Total $L_c$** = 10 x 17 = 170 ft.

(Total # of Windows) ($L_c$)

## 4. ANNUAL HEAT LOSS (HEATING SEASON)

### BEFORE RETROFIT

*(All values in this top section apply only to existing windows before retrofit.)*

| | | | | Source |
|---|---|---|---|---|
| a. | Overall glazing and frame U-value : | 0.90 | Btu-hr-ft$^2$-F | *(Line 2h)* |
| b. | Adjustment for Window Covering: *(Assume coverings are used 50% of the day)* | 0.035 | | *If none used, enter 0; else: ((Line 2h - 2l ) x 0.5)* |
| c. | Corrected U-value : | 0.865 | Btu-hr-ft$^2$-F | *(Line 4a - 4b)* |
| d. | Total Window Area : | 120 | ft$^2$ | *(Line 3c)* |
| e. | # of Annual Heating Degree Days: | 3421 | F-day/yr | *(Line 1a)* |
| f. | Multiplier: | 24 | hr/day | - |
| g. | Total Conduction Heat Loss : | 8.52 | MBtu/yr | *(Lines 4c x 4d x 4e x 4f)/10$^6$* |
| h. | Air infiltration rate : | 1.67 | ft$^3$/min-ft | *(Line 2k)* |
| i. | Total window crack length: | 170 | ft | *(Line 3e)* |
| j. | # of Annual Heating Degree Days: | 3421 | F-day/yr | *(Line 1a)* |
| k. | Multiplier: | 26.46 | Btu-min/ft$^3$-day-F | *(See Appendix C)* |
| l. | Total Infiltration Heat Loss: | 25.70 | MBtu/yr | *(Lines 4h x 4i x 4j x 4k)/10$^6$* |
| m. | **Total Annual Heat Loss Before Retrofit:** | 34.22 | MBtu/yr | *(Line 4g + 4l)* |

### AFTER RETROFIT

*(All values in this bottom section apply only to new vinyl replacement windows after retrofit.)*

| | | | | Source |
|---|---|---|---|---|
| a. | Overall glazing and frame U-value : | 0.45 | Btu-hr-ft$^2$-F | *(Line 2h)* |
| b. | Adjustment for Window Covering: *(Assume coverings are used 50% of the day)* | 0.01 | | *If none used, enter 0; else: (( Line 2h - 2l ) x 0.5)* |
| c. | Corrected U-value : | 0.44 | Btu-hr-ft$^2$-F | *(Line 4a - 4b)* |
| d. | Total Window Area : | 120 | ft$^2$ | *(Line 3c)* |
| e. | # of Annual Heating Degree Days: | 3421 | F-day/yr | *(Line 1a)* |
| f. | Multiplier: | 24 | hr/day | - |
| g. | Total Conduction Heat Loss : | 4.34 | MBtu/yr | *(Lines 4c x 4d x 4e x 4f)/10$^6$* |
| h. | Air infiltration rate : | 0.16 | ft$^3$/min-ft | *(Line 2k)* |
| i. | Total window crack length: | 170 | ft | *(Line 3e)* |
| j. | # of Annual Heating Degree Days: | 3421 | F-day/yr | *(Line 1a)* |
| k. | Multiplier: | 26.46 | Btu-min/ft$^3$-day-F | *(See Appendix C)* |
| l. | Total Infiltration Heat Loss: | 2.46 | MBtu/yr | *(Lines 4h x 4i x 4j x 4k)/10$^6$* |
| m. | **Total Annual Heat Loss After Retrofit:** | 6.8 | MBtu/yr | *(Line 4g + 4l)* |

## 5. COST SAVINGS IN HEATING ENERGY:

*(Note: Subscript "br" refers to "before retrofit", and subscript "ar" refers to "after retrofit")*

**a. Calculate heating cost Before Retrofit:** **Source**

Annual heating cost Before Retrofit = ( 34.22 MBtu/yr) x ( 6.73 $/MBtu) x (100 / 65 ) = 354.31 $/yr

( Line $4m_{br}$ ) ( Line 3a ) (Line 1c)

*Source: Line 4m, Line 1c, and Line 3a*

**b. Calculate heating cost After Retrofit:**

Annual heating cost After Retrofit = ( 6.8 MBtu/yr) x ( 6.73 $/MBtu) x (100 / 65 ) = 70.41 $/yr

( Line $4m_{ar}$ ) ( Line 3a) (Line 1c)

*Source: Line 4m, Line 1c, and Line 3a*

**c. Calculate first year heating cost savings:**

First year heating cost savings = 354.31 $/yr - 70.41 $/yr = 283.90 $/yr

(Line 5a) (Line 5b)

*Source: Line 5a and Line 5b*

### 4.3.5 Summary of Results from Worksheet I Example

The example shown in the previous section examines the savings in heating energy that can be realized if existing single-glazed, non-weatherstripped wood windows were to be replaced by new, factory-weatherstripped, double-glazed low-e vinyl windows.

From the results given in Section 4 of the sample worksheet, page 52, the annual window heat loss for the 10 existing wood windows in the building was estimated to be 34.22 MBtu/yr. Of this total heat loss, a significant portion can be attributed to air infiltration.

The annual heat loss after retrofit with new thermally-improved windows was estimated to be 6.8 MBtu/yr. This shows that an *80% reduction in heat loss* is possible by installing energy-efficient window units to replace existing windows that lose valuable heating energy.

According to the results given in Section 5 of the sample Worksheet, page 53, heating energy cost after retrofit is also reduced by 80%, resulting in a heating energy savings of $283.90 /yr. This shows that for a total of 10 windows replaced in the housing unit, as much as $283.90 /yr in heating costs can be saved. If this were multiplied by an estimated 90,000 housing units in the Navy and Marine Corps inventory, the total heating cost savings can be over $25 million/yr.

Of course, these estimates are for comparison only, and actual energy savings will need to be verified on a case by case basis. Energy costs will vary depending upon location, the types of windows to be replaced, the number of windows, present condition, etc. Proper use of the worksheets will aid in estimating actual window energy losses.

### 4.3.6 Economics

In order to confirm a replacement action, one must first determine whether the replacement of the existing window will result in long-term energy and cost savings. To accomplish this, life-cycle cost analysis will be used to compare the long-term cost savings of replacing the existing window by a new thermally-improved window.

There are several procedures for performing life-cycle cost analysis. The recommended procedures in this UDP consists of determining:

a) Present Value, and
b) Savings-to-investment Ratio (SIR).

[An additional discussion of life-cycle cost techniques is also given in Appendix B.]

**a. Present Value**

This is one of the most commonly used life-cycle costing technique. The present value method *compares the equivalent cash needed to own and operate a system over the life of the system.* The system which has the lowest life cycle cost considering all the expenditures throughout its life is the one selected.

An expression used to obtain the present value of a cash flow occuring during the life of the system is as follows:

$$\text{Present Value} = F_n \left[ 1/(1+i)^n \right]$$

where:

$n$ = number of years

$F_n$ = dollar amount of cash flow after n years

$i$ = annual discount rate

The number obtained for the present value is that amount needed to be set aside today to cover a future cash flow.

**b) Savings-to-Investment Ratio (SIR)**

SIR is a technique to determine whether an existing system should be retrofitted or replaced with an alternative system on the basis of cost savings. Replacement should be considered cost-effective if the value for SIR is greater than 1.0 (see Appendix B).

$$SIR = [(\Delta E_1 \times DERF) + (\Delta E_2 \times DERF) + (\Delta O\&M \times PYDF)] / (C \times PIF)$$

where:

$\Delta E_1$ = Energy savings due to heating

$\Delta E_2$ = Energy savings due to cooling

DERF = Differential escalation rate factor

PYDF = Project year discount factor

PIF = Periodic Investment Factor

C = Startup cost of replacement system

$\Delta$ O&M = Change in annual O&M cost due to replacement option

Appropriate values for DERF, PYDF, and PIF can be obtained from Table B-1 through Table B-3 in Appendix B.

### 4.3.7 Example of Life-Cycle Cost Analysis

The two life-cycle costing procedures discussed above will now be used to compare the life-cycle costs of the windows used in the Worksheet I example. This exercise is intended to *show how to use the worksheet information in performing a life-cycle cost analyis using the* Present Value and SIR evaluation methods.

### a) Example of Present Value method

When performing a life-cycle cost analysis, all of the cost elements pertaining to the window should be considered. This involves the total cost of acquisition and ownership, such as: the cost of a new installed window, the cost of heating energy due to window heat loss, cost of maintenance, such as painting, and cost of disposal of the old window. (Most of these are one-time costs only, with the exception of painting costs; therefore, painting costs scheduled for the life of the window should be adjusted for its present value.)

The life-cycle costs of the existing wood window (before retrofit) and the new vinyl replacement window (after retrofit) used in the Worksheet I example will now be compared. The following analysis will be based on *one window*.

Prior to conducting the analysis, the following assumptions are made:

1) Both windows are 48"x36" double-hung units. The average life for both windows is assumed to be 25 yrs.

2) Removal cost for existing windows is estimated to be $40.00

3) Installed price of new window is estimated to be $176.00

4) Fuel Discount Factor is 13.5. [23]

5) First year heating cost before retrofit: $354.41 (See Section 5, Worksheet I, page 53.)
Since there are 10 existing windows, then the *heating cost per window before retrofit is ( $ 354.41 / 10 ) = $ 35.41.*

6) First year heating cost after retrofit: $ 70.41. (See Section 5, Worksheet I, page 53.)
Since there are 10 windows to be replaced, then the *heating cost per window after retrofit is ($ 70.41 / 10) = $ 7.04.*

7) Painting for existing wood window is required. The painting schedule is assumed to be as follows: interior painting every 6 years and exterior painting every 7 years. The estimated cost of painting *one side* of the wood window is $ 16.50. The vinyl replacement window never needs painting.

8) Assume the annual discount rate for adjusting to present value = 10%.

10) Present value of painting = $\$16.50 \times [\, 1/(1+i)^n \,]$.
This present value equation will be used to calculate the present value of painting costs for n = 6, 7, 12, 14, 18, 21, and 24 years. These are the years when painting is due over the 25-year life of the wood window.

The life-cycle cost comparison of the two windows is illustrated as follows:

| | | New Vinyl Window w/ low-e glass | Existing Wood Window w/ single-glazing |
|---|---|---|---|
| A. | Existing window removal | $ 40.00 | - |
| B. | Installed purchase price | $ 176.00 | - |
| C. | Annual heating energy cost | $7.04 | $35.41 |
| D. | Fuel Discount Factor | 13.5 | 13.5 |
| E. | Life Cycle Energy Cost (C x D) | $ 95.04 | $ 478.31 |
| F. | Painting Cost | - | $ 33.00 |
| | 6th year ($16.50 x 0.565) | - | $ 9.32 |
| | 7th year ($16.50 x 0.513) | - | $ 8.46 |
| | 12th year ($16.50 x 0.319) | - | $ 5.26 |
| | 14th year ($16.50 x 0.263) | - | $ 4.34 |
| | 18th year ($16.50 x 0.180) | - | $ 2.97 |
| | 21st year ($16.50 x 0.135) | - | $ 2.23 |
| | 24th year ($16.50 x 0.102) | - | $ 1.68 |
| G. | Life-Cycle Painting Cost | | $ 67.26 |
| H. | Total Life-Cycle Cost (A + B + E + G) | $ 311.04 | $ 545.58 |
| I. | Annual Cost per Window (H/25) | $ 12.44 | $ 21.82 |

From the above, the annual cost of the replacement window is $12.44 as compared to $21.82 for the existing wood window. Since the life-cycle cost of the thermally-improved window is lower than that of the existing window, then window replacement can be recommended.

**b) Savings-to-investment ratio (SIR) method)**

The SIR method shows that a replacement option can be considered cost-effective if the expected lifetime savings exceed the initial investment required. That is, if the value for SIR is greater than 1.0, then the replacement option is recommended. For this example, the following assumptions will be made:

1) The annual discount rate is 10%. From Table B-1 in Appendix B, the value for PYDF (project year discount factor) is 9.524 at this annual discount rate.

2) Assume fuel oil escalation rate is 8%. From Table B-2, Appendix B, at a 10% discount rate, the value for DERF (diff. escalation rate factor) is 20.051.

3) Assumed life of replacement option is 25 years. Then from Table B-3 in Appendix B, the value for PIF (periodic investment factor) is 1.0.

4) The first year heating cost per window before retrofit = \$35.41.
The first year heating cost per window after retrofit = \$7.04.

Therefore, the change in annual heating energy cost, $\Delta E_1$, is the difference in energy costs of the window before retrofit and after retrofit.
$\Delta E_1$ = (\$35.41 - \$7.04) = \$28.37.
Cooling was not considered in Worksheet I, so $\Delta E_2$ is neglected.

5) The change in O&M costs is simply the difference in costs for maintenance before retrofit and after retrofit. Since the vinyl replacement window has no maintenance costs, O&M will be the cost of maintenance due to the wood window only. This is the cost required to paint the wood window. Assuming the estimated cost of painting each side is \$16.50, then, the total cost for painting both sides is (\$16.50 x 2 ) = \$33.00.

6) The startup cost, C, of the replacement option is the purchase cost of the new vinyl window plus the cost for removing the existing window. Assuming the installed price of the new window is \$176 and removal cost is \$40, then the startup cost C is (\$176 + \$40) = \$216.00.
Using the SIR equation given in page 55, and substituting values of C, PYDF, DERF, PIF, $\Delta E_1$, and $\Delta$O&M, the equation becomes:

$$[(28.37) \times (20.051) + (33 \times 9.524)] / (216 \times 1) = \underline{4.09.}$$

Since the value for SIR in this example is greater than 1.0, then replacement of existing wood windows with thermally-efficient vinyl windows can be recommended.

# 5. RECOMMENDATIONS AND SPECIFICATIONS

## 5.1 SUMMARY OF RECOMMENDATIONS

### 5.1.1 Windows for Navy Housing

- Because of the large potential savings in energy and costs, existing windows which are judged to be poor thermal performers and big sources of energy losses should be considered for retrofit or replacement by a more energy-efficient option. Windows that have sash leaks or excessive air infiltration, installation deficiencies, or which have deteriorated to the point that caulking and weatherstripping cannot be made effective, are likely candidates for replacement.

- Selected energy-efficient option should have high R-value (conversely, low U-value) and low air infiltration rate. When selecting windows for Navy housing, it is recommended that window performance be verified through independent laboratory test results to make certain that the R-values and air-infiltration value are true. Thermal and structural test reports should be requested to verify this information.

- Vinyl-framed windows are recommended for new or existing Navy housing due to their low heat transmission properties and low maintenance characteristics. Vinyl is an effective insulator, meaning that it has a high R-value. Rigid vinyl is durable, lightweight, is resistant to abrasion, rain, humidity, corrosion and pollution effects, and will not support combustion. Vinyl will not chip, flake, rust, rot, peel, or blister, and because it is self-colored, vinyl never needs to be painted. Only vinyl windows that have been certified through reliable programs, such as those sponsored by AAMA (American Architectural Manufacturers Association) or SPI (Society of Plastics Industry), should be selected.

- When selecting vinyl windows, specify white or beige colors for vinyl for greatest durability and best performance. Darker-colored vinyl, such as those with shades of brown, are presently not recommended for Navy housing.

- For areas where heating and air-conditioning are frequently used, it is recommended that windows in residential Navy housing be double-glazed rather than single-glazed in order to conserve energy. For even greater energy-savings potential, the use of a low-emissivity coating on the glass is recommended to increase the window's overall thermal performance. Low-emissivity glass manufactured by the pyrolitic method (hard-coat low-e glass) is suggested as the coating of choice due to its durability, ease of handling, and lower cost.

- When specifying low-e glass, it is preferred to have the coating placed on surface 3 (outer side of inner glazing) in areas where heating is the primary concern (e.g., areas with a high number of heating degree days). Where cooling is the primary concern (e.g., areas with high number of dry-bulb degree hours), it is preferred to have the coating on surface 2 (inner side of outer glazing) for reduction of solar gain.

- For areas where cooling is of greater importance than heating, consider low-emissivity hard coat glass with **low shading coefficients** for greater protection against the sun. For all areas, choose low-emissivity coatings with emissivity values lower than 0.40.
- It is recommended that double-strength glass, rather than single-strength glass, be used for Navy housing as a safety measure against incidences involving breakage.
- In double-glazed units, it is recommended that the air space between panes be at least 3/16-in. (but not exceeding 1-in.) for effective insulation. A nominal air space width of between 1/4-in. to 3/4-in. is usually adequate. Insulating glass units that are dual-sealed are also recommended for longest life, and for better protection against moisture penetration. Also, all replacement windows must have factory-installed weatherstripping.
- Window units with long warranty periods are a measure of quality workmanship and manufacturer confidence. Look for extended warranty periods for both frame and insulating glass units.
- Prior to selecting windows for Navy housing, high-efficiency replacement options should be considered only if the option clearly shows meaningful savings. This should be evaluated using cost vs. savings analysis, as shown in the UDP.
- It is recommended that window installation be performed by qualified and experienced installers to ensure best and proper window fit and to reduce the likelihood of window deficiencies due to faulty installation.

### 5.1.2 Window Coverings for Navy Housing

- Energy-efficient window coverings help to enhance a window's thermal performance; however, effective usage of any window covering device implies a tremendous degree of occupant participation. Because of the critical need for user participation in window management, it is first recommended that existing windows be replaced with an energy-efficient unit, where economic analysis clearly shows energy and cost-savings. Thus, the upgraded window will reduce energy costs automatically without reliance on the occupant. Once the new window is in place, use of an energy-efficient window covering device becomes unnecessary because it will only offer slight improvements in thermal efficiency. If a window covering is desired to provide privacy or shade, the least-cost window covering option should be considered. Conventional devices, such as blinds, shades, or drapes, are equally suitable for providing privacy.

- In cases where existing windows are in good condition and have not been upgraded with thermally- efficient units, then thermally-efficient window coverings are recommended in order to enhance window performance and to supplement energy and cost savings.

- Prior to selecting an energy-efficient window covering device, it is recommended that potential air leaks in the existing window be eliminated with caulking or weatherstripping. The heat lost in winter and gained in summer through drafts and poorly-fitted frames could easily offset the benefits of installing energy- efficient window coverings.

- Of all window coverings, shades that roll up and down are the most convenient and are recommended for Navy housing. Once installed, shades do not interfere with the movement of air from heating or cooling vents, as draperies can. To realize any significant savings in winter, the shade should have high thermal resistance (high R-value) in order to be an effective thermal insulator. Furthermore, it should be edge-sealed at the top, bottom, and sides in order to reduce air leakage to and from the outdoors, and to reduce convective air currents around the installed insulation device. To minimize cooling loads in summar, shade materials with a light-colored or reflective outer facing to help block solar heat gain, are recommended.

- Again, building occupants are the key factor in maximizing the effectiveness of energy-efficient window covering options. Coverings that are easy to use, easy to maintain, and that fit best with the occupant's habit and lifestyle will encourage proper operation of window coverings and will accrue highest energy and cost savings.

- Cost is another significant factor in selecting window coverings. More complex, or advanced types of coverings are not recommended because proper occupant use cannot be monitored or controlled. Therefore, simple, uncomplicated, and easy-to-use coverings are most cost-effective.

- Window coverings must be used intermittently during the course of the day in order to prevent the occurrence of overheating, especially if the covering is tightly sealed to the window and is left in place for prolonged or extended periods of time throughout the year.

## 5.2 SPECIFICATIONS

### General

All windows under consideration for procurement must adhere to standardized performance requirements and testing set forth by an accredited window certification program, such as that sponsored by AAMA (American Architectural Manufacturer's Association) or SPI (Society of Plastics Industries). These certification programs are voluntary; however, they are widely recognized by the industry as a valuable method for monitoring quality control in window products, and provide assurance to the public that a given product meets performance standards.

Certified products tested at an approved laboratory must meet all requirements established within the specifications. The program sponsored by AAMA conforms to the specifications under AAMA 101V-86, "Voluntary Specifications for Poly (Vinyl Chloride) (PVC) Prime Windows and Sliding Glass Doors." The program sponsored by SPI conforms to ASTM D-4099, "Standard Specifications for Poly (Vinyl Chloride) (PVC) Prime Windows."

The ability of vinyl windows to meet the primary performance requirements is determined by tests established by ASTM (American Society of Testing and Materials) standard methods. Several basic tests are conducted, some of which are the following:

**Air Infiltration** - This test determines how well the window resists air infiltration resulting from static air pressure differentials. The window is placed in a chamber pressurized to the equivalent of 25 mph. The air infiltration rate is calculated in accordance with ASTM E283.

**Water Penetration** - In this test, deluges of water are applied to the exterior of the window. Simultaneously, air pressure differentials are applied to the interior and exterior of the window in cycles. No leakage may pass the interior face of the test window.

**Stru [illegible]ral Performance/Wind Load** - This test method is used to simulate the conditions of installed vinyl windows to environmental wind loads. Under laboratory conditions, static air pressures are applied to the interior and exterior of the test specimen. The window is then reviewed for glass breakage and any permanent deflection, in accordance with ASTM E330.

Primary performance requirements of residential windows (grade 15) for AAMA V101- 86 or ASTM D-4099 certification are listed below:

| | Performance Class (Design Pressure) $lbs/ft^2$ | Structural Test Pressure $lbs/ft^2$ | Water Resistance Test Pressure $lbs/ft^2$ | Air Infiltration Test Pressure $lbs/ft^2$ | Air Infiltration Max. Rate @25mph cfm /ft |
|---|---|---|---|---|---|
| AAMA V101-86 | 15 | 22.5 | 2.86 | 1.57 | 0.37 |
| ASTM D-4099 | 15 | 22.5 | 2.86 | 1.57 | $\leq$0.375 |

The following inputs to NAVFAC documents have been prepared to replace or augment existing specification guidelines. These suggested inputs are directly related to the contents of this UDP and concern the use of energy-efficient windows and window coverings to be procured for retrofit or replacement of units in existing Navy housing or for new construction applications.

### 5.2.1 Input to NAVFAC Guide DM-35, August 1971

**a. Page 35-3-1, Section 1, following paragraph 2c(3), insert:**

- (f) "A low emissivity coating should be considered for all outer wall windows where heating and/or cooling loads are significant and where economic analysis clearly show meaningful energy and cost savings. The coating should be preferentially applied to surface 2 of the double-glazing panel (where surface 2 is the inner surface of the external glass pane). Where reduced heat gain is desirable, use of low-emissivity coatings with lowest shading coefficients should be considered. Glazing shall be classified as "double-strength (1/8-in. thick or greater), and insulating glass unit shall have a nominal air space width of 3/8-in. or more, but not exceeding 1-in. width."

**b. Page 35-3-1, Section 1, following paragraph 2c(3):**

- Renumber remaining subparagraph (f) to (g)

**c. Page 35-3-1, Section 1, following paragraph 2c(4), modify by:**

- (a) "Housing in climates having more than 4,000 heating degree-days annually shall be designed with small windows on northern elevations or on elevations exposed to winter winds."

- (b) "A low-emissivity coating should be considered for all outer wall windows where economic analysis clearly show meaningful energy and cost savings. The coating should be preferentially applied to surface 3 of the double-glazing panel (where surface 3 is the outer surface of the interior glass pane). Glazing shall be classified as "double-strength (1/8-in. thick or greater), and insulating glass unit shall have a nominal air space width of 3/8-in. or more, but not exceeding 1-in. width."

**d. Page 35-3-1, Section 1, paragraph 2d, modify by deleting current paragraph and replacing with**

- "Interior treatment of windows are to be provided by the Navy for all family housing. Window treatments will be utilized to provide privacy for occupants, as well as to supplement thermal performance of existing windows. Proper usage of interior window treatments shall be the occupants responsibility, and should entail frequent use in a manner such that heat losses and heat gains are reduced during winter and summer, respectively, to minimize heating and cooling costs."

**Replace paragraph 2d(1) with:**

- (1)" Standard Treatment. The standard window treatment for Navy housing retrofitted with energy-efficient windows shall be conventional shades, drapes, blinds, or whichever may be the least-cost option. For existing windows in good condition, and that have not been retrofitted with energy-efficient windows, then energy-efficient shades may be used to enhance window thermal performance provided that the shades are found to be cost-effective."

**Delete paragraph 2d(2).**

**Replace paragraph 2d(2) with paragraph 2d(3).**

**e. Page 35-4-5, Section 1, paragraph 8, modify by:**

- Replace reference to "paragraph 2d" with "paragraph 2c".

**f. Page 35-4-5, Section 1, paragraph 8a, modify by:**

- Replace reference to "standard stock items" with "vinyl-framed low-emissivity-coated double-glazed windows with a nominal air space width of 3/8-inch or more between glazings, but not exceeding 1 inch."

**g. page 35-4-5, Section 1, paragraph 8a(1-3), renumber 1 through 3 to 2 through 4, and insert (1):**

- (1)" Vinyl Windows. Vinyl-framed windows are to be used for new construction of residential housing or for replacement of existing windows due to its high thermal performance and low-maintenance requirements. White or beige vinyl products should be specified. Dark-colored vinyl such as brown (or shades of brown) shall not be considered for use."

**h. Page 35-4-6, Section 1, pargraph 8b(3), modify by:**

- (3)" Storm Sash. Requirements for storm sash in areas where winter design temperature is 0 degrees F dry bulb or less may be unnecessary if the window is currently of a double-glazed type. If currently a single-glazed unit, consideration must be given to replacement of the window with a double-glazed insulating glass unit. This determination should be based on economic study."

**i. Page 35-4-6, Section 1, paragraph 8d, modify by:**

- Replace reference to "Paragraph 2c" with "paragraph 2c and 2d".

### 5.2.2 Input to NAVFAC DM-11.1, Tropical Engineering, March1980.

**a. Page 11.1-53, Section 2, following paragraph 2b(3), add:**

- (4) If considered desirable to reduce heat loss (or reduce heat gain), double-glazed windows with (or without) a low-emissivity coating should be considered for all outer wall windows. Details of this approach are given in DM-35, Family Housing. If these thermally efficient windows are found to be suitable from the standpoint of energy savings and compatability with the lcoal environmental conditions, their use might necessitate changes in pages 11.1-53 through 11.1-57.

**b. Page Reference-2. Between "DM-8" and "P-89", insert:**

- "DM-35 Family Housing"

### 5.2.3 Input to NAVFAC DM-33.02, Naval Hospitals, January 1987.

**a. Page 33.02-14, paragraph 4.4.1, line 3, add:**

- "with a low-emissivity coating" between "glazing" and "shall".

**b. Page 33.02-29, after paragraph 6.3, add:**

- 6.3.1 Energy Conserving Windows. All outer wall windows shall be low-emissivity coated, double-glazed to reduce heating and/or air conditioning requirements. Design details are given in DM-35, Family Housing.

**c. Page 33.02-29 and 30.**

- Renumber remaining paragraphs of 6.3.

**d. Page Reference-2. Between "NAVFAC DM-23.01" and "NAVFAC P-89" insert:**

- "NAVFAC DM-35, Family Housing"

**5.2.4 Input to NAVFAC DM-36.2. Unaccompanied Enlisted Personnel Housing, November 1983.**

**a. Page 36.2-11 paragraph (5) Renumber this paragraph to (6) and add a new paragraph (5) as follows:**

- (5) "Wherever possible, to reduce energy consumption, low-emissivity coated, double-glazed windows shall be used for all housings having significant heating and/or air conditioning requirements. This action should be verified through economic study. Design details are given in DM-35, Family Housing."

**b. Page Reference-1. Between "DM-8" and "DM-36 Series," insert:**

- "DM-35 Family Housing"

**c. Changes similar to paragraph 3(a) are also recommended for both DM-36.1 and DM-36.3.**

**5.2.5 Input to NAVFAC P-455, Book 8: Doors, Windows, and Glass, July 1974.**

- In view of energy conserving changes in windows proposed for DM-35, it is necessary to substantially revise this document. The revisions are quite extensive, and outside the scope of this UDP. It is recommended that this revision be carried out as soon as funds could be made available for this effort.

**5.2.6 Input to NAVFAC NFGS-08630, Poly (Vinyl Chloride) (PVC) (Windows), February 1990.**

**a. Paragraph 1.4.2.** At end of paragraph, add: "A certified test report prepared by an independent laboratory should be submitted attesting the window's R-value of at least ( )."

**b. Paragraph 2.1, GENERAL REQUIREMENTS FOR WINDOWS.** Add the following at the end of this section: "Energy conservation must be one of the most important criteria in selecting windows (see Defense Energy Program Policy Memorandum (DEPM) 88-3 of 30 Sep 1988). A procedure for selecting cost effective, energy-efficient windows is detailed in the User Data Package (UDP) prepared by the Naval Civil Engineering Laboratory (published as NCEL CR 90.011, July 1990). Use of double-glazed, low-emissivity coated, vinyl windows is a cost effective way of preventing significant energy losses from Naval housing.

**c. Paragraph 2.4.7 Color, NOTE, lines 8 and 9,** change "and aesthetic need." to read: "aesthetic need, and expected life which shall be no less than the expected life of white PVC (about 25 years).

**d. CRITERIA NOTES, NOTE A-3:** After "glazing" add: "to achieve the desired R-value."

**e. CRITERIA NOTES, NOTE C, paragraph 2, line 6.** Between "cost" and "as well as," add: "life cycle cost savings due to reduced heating and/or cooling requirements of a low-emissivity coated double-glazed window when compared with the standard single-glazed window."

**f. CRITERIA NOTES, NOTE F, line 12.** Between "specified." and "Allow," add: "Specify low-emissivity coating and indicate if the coating should be placed on the outside of the inner glazing, inside of the outer glazing, or on a separate plastic sheet mounted between the two glazings for all double-glazed windows to achieve required overall window R-value. Consult manufacturer's literature for available options."

# 6. INSTALLATION

This section mainly serves as a reference for general procedural guidelines for ensuring proper installation of windows and window coverings, and points out a number of items which must be taken into consideration to ensure satisfactory performance . These guidelines are very general and by no means complete, and may vary from window to window, and from window covering type to another. Individual manufacturer brochures or installation manuals must be consulted for more detailed directions on proper installation for replacement or new construction applications.

*Included in Appendix F and G are copies of typical installation instructions from several manufacturers of windows and window coverings. Please note that the selection of these particular manufacturers for inclusion within the Appendix should not be taken as a recommendation, approval, or endorsement of these products.*

## 6.1 WINDOW INSTALLATION

Proper installation is essential for obtaining maximum effectiveness from any window. Improper installation of units may reduce their thermal effectiveness, lead to excessive air and water leakage, condensation, and interior damage.

When assessing a builing's window needs, it must be remembered that actual conditions in existing buildings vary greatly; therefore, each building should be considered on a case by case basis whenever possible. The following are some general guidelines for window installation:

a. Measure the rough wall opening and the new window to insure its proper fit.

b. Check the existing opening for signs of decay that may lead to air or water leakage and correct the problem, if any.

c. Openings should be designed so that water will not be trapped and will drain away from the window to the outside of the building.

d. Minimum requirements for window installation calls for windows to be securely anchored in place to a straight, plumb and level condition.

e. Care in handling the window during actual installation in the opening is important. Window should not be racked, warped or distorted to fit an inaccurate opening. Where such inaccuracies occur, shimming of the window frame is essential.

f. Caulking with a good sealant between the window frame and the opening is essential in order to resist the infiltration of air and water. In caulking around the frame, care must be taken not to block off drainage of water from the window.

## 6.2 WINDOW COVERING INSTALLATION

The specific details on installation for individual types of window coverings are provided by the individual manufacturer and should be carefully followed to ensure that the covering will perform its functions satisfactorily. Some basic guidelines for installation of window coverings are as follows:

a. Check the window covering option to make sure that the component fits the dimensions of the window opening.

b. Check the mounting area to be sure there are no obstructions that would interfere with the operation of the window covering when installed.

c. Check that all hardware and accessories for the window covering are on hand and complete.

# 7. MAINTENANCE AND OPERATION

## 7.1 MAINTENANCE

### 7.1.1 Window Maintenance

Window maintenance is an important step to prolonging the life and appearance of new windows. Requirements vary for different window types, and should be verified through individual manufacturers for proper care.

For vinyl-framed windows, maintenance needs are minimal. Vinyl never needs to be painted or stained because it is self-colored. To clean, soap and water are all that is required to keep the vinyl surface free from dust or accumulated dirt.

For wood-framed windows, maintenance needs are highest. Wood must be frequently and periodically painted, sealed, or stained as preventive maintenance in order to reduce the deteriorating effects of sun, rain, and other elements. Painting must be performed on a scheduled basis, particularly on the exterior part of the window. High-quality paint should be applied for longest wear.

Caulking should be applied wherever there are seals. This includes joints between window frames or sills and siding, taking care not to block off drain holes at the window sill. Caulking is an inexpensive form of preventive maintenance and should be used for all window types. Apply caulking also in places where noticeable drafts appear, or where previous caulking has become hard and brittle. Caulking is readily available in oil-based, latex, butyl, silicone-based and other varieties. Use a high-quality caulk for highest durability, effectiveness and long-lasting wear.

Weatherstripping should be checked to ensure that the weatherstripping material is intact and in place. This is to minimize the air infiltration effects, which can potentially lead to large energy losses. Replace weatherstripping where it is missing, damaged, or broken off.

### 7.1.2 Window Covering Maintenance

Maintenance of selected window coverings should be performed as-needed by the responsible parties in housing maintenance. For all types of window coverings, cleaning is the prime maintenance concern, followed by repair or replacement of parts or accessories.

Drapes are generally easier to remove for washing than are blinds or shades. Fabrics that are more easily and inexpensively laundered rather than dry-cleaned are most suitable for residential housing. Slats in venetian blinds should be periodically cleaned or wiped off to remove accumulated dust. Shades are not easily cleaned, unless the material is of a non-fabric type that can simply be wiped with a cloth. Instructions on general cleaning and maintenance procedures will vary from one window covering type to another, and from manufacturer to manufacturer. Consult available product literature for specific details on basic care.

It should be noted that window coverings with many moving parts (pulleys, tracks, etc.) will require far more frequent maintenance than those that have few moving parts. Avoid window covering types with automated hardware.

## 7.2 OPERATION

### 7.2.1 Window Operation

There is no more energy-efficient way to operate a window than to keep it shut tightly in cold weather, and closed off and shaded during warmer weather if the room is being cooled with air-conditioning. A well-insulated window with high thermal performance will work nicely by itself in preventing excessive heating and cooling losses year-round. For maximum energy savings, window performance can be enhanced through proper window management.

### 7.2.2 Window Covering Operation

Window coverings are of advantage in further reducing heating and cooling energy costs, but rely on proper and frequent use for maximum energy savings. This means that in order to be energy-efficient, window coverings must be operated strategically. The following operational guidelines should be kept in mind:

a. When using air conditioning in the summer, keep windows tightly covered during the day, especially on sunny sides of the building.

b. In the summer, keep windows covered on the east side during mornings, and covered on the west side during afternoons.

c. Open shades and window to use natural ventilation during summer nights to cool the building when there are fresh breezes, in order to eliminate the need for air-conditioning.

d. In the winter, keep windows uncovered on the east, west and south sides of the house during sunny days to take advantage of winter heat gain, and close them during the night to prevent nighttime heat losses.

e. On cloudy winter days, cover windows to prevent excess heat loss.

f. Shut windows and keep windows covered on the north side as much as possible during the winter, as north-facing windows get very little sun.

## 8. REFERENCES


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## Table 1. ANNUAL HEATING DEGREE DAYS (BASE 65 F) AND LATITUDES (°) FOR VARIOUS CITIES IN THE UNITED STATES

| Location | Heating Degree Days | Latitude (°) |
|---|---|---|
| **Alabama** | | |
| Birmingham | 2551 | 34 |
| Huntsville | 3070 | 35 |
| Mobile | 1560 | 31 |
| Montgomery | 2291 | 32 |
| **Alaska** | | |
| Anchorage | 10864 | 61 |
| Barrow | 20174 | 71 |
| Fairbanks | 14279 | 65 |
| Juneau | 9075 | 58 |
| Nome | 14171 | 64 |
| **Arizona** | | |
| Flagstaff | 7152 | 35 |
| Phoenix | 1765 | 33 |
| Tucson | 1800 | 32 |
| Winslow | 4782 | 35 |
| Yuma | 974 | 33 |
| **Arkansas** | | |
| Fort Smith | 3292 | 35 |
| Little Rock | 3219 | 35 |
| Texarkana | 2533 | 33 |
| **California** | | |
| Bakersfield | 2122 | 35 |
| Eureka | 4643 | 41 |
| Fresno | 2611 | 37 |
| Long Beach | 1803 | 34 |
| Los Angeles | 2000 | 34 |
| Oakland | 2870 | 38 |
| San Diego | 1458 | 33 |
| San Francisco | 3000 | 38 |
| **Colorado** | | |
| Colorado Springs | 6423 | 39 |
| Denver | 6283 | 40 |
| Grand Junction | 5641 | 39 |
| Pueblo | 5462 | 38 |
| **Connecticut** | | |
| Bridgeport | 5617 | 41 |
| Hartford | 6235 | 42 |
| New Haven | 5897 | 41 |
| **Delaware** | | |
| Wilmington | 4930 | 40 |
| **D.C.** | | |
| Washington | 4224 | 39 |
| **Florida** | | |
| Daytona Beach | 879 | 29 |
| Fort Myers | 442 | 27 |
| Jacksonville | 1239 | 30 |
| Lakeland | 661 | 28 |
| Miami | 214 | 26 |
| Orlando | 766 | 29 |
| Pensacola | 1463 | 30 |
| Tallahassee | 1485 | 30 |
| Tampa | 683 | 28 |
| West Palm Beach | 253 | 27 |
| **Georgia** | | |
| Athens | 2929 | 34 |
| Atlanta | 2961 | 34 |
| Augusta | 2397 | 33 |
| Columbus | 2383 | 33 |
| Macon | 2136 | 33 |
| Savannah | 1819 | 32 |
| **Idaho** | | |
| Boise | 5809 | 44 |
| Lewiston | 5542 | 46 |
| Pocatello | 7033 | 43 |
| **Illinois** | | |
| Chicago | 6630 | 42 |
| Moline | 6408 | 41 |
| Peoria | 6025 | 41 |
| Rockford | 6830 | 42 |
| Springfield | 5429 | 40 |
| **Indiana** | | |
| Evansville | 4435 | 38 |
| Fort Wayne | 6205 | 41 |
| Indianapolis | 5699 | 40 |
| South Bend | 6439 | 42 |
| **Iowa** | | |
| Burlington | 6114 | 41 |
| Des Moines | 6588 | 42 |
| Dubuque | 7376 | 42 |
| Sioux City | 6951 | 42 |
| Waterloo | 7320 | 43 |
| **Kansas** | | |
| Dodge City | 4986 | 38 |
| Topeka | 5182 | 39 |
| Wichita | 4620 | 38 |
| **Kentucky** | | |
| Covington | 5265 | 39 |
| Lexington | 4683 | 38 |
| Louisville | 4660 | 38 |

| Table 1 (cont'd.) Location | Heating Degree Days | Latitude (°) |
|---|---|---|
| **Louisiana** | | |
| Alexandria | 1921 | 31 |
| Baton Rouge | 1560 | 31 |
| Lake Charles | 1459 | 30 |
| New Orleans | 1385 | 30 |
| Shreveport | 2184 | 32 |
| **Maine** | | |
| Portland | 7511 | 44 |
| **Maryland** | | |
| Baltimore | 4654 | 39 |
| Frederick | 5087 | 39 |
| **Massachusetts** | | |
| Boston | 5634 | 42 |
| Pittsfield | 7578 | 42 |
| Worcester | 6969 | 42 |
| **Michigan** | | |
| Alpena | 8506 | 45 |
| Detroit | 6232 | 42 |
| Escanaba | 8481 | 46 |
| Flint | 7377 | 43 |
| Grand Rapids | 6894 | 43 |
| Lansing | 6909 | 43 |
| Marquette | 8393 | 47 |
| Muskegon | 6696 | 43 |
| Sault Ste. Marie | 9048 | 46 |
| **Minnesota** | | |
| Duluth | 10000 | 47 |
| Minneapolis | 8382 | 45 |
| Rochester | 8295 | 44 |
| **Mississippi** | | |
| Jackson | 2239 | 32 |
| Meridian | 2289 | 32 |
| Vicksburg | 2041 | 32 |
| **Missouri** | | |
| Columbia | 5046 | 39 |
| Kansas City | 4711 | 39 |
| St. Joseph | 5484 | 40 |
| St. Louis | 4900 | 39 |
| Springfield | 4900 | 37 |
| **Montana** | | |
| Billings | 7049 | 46 |
| Butte | 9800 | 46 |
| Great Falls | 7750 | 47 |
| Helena | 8129 | 47 |
| Missoula | 8125 | 47 |
| **Nebraska** | | |
| Grand Island | 6530 | 41 |
| Lincoln | 5864 | 41 |
| Norfolk | 6979 | 42 |
| North Patte | 6684 | 41 |
| Omaha | 6612 | 41 |
| Scottsbluff | 6673 | 42 |
| **Nevada** | | |
| Elko | 7433 | 41 |
| Las Vegas | 2709 | 36 |
| Reno | 6332 | 39 |
| **New Hampshire** | | |
| Concord | 7383 | 43 |
| Manchester | 7200 | 43 |
| **New Jersey** | | |
| Atlantic City | 4812 | 39 |
| Newark | 4589 | 41 |
| Trenton | 4980 | 40 |
| **New Mexico** | | |
| Albuquerque | 4348 | 35 |
| Carlsbad | 2600 | 32 |
| Roswell | 3793 | 33 |
| Santa Fe | 6200 | 36 |
| **New York** | | |
| Albany | 6875 | 43 |
| Binghamton | 7286 | 42 |
| Buffalo | 7062 | 43 |
| New York | 5219 | 41 |
| Rochester | 6748 | 43 |
| Schenectady | 6650 | 43 |
| Syracuse | 6756 | 43 |
| **North Carolina** | | |
| Aheville | 4042 | 35 |
| Charlotte | 3191 | 35 |
| Greensboro | 3805 | 36 |
| Raleigh | 3393 | 36 |
| Wilmington | 2347 | 34 |
| Winston-Salem | 3595 | 36 |
| **North Dakota** | | |
| Bismarck | 8851 | 47 |
| Fargo | 9226 | 47 |
| Grand Forks | 9800 | 48 |
| **Ohio** | | |
| Akron-Canton | 6037 | 41 |
| Cincinnati | 4410 | 39 |
| Cleveland | 6351 | 41 |
| Columbus | 5660 | 40 |
| Dayton | 5622 | 40 |
| Mansfield | 6403 | 41 |
| Sandusky | 5796 | 41 |

| *Table 1 (cont'd.)* Location | Heating Degree Days | Latitude (°) |
|---|---|---|
| **Ohio (Continued)** | | |
| Toledo | 6494 | 42 |
| Youngstown | 6417 | 41 |
| **Oklahoma** | | |
| Oklahoma City | 3725 | 35 |
| Tulsa | 3860 | 36 |
| **Oregon** | | |
| Medford | 5008 | 42 |
| Pendleton | 5127 | 46 |
| Portland | 4635 | 46 |
| **Pennsyvania** | | |
| Allentown | 5810 | 41 |
| Erie | 6451 | 42 |
| Harrisburg | 5251 | 40 |
| Philadelphia | 5144 | 40 |
| Pittsburgh | 5987 | 40 |
| Reading | 4945 | 40 |
| Scranton | 6254 | 41 |
| Williamsport | 5934 | 41 |
| **Rhode Island** | | |
| Newport | 5800 | 41 |
| Providence | 5954 | 42 |
| **South Carolina** | | |
| Charleston | 2033 | 33 |
| Columbia | 2484 | 34 |
| Florence | 2387 | 34 |
| Greenville | 2980 | 35 |
| **South Dakota** | | |
| Huron | 8223 | 44 |
| Rapid City | 7345 | 44 |
| Sioux Falls | 7839 | 44 |
| **Tennessee** | | |
| Chattanooga | 3254 | 35 |
| Knoxville | 3494 | 36 |
| Memphis | 3232 | 35 |
| Nashville | 3578 | 36 |
| **Texas** | | |
| Abilene | 2624 | 32 |
| Amarillo | 3985 | 35 |
| Austin | 1711 | 30 |
| Brownsville | 600 | 26 |
| Corpus Christi | 914 | 28 |
| Dallas | 2363 | 33 |
| El Paso | 2700 | 32 |
| Fort Worth | 2405 | 33 |
| Galveston | 1235 | 29 |
| Houston | 1396 | 30 |
| **Texas (continued)** | | |
| Lubbock | 3578 | 34 |
| San Angelo | 2255 | 31 |
| San Antonio | 1546 | 30 |
| Victoria | 1173 | 29 |
| Waco | 2030 | 32 |
| Wichita Falls | 2832 | 34 |
| **Utah** | | |
| Ogden | 5600 | 41 |
| Salt Lake City | 6052 | 41 |
| **Vermont** | | |
| Burlington | 8269 | 44 |
| **Virginia** | | |
| Lynchburg | 4166 | 37 |
| Norfolk | 3421 | 37 |
| Richmond | 3865 | 37 |
| Roanoke | 4150 | 37 |
| **Washington** | | |
| Olympia | 5236 | 47 |
| Seattle-Tacoma | 5145 | 47 |
| Spokane | 6655 | 48 |
| Walla Walla | 4805 | 46 |
| Yakima | 5941 | 47 |
| **West Virginia** | | |
| Charleston | 4476 | 38 |
| Huntington | 4446 | 38 |
| Parkersburg | 4754 | 39 |
| Wheeling | 5200 | 40 |
| **Wisconsin** | | |
| Green Bay | 8029 | 44 |
| La Crosse | 7589 | 44 |
| Madison | 7863 | 43 |
| Milwaukee | 7635 | 43 |
| **Wyoming** | | |
| Casper | 7410 | 43 |
| Cheyenne | 7381 | 41 |
| Sheridan | 7680 | 45 |

**Table 2.**

**OVERALL COEFFICIENTS OF HEAT TRANSMISSION OF VARIOUS WINDOW PRODUCTS ***
**(Including Frame and Edge Effects)**
**( U-Values, Btu/hr-$ft^2$- F ) ****

| Type of Glazing | Shading Coefficient (S.C.) | GLASS U-VALUE Center of Glass | Edge of Glass | OVERALL FRAME AND GLASS U-VALUE Wood or Vinyl | Alum. w/ Thermal Break | Alum. w/o Thermal Break |
|---|---|---|---|---|---|---|
| (Frame U-value) | - | - | - | 0.40 | 1.00 | 1.90 |
| Single-glazing | 1.00 | 1.11 | 1.11 | 0.90 | 1.09 | 1.31 |
| Double-glazing (3/8-in. space) | 0.88 | 0.52 | 0.62 | 0.50 | 0.66 | 0.88 |
| Double-glazing w/ Hard-coat Low-e (3/8-in. space) | 0.82 | 0.43 | 0.55 | 0.45 | 0.60 | 0.83 |

* (Source - 1989 ASHRAE Handbook of Fundamentals)

** All U-values are based on standard ASHRAE winter conditions of 70F indoor and 0F outdoor air temperatures with 15mph outdoor air velocity. Overall U-values are based on products in which the glazing unit is about 6 $ft^2$ in area and the overall size corresponds to a 3 ft. by 4 ft. window.

## Table 3.

### NOMINAL RATES OF AIR INFILTRATION FOR VARIOUS WINDOW TYPES*

**( Air Infiltration Rate, cfm/ft. at 25 mph air velocity)**

| Fit of Window | Is Window Weatherstripped? | Double Hung | Casement | Horizontal Slider | Awning |
|---|---|---|---|---|---|
| Poor | No | 3.33 | 0.80 | 4.80 | 0.80 |
| Average | No | 1.67 | 0.40 | 2.40 | 0.40 |
| Average | Yes | 0.67 | 0.16 | 0.86 | 0.16 |
| Excellent | Yes | 0.16 | 0.04 | 0.24 | 0.04 |

* (Source - "Thermal Shutters and Shades", W. Schurcliffe, 1980)

## Table 4.

### SHADING COEFFICIENTS AND THERMAL PERFORMANCE COEFFICIENTS OF INTERIOR WINDOW COVERINGS OVER SINGLE OR DOUBLE GLASS

| | Combined Glazing and Covering S.C.* | | Combined Glazing and Covering U-Value** | |
|---|---|---|---|---|
| | w/ Single | w/ Double | w/ Single | w/ Double |
| A. No covering | 1.00 | 0.88 | 1.11 | 0.50 |
| B. Medium-colored blinds | 0.64 | 0.57 | 0.83 | 0.43 |
| C. Light-colored blinds | 0.55 | 0.51 | 0.83 | 0.43 |
| D. Opaque white shades | 0.25 | 0.25 | 0.85 | 0.43 |
| E. Open-weave dark drapery | 0.75 | 0.62 | 0.83 | 0.43 |
| F. Close-weave dark drapery | 0.45 | 0.45 | 0.83 | 0.43 |

* (Source: ASHRAE Fundamentals, 1985)

** (U.S. Dept. of Energy - "A Comparison of Products for Reducing Heat Loss through Windows", 8.15(d) Us. U-values are estimated from manufacturer data and other sources.)

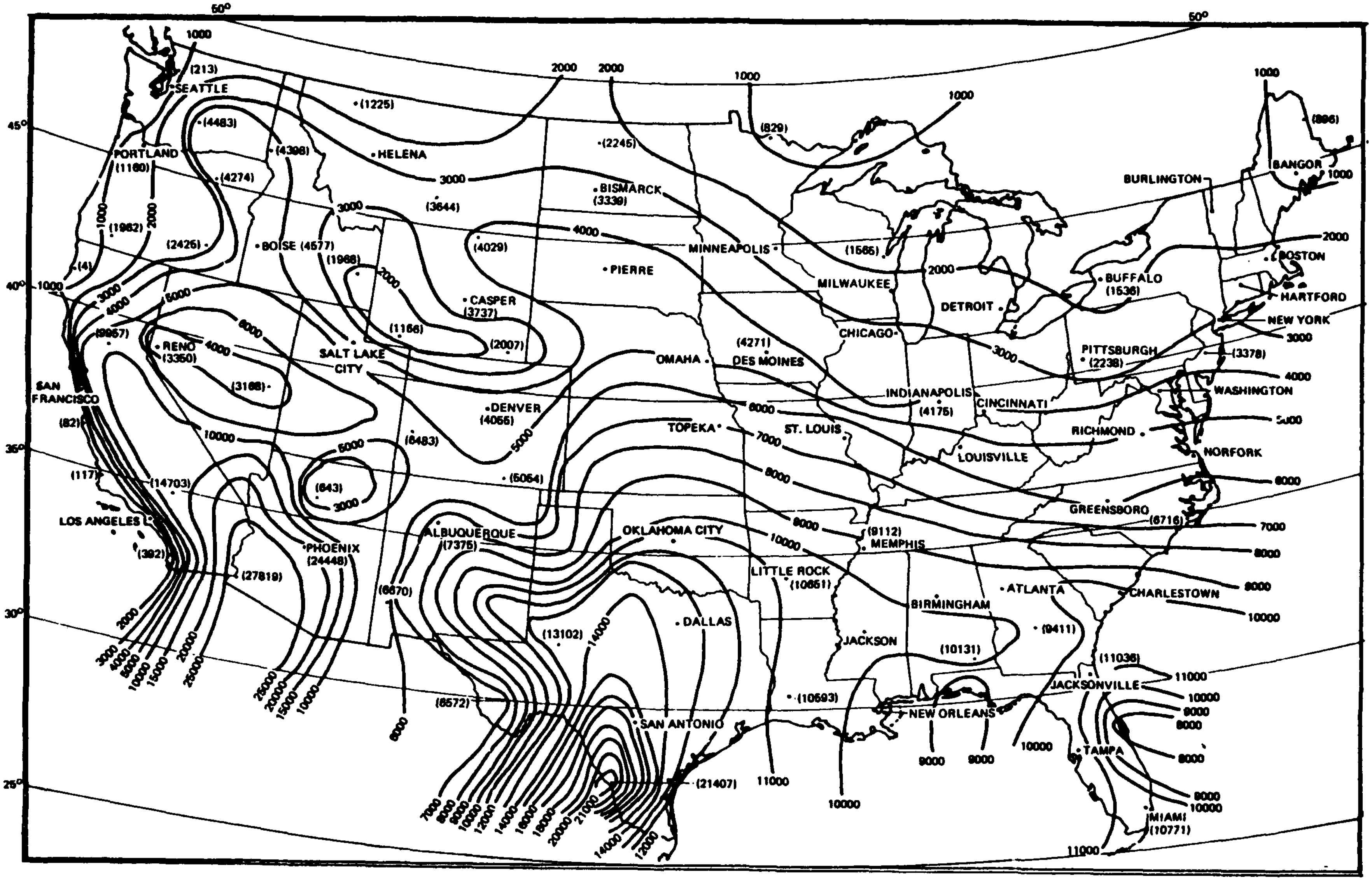


Figure 22.

**Annual Dry Bulb Degree Hours Above 78°F**

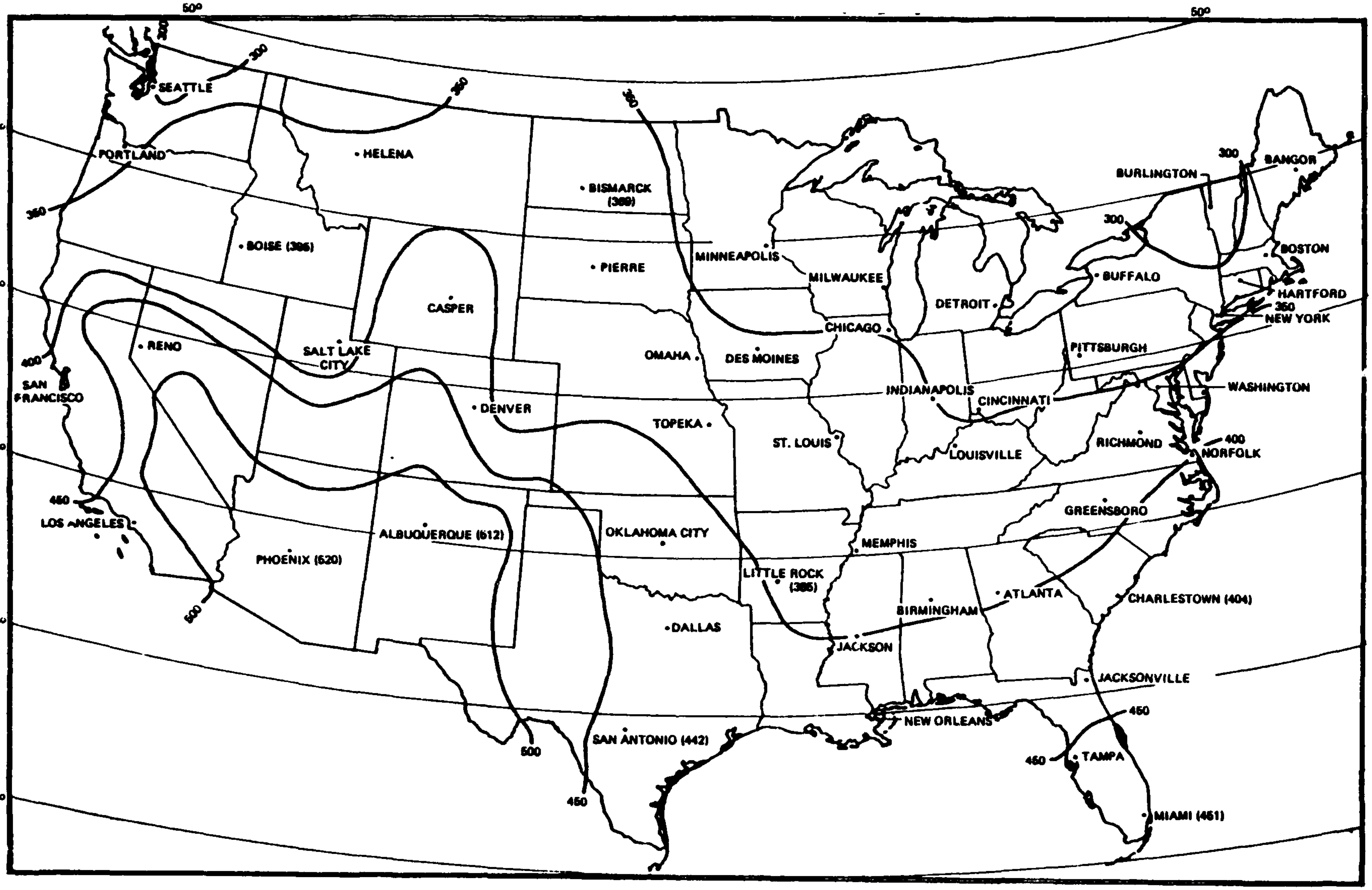


Figure 23.

**Annual Mean Daily Solar Radiation in Langleys**

## Figure 24 - Annual Heat Loss Through Windows, Latitude 25°N - 35°N

Source of Data: 1) Navy Activity-Level Energy Systems Planning Procedure (A-LESP), and

2) Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 68°F indoor temperature.

Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10 percent; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. The data was then plotted and extrapolated to include the entire range of degree days. Figure 24 was derived from locations with latitudes between 25 and 35 degrees north.

**Instructions for use of Figure 24:**

1.Confirm that local latitude falls within the range of the figure.

2.Find the number on the bottom left-hand vertical line for the heating degree days.

3.Proceed horizontally right to the number of Langleys.

4.Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5.Proceed horizontally left from this intersection to read the annual heat loss in Btu x $10^3$ per square foot.

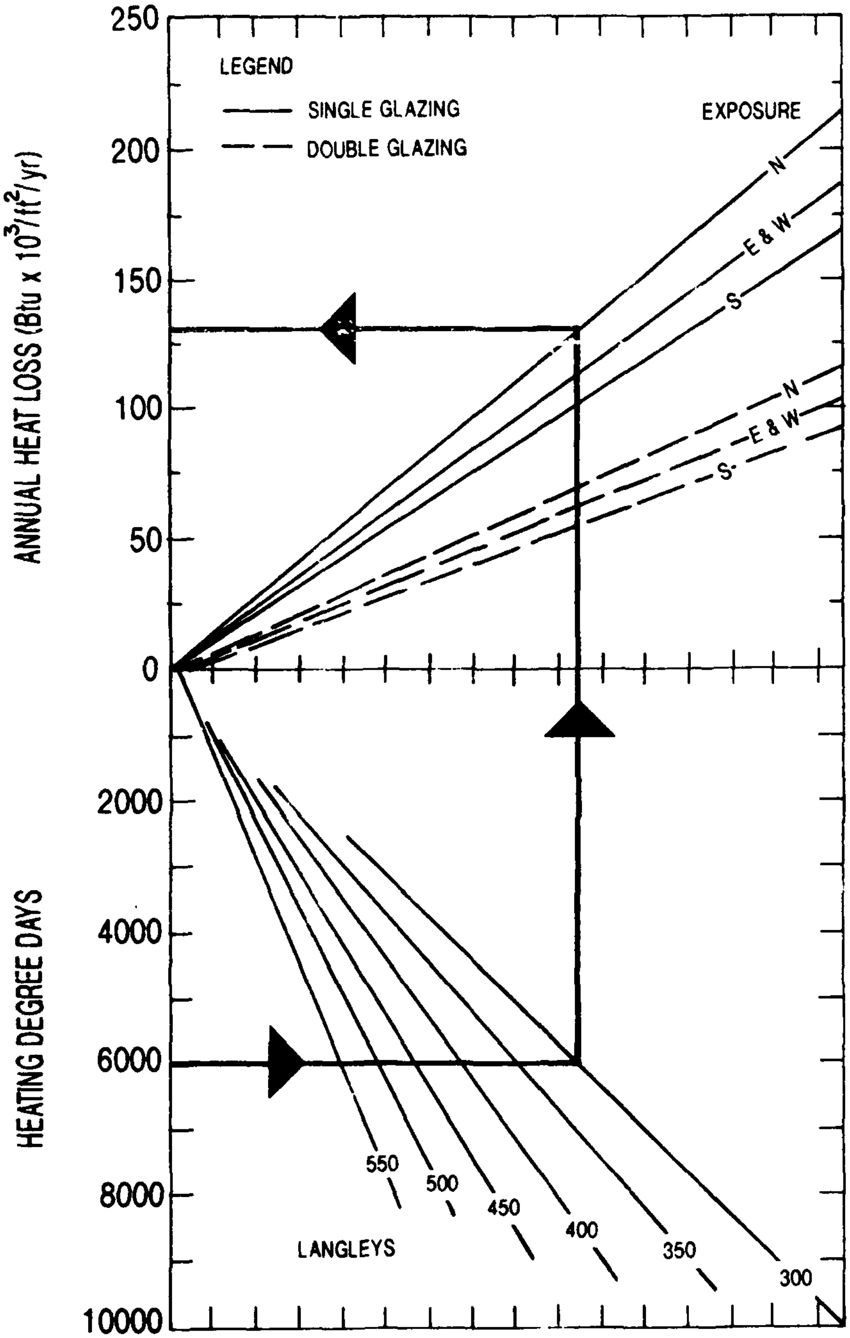


Figure 24.

Heating - Annual Heat Loss Through Windows
Latitude 25° N - 35° N

## Figure 25 - Annual Heat Loss Through Windows, Latitude 35°N - 45°N

Source of Data: 1) Navy Activity-Level Energy Systems Planning Procedure (A-LESP), and

2) Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 68°F indoor temperature.

Additional assumptions were: 1) total internal heat gain of 12 Btu per square foot; 2) average outdoor air ventilation rate of 10 percent; and 3) infiltration rate of one-half air change per hour. Daily totals were then summed for the number of days in each month to arrive at monthly heat losses. The length of the heating season for each location considered was determined from weather data and characteristic operating periods. Yearly heat losses were derived by summing monthly totals for the length of the heating season. These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. The data was then plotted and extrapolated to include the entire range of degree days. Figure 25 was derived from locations with latitudes between 35 and 45 degrees north.

**Instructions for use of Figure 25:**

1.Confirm that local latitude falls within the range of the figure.

2.Find the number on the bottom left-hand vertical line for the heating degree days.

3.Proceed horizontally right to the number of Langleys.

4.Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5.Proceed horizontally left from this intersection to read the annual heat loss in Btu x $10^3$ per square foot.

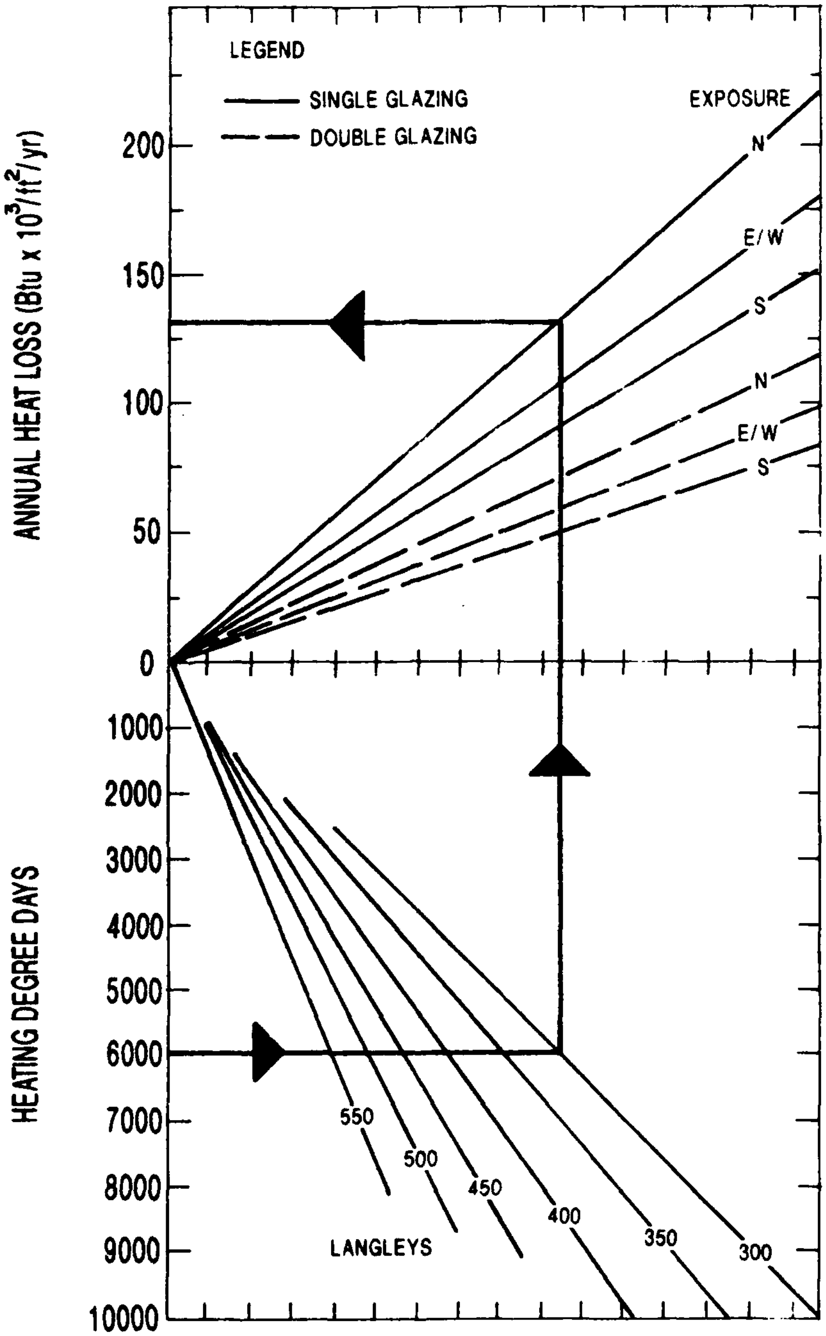


Figure 25.
Heating - Annual Heat Loss Through Windows
Latitude 35°N - 45°N

# Figure 26 - Annual Solar Heat Gain Through Windows, Latitude 25°N - 35°N

Source of Data: 1) Navy Activity-Level Energy Systems Planning Procedure (A-LESP), and

2) Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature. During the cooling season, internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the windows was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. Increases in the conduction heat gain through windows were deducted from the total heat gains to derive the solar component. The solar component was then plotted and extrapolated to include the entire range of degree hours. Figure 26 was derived from locations with latitudes between 25 and 35 degrees north. The heat gains assume that the windows are subjected to direct sunshine. If shaded, gains should be read from the north exposure line. The accuracy of the graph diminishes for locations with less than 5,000 degree hours.

**Instructions for use of Figure 26:**

1.Confirm that local latitude falls within the range of the figure.

2.Find the number on the bottom left-hand vertical line for the annual dry bulb degree hours above 78°F (DBT).

3.Proceed horizontally right to the number of Langleys.

4.Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5.Proceed horizontally left from this intersection to read the annual heat gain in Btu x $10^3$ per square foot.

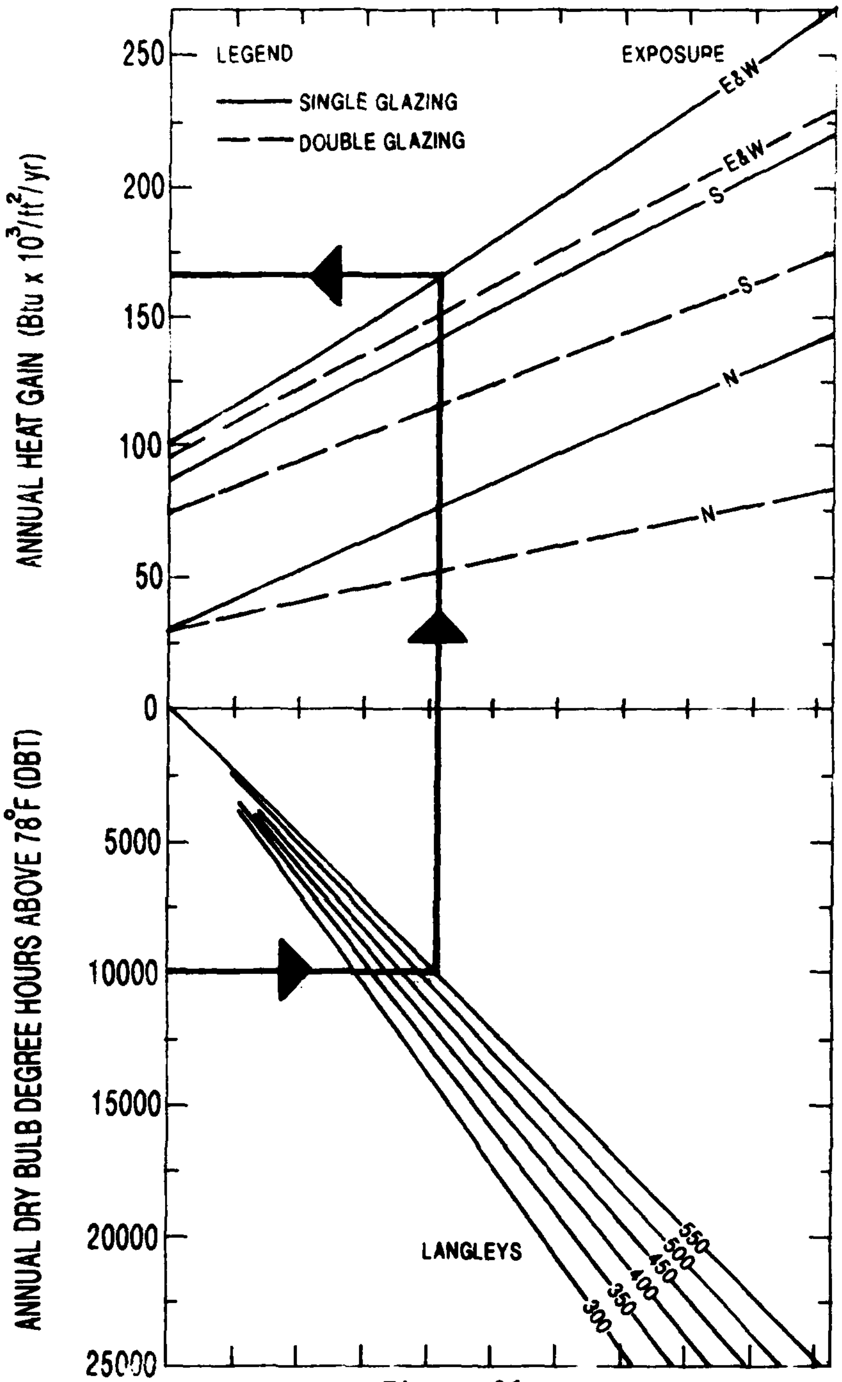


Figure 26.

Cooling - Annual Solar Heat Gain Through Windows

Latitude 25°N - 35°N

## Figure 27 - Annual Solar Heat Gain Through Windows, Latitude 35°N - 45°N

Source of Data: 1) Navy Activity-Level Energy Systems Planning Procedure (A-LESP), and

2) Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132)

This nomograph is based on the "Sunset" computer program which was used to calculate solar effect on windows for 12 locations. The program calculates hourly solar angles and intensities for the 21st day of each month. Radiation intensity values were modified by the average percentage of cloud cover taken from weather records on an hourly basis. Heat gains are based on a 78°F indoor temperature. During the cooling season, internal gains, ventilation, infiltration, and conduction through the building skin can create a cooling load. The additional load caused by heat gain through the windows was calculated for each day. Daily totals were then summed for the number of days in each month to arrive at monthly heat gains. The length of the cooling season for each location considered was determined from weather data and characteristic operating periods. Yearly heat gains were derived by summing monthly totals for the length of the cooling season.

These are summarized in Architects and Engineers Guide to Energy Conservation in Existing Buildings, (DOE/CS-0132), table 8-56 for the 12 locations. Increases in the conduction heat gain through windows were deducted from the total heat gains to derive the solar component. The solar component was then plotted and extrapolated to include the entire range of degree hours. Figure 27 was derived from locations with latitudes between 35 and 45 degrees north. The heat gains assume that the windows are subjected to direct sunshine. If shaded, gains should be read from the north exposure line. The accuracy of the graph diminishes for locations with less than 5,000 degree hours.

**Instructions for use of Figure 27:**

1.Confirm that local latitude falls within the range of the figure.

2.Find the number on the bottom left-hand vertical line for the annual dry bulb degree hours above 78°F (DBT).

3.Proceed horizontally right to the number of Langleys.

4.Proceed vertically upward from this intersection to the orientation exposure being investigated corresponding to existing glazing.

5.Proceed horizontally left from this intersection to read the annual heat gain in Btu x $10^3$ per square foot.

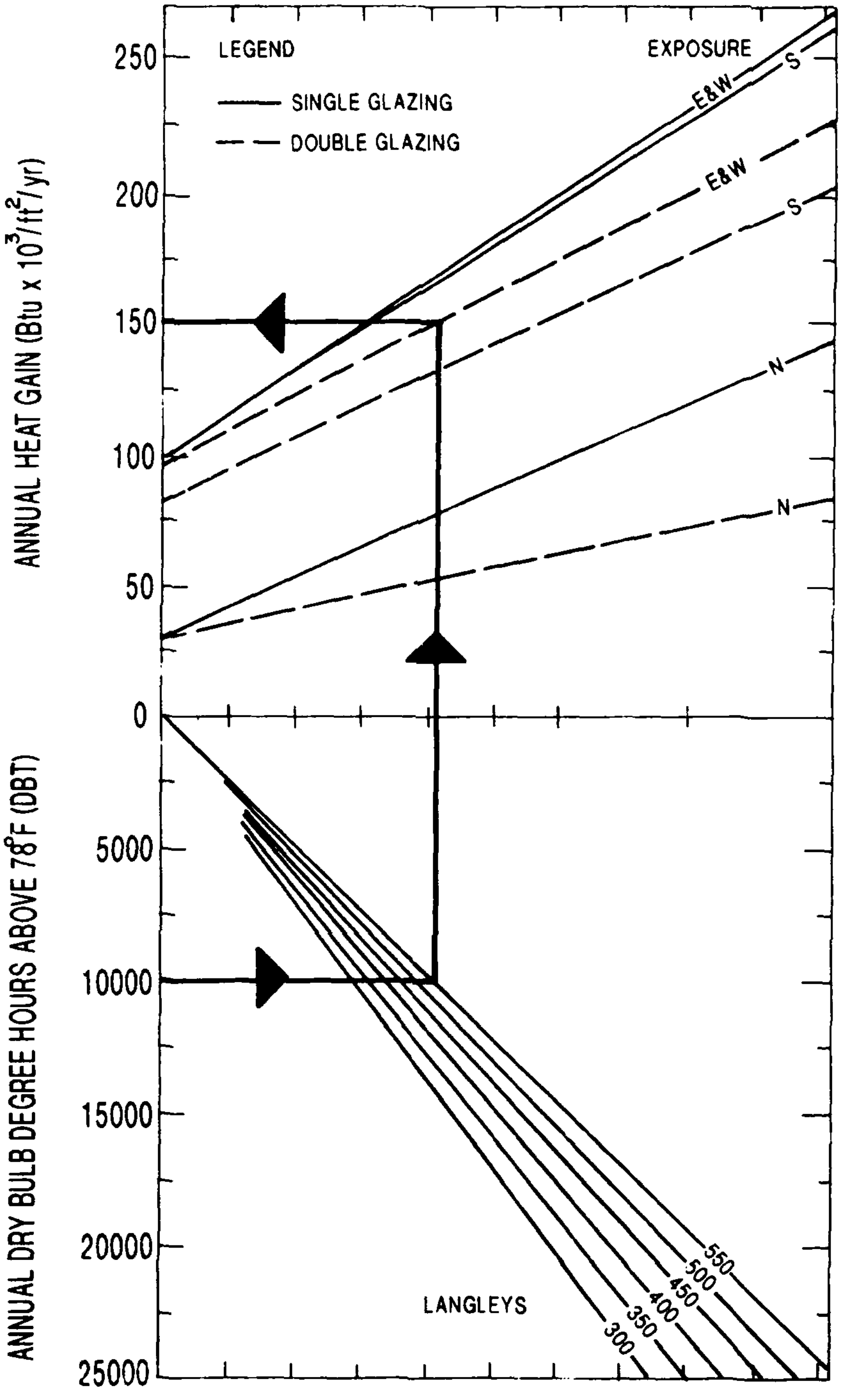


Figure 27.

Cooling - Annual Solar Heat Gain Through Windows

Latitude 35°N - 45°N

# APPENDIX A

**TEAR-OUT COPIES OF**

**Field Data Sheet (Window Survey)**

**Worksheet I (Short Version)**

**Worksheet II (Long Version)**

**and**

**General Instructions for Worksheet II**

# FIELD DATA SHEET
## WINDOW SURVEY

**FACILITY:** ______________________ **BUILDING:** ______________________

**LOCATION:** ______________________ **PERFORMED BY:** ______________________

*Directions:*
*Inspect the existing windows in the building. For each question below, circle one of the items which best describes the windows and fill in the blanks, where indicated.*

1. **WINDOW TYPE:** *(circle one)* Double-Hung / Casement / Horizontal Slider / Awning

2. **AVERAGE WINDOW SIZE:** Height (in.):__________
Width (in.): __________

3. **NUMBER OF WINDOWS: @ EACH EXPOSURE:** North ______ South ______ East ______ West ______ **TOTAL # of WINDOWS** ______

4. **WINDOW FRAME MATERIAL:** *(circle one)* Wood / Vinyl / Aluminum / Aluminum w/ thermal break

5. **GLAZING TYPE:** *(circle one)* Single-Glazing / Double-Glazing

6. **ARE THE WINDOWS WEATHERSTRIPPED?** *(circle one)* Yes / No

7. **CONDITION OF WINDOW FIT:** *(circle one)* Poor / Average / Excellent

8. **INDICATE THE TYPE OF WINDOW COVERING USED , IF ANY:**

(Select one type only)
A - No covering used
B - Medium-colored blinds
C - Light-colored blinds
D - Opaque white shades
E - Open-weave dark drapery
F - Close-weave dark drapery

**Window Covering Type** ______________________

9. **HEATING FUEL TYPE:** *(circle one)* Oil / Gas / None

10. **HEATING SYSTEM EFFICIENCY:** ______%
*(If unknown, select a nominal system efficiency from the table provided)*

*Nominal Heating System Efficiencies*

| *Condition* | *Oil-Fired* | *Gas-Fired* |
|---|---|---|
| *Poor* | *50%* | *45%* |
| *Fair* | *65%* | *60%* |
| *Good* | *85%* | *80%* |

11. **IS THE BUILDING AIR-CONDITIONED?** *(circle one)* Yes / No

12. **COOLING SYSTEM ENERGY EFFICIENCY RATIO (EER):** ______EER
*(If unknown, select a nominal system EER rating from the table provided)*

*Nominal Cooling System Energy Efficieny Ratios*

| *Condition* | *EER* |
|---|---|
| *Poor* | *6.0 to 7.0* |
| *Fair* | *7.0 to 9.0* |
| *Good* | *9.0 to 11.0* |

# WORKSHEET I

*Worksheet I provides a quick procedure for estimating the annual energy savings from retrofitting existing windows with new vinyl -framed, hard-coat low-e insulating glass windows. Worksheet I considers the energy losses due to heating only, and does not take into account beneficial winter heat gain.*

*Directions:*
*For each question below, circle one of the items which best describes the windows and fill in the blanks, where indicated, using information from the right-hand column marked "Source".*

## 1. SITE INFORMATION

| | **Input** | **Source** |
|---|---|---|
| **a. Annual Heating Degree Days:** | ________ F-day/yr | *Table 1* |
| **b. Heating Fuel Type:** *(circle one)* | Oil / Gas / None | *Field Data* |
| **c. Heating System Efficiency:** | ________ % | *Field Data* |
| **d. Cost of Heating Fuel:** *(select one)* | Oil ________ $/gallon<br>Gas ________ $/therm | *Local Price* |

## 2. WINDOW INFORMATION

| | | |
|---|---|---|
| **a. Window type:** *(circle one)* | Double-Hung / Casement / Slider / Awning | *Field Data* |
| **b. Average window size:** | Height: ________ in. Width: ________ in. | *Field Data* |
| **c. Total Number of windows:** | Total # ______ | *Field Data* |
| **d. Window covering type most used:** | Window Covering type ____________________ | *Field Data* |

| | (BEFORE RETROFIT) | (AFTER RETROFIT) | |
|---|---|---|---|
| **e. Window Frame Material:** *(circle one)* | Wood/ Alum./Alum. w/Th.Br. | *Vinyl* | *Field Data* |
| **f. Window Frame U-value:** | ______ Btu/hr-ft$^2$-F | *0.40* *Btu/hr-ft$^2$-F* | *Table 2* |
| **g. Glazing Type:** *(circle one)* | Single / Double | *Double w/Low-e* | *Field Data* |
| **h. Overall glazing and frame U-value:** | _______ Btu/hr-ft$^2$-F | *0.45* *Btu/hr-ft$^2$-F* | *Table 2* |
| **i. Are window weatherstripped?** *(circle one)* | Yes / No | *Yes* | *Field Data* |
| **j. Condition of fit:** *(circle one)* | Poor/ Average/ Excellent | *Excellent* | *Field Data* |
| **k. Air Infiltration Rate:** | ______ cfm/ft. | _____ *cfm/ft* | *Table 3* |
| **l. Combined glazing and covering U-Value:** | ______ Btu/hr-ft$^2$-F | _____ *Btu/hr-ft$^2$-F* | *Table 4* |

## 3. GENERAL CALCULATIONS

**Source**

**a. Calculate cost of fuel in $ / MBtu:**

Oil: [(____ $ / gallon) / 139,600 Btu/gallon ] x $10^6$ = ____ $ / MBtu — *Line 1d*

or Gas: [(____ $ / therm) / 100,000 Btu/therm ] x $10^6$ = ____ $ / MBtu

**b. Calculate area of representative window:**

Area = (______ in. x ______ in.) / 144 = ______ ft$^2$ — *Line 2b*

(Height) (Width)

**c. Calculate total window area in building:**

Total Area = ______ x ______ = ______ ft$^2$ — *Line 2c*

(Total # of Windows) (Line 3b)

**d. Calculate crack length, $L_c$, for representative window type:** — *Line 2a and Line 2b*

$L_c$: (Double-Hung) = [(2 x ____ in.) + (3 x ____ in.)] / 12 = ____ ft.
(Height) (Width)

$L_c$: (Casement) = [(2 x ____ in.) + (2 x ____ in.)] / 12 = ____ ft.
(Height) (Width)

$L_c$: (Slider) = [(3 x ____ in.) + (2 x ____ in )] / 12 = ____ ft.
(Height) (Width)

$L_c$: (Awning) = [(2 x ____ in.) + (2 x ____ in.)] / 12 = ____ ft.
(Height) (Width)

**e. Calculate total crack length for all windows in the building:** — *Line 2c and Line 3d*

**Total $L_c$** = ______ x ______ = ______ ft.

(Total # of Windows) ($L_c$)

## 4. ANNUAL HEAT LOSS (HEATING SEASON)

### BEFORE RETROFIT

*(All values in this top section apply only to existing windows before retrofit.)*

| | | | Source |
|---|---|---|---|
| a. Overall glazing and frame U-value : | ________ | Btu-hr-ft$^2$-F | *(Line 2h)* |
| b. Adjustment for Window Covering: *(Assume coverings are used 50% of the day)* | ________ | | *If none used, enter 0; else: ((Line 2h - 2l ) x 0.5)* |
| c. Corrected U-value : | ________ | Btu-hr-ft$^2$-F | *(Line 4a - 4b)* |
| d. Total Window Area : | ________ | ft$^2$ | *(Line 3c)* |
| e. # of Annual Heating Degree Days: | ________ | F-day/yr | *(Line 1a)* |
| f. Multiplier: | 24 | hr/day | - |
| g. Total Conduction Heat Loss : | ________ | MBtu/yr | *(Lines 4c x 4d x 4e x 4f)/10$^6$* |
| h. Air infiltration rate : | ________ | ft$^3$/min-ft | *(Line 2k)* |
| i. Total window crack length: | ________ | ft | *(Line 3e)* |
| j. # of Annual Heating Degree Days: | ________ | F-day/yr | *(Line 1a)* |
| k. Multiplier: | 26.46 | Btu-min/ft$^3$-day-F | *(See Appendix C)* |
| l. Total Infiltration Heat Loss: | ________ | MBtu/yr | *(Lines 4h x 4i x 4j x 4k)/10$^6$* |
| m. **Total Annual Heat Loss Before Retrofit:** | ________ | MBtu/yr | *(Line 4g + 4l)* |

### AFTER RETROFIT

*(All values in this bottom section apply only to new vinyl replacement windows after retrofit.)*

| | | | Source |
|---|---|---|---|
| a. Overall glazing and frame U-value : | 0.45 | Btu-hr-ft$^2$-F | *(Line 2h)* |
| b. Adjustment for Window Covering: *(Assume coverings are used 50% of the day)* | ________ | | *If none used, enter 0; else: (( Line 2h - 2l ) x 0.5)* |
| c. Corrected U-value : | ________ | Btu-hr-ft$^2$-F | *(Line 4a - 4b)* |
| d. Total Window Area : | ________ | ft$^2$ | *(Line 3c)* |
| e. # of Annual Heating Degree Days: | ________ | F-day/yr | *(Line 1a)* |
| f. Multiplier: | 24 | hr/day | - |
| g. Total Conduction Heat Loss : | ________ | MBtu/yr | *(Lines 4c x 4d x 4e x 4f)/10$^6$* |
| h. Air infiltration rate : | ________ | ft$^3$/min-ft | *(Line 2k)* |
| i. Total window crack length: | ________ | ft | *(Line 3e)* |
| j. # of Annual Heating Degree Days: | ________ | F-day/yr | *(Line 1a)* |
| k. Multiplier: | 26.46 | Btu-min/ft$^3$-day-F | *(See Appendix C)* |
| l. Total Infiltration Heat Loss: | ________ | MBtu/yr | *(Lines 4h x 4i x 4j x 4k)/10$^6$* |
| m. **Total Annual Heat Loss After Retrofit:** | ________ | MBtu/yr | *(Line 4g + 4l)* |

## 5. COST SAVINGS IN HEATING ENERGY:

*(Note: Subscript "br" refers to "before retrofit",*
*and subscript "ar" refers to "after retrofit")*

**a. Calculate heating cost <u>Before</u> Retrofit:** **Source**

Annual heating cost = ( ________ MBtu/yr) x ( ________ \$/MBtu) x (100 / ______ ) = ________ \$/yr *Line 4m, Line 1c, and Line 3a*
Before Retrofit ( Line $4m_{br}$ ) ( Line 3a ) (Line 1c)

**b. Calculate heating cost <u>After</u> Retrofit:**

Annual heating cost = ( ________ MBtu/yr) x ( ________ \$/MBtu) x (100 / ______ ) = ________ \$/yr *Line 4m, Line 1c, and Line 3a*
After Retrofit ( Line $4m_{ar}$ ) ( Line 3a) (Line 1c)

**c. Calculate first year heating cost savings:**

First year heating cost savings = __________ \$/yr - __________ \$/yr = __________ \$/yr *Line 5a and Line 5b*
(Line 5a) (Line 5b)

# GENERAL INSTRUCTIONS FOR WORKSHEET II

**Directions:**

**These instructions are intended for use with Worksheet II (Long Version). For each item on the Worksheet form, a corresponding instruction is provided. Read each instruction carefully prior to filling out the Worksheet form.**

**1. SITE INFORMATION** *(Fill out this section once only)*

a. Locate the city nearest to your facility from Table 1, pages 73-75. Enter the number of annual heating degree days for that location.

b. Locate the city identified in step a on Figure 22, page 78. Enter the approximate number of annual dry-bulb degree hours greater than 78F (cooling degree hours) for that location.

c. From Figure 23, page 79, enter the approximate number of Langleys of solar radiation for that location.

d. From Table 1, enter the latitude for that location.

e. Circle the type of heating fuel used in the building. (Item 9, Field Data Sheet).

f. Enter the heating system efficiency. (Item 10, Field Data Sheet).

g. Indicate the unit cost of the selected heating fuel. Refer to local billing rates.

h. Specify if the building is air-conditioned by circling yes or no. (Item 11 - Field Data Sheet)

i. If "yes" is entered above, enter the cooling system energy- efficiency ratio (EER). (Item 11 - Field Data Sheet)

j. Indicate the unit cost of electricity. Refer to local billing rates.

**2. WINDOW INFORMATION**
*(Fill out this section once for Before Retrofit and once for After Retrofit, where indicated.)*

a. Circle the predominant type of window in the building. (Item 1 - Field Data Sheet).

b. Enter the average window size. Round off to the nearest inch. (Item 2 - Field Data Sheet).

c. Enter the number of windows (of the size and type indicated) for each exposure direction. Enter the total number. (Item 3 - Field Data Sheet)

d. Enter the type of window covering used, if any, from the table provided in the Field Data Sheet. (Item 8 - Field Data Sheet)

e. Circle the window frame material for the Before Retrofit case. (Item 4 - Field Data Sheet) For the After Retrofit case, "vinyl" has been pre-entered.

f. From Table 2, page 76, look up the U-value of the window frame material for the Before Retrofit case. For the After Retrofit case, "0.40" has been pre-entered.

g. Circle the glazing type for the Before Retrofit case. (Item 5 - Field Data Sheet). For the After Retrofit case, "double-glazing with low-e coat" has been pre-entered.

h. From Table 2, look up the Shading Coefficient (S.C.) of the glazing for the Before Retrofit case. For the After Retrofit case, "0.82" has been pre-entered.

i. From Table 2, look up the center of glass U-value for the Before Retrofit case. For the After Retrofit case, "0.43" has been pre-entered.

j. From Table 2, look up the edge of glass U-value for the Before Retrofit case. For the After Retrofit case, "0.55" has been pre-entered.

k. From Table 2, look up the overall glass and frame U-value for the Before Retrofit case. For the After Retrofit case, "0.45" has been pre-entered.

l. Specify whether or not the majority of the existing windows are equipped with weatherstripping. For the After Retrofit case, "yes" has been pre-entered.

m. Specify whether the fit of the existing windows are in poor, average, or excellent condition. For the After Retrofit case, "excellent" has been pre-entered.

n. From Table 3, page 77, look up the nominal rate of air infiltration for both cases, knowing the condition of the window fit and the type of window.

o. From Table 4, page 77, look up the combined glazing and covering U-value for both cases and enter the number in the blanks provided.

p. From Table 4, look up the combined glazing and covering Shading Coefficient for both cases and enter the number in the blanks provided.

**3. GENERAL CALCULATIONS** *(Fill out this section once only.)*

a. For the type of heating fuel in use, convert the cost of fuel specified in Line 1g to units of $/MBtu.

b. Convert the cost of electricity specified in Line 1j to units of $/MBtu.

c. Calculate the area of the representative window, whose dimensions are specified in Line 2b.

d. Calculate the window area at each exposure direction by multiplying the area of the representative window (Line 3c) by the # of windows @ each exposure (Line 2c). Enter the total window area by adding the window areas for each of the four exposure directions.

e. Calculate the crack length, Lc, for the representative window type selected using the dimensions specified in Line 2b.

f. Calculate the total crack length for all windows in the building, using the <u>total #</u> of windows (Line 2c) and the crack length, Lc, of the representative window (Line 3e).

**4. ANNUAL WINDOW HEAT LOSS (HEATING SEASON)**
*(Fill out this section once for Before Retrofit and repeat again for After Retrofit.)*

a. Based on your latitude (Line 1d), select either Figure 24 or 25 (pp. 80-83) to determine the annual conduction heat loss through glazing for N,S,E, and W exposures. You will need the # of annual heating degree days (Line 1a) and the amount of solar radiation in Langleys (Line 1c) in order to use the figure.

For the Before Retrofit case, look up the glazing type specified in Line 2g to find the appropriate set of curves. For the After Retrofit case, use the set of curves for double-glazing. This will be adjusted in step b below to account for the low-e glass.

b. For the Before Retrofit case, no adjustment is needed; therefore, enter 0.
For After Retrofit, multiply: (Line 1a x 24 x 0.0826). Enter this value. This equation is used to adjust the annual glazing heat loss estimated for double-glazing (through Fig. 24 or 25) to account for the added benefit of the low-e coat. To obtain the estimated adjustment of 0.0826, the following equation was used:

$$\text{Adjustment} = [(U_{\text{Double glazing}}) - (U_{\text{Double w/low-e}})], \text{ or}$$

$$[(U_{cg} \times A_{cg}) + (U_{eg} \times A_{eg})]/(A_{cg} + A_{eg})]_{\text{Double glazing}} - [(U_{cg} \times A_{cg}) + (U_{eg} \times U_{eg})/(A_{cg} + A_{eg})]_{\text{Double w/low-e}}$$

where the subscripts $_{cg}$ and $_{eg}$ refer to center-of-glass and edge-of-glass, respectively.

Assuming that the nominal area of the center-of-glass is 63% and the nominal area of the edge-of-glass is 37%, then the equation becomes:

$$\text{Adjustment} = [(U_{cg} \times 0.63) + (U_{eg} \times 0.37)/1.0]_{\text{Double glazing}} - [(U_{cg} \times 0.63) + (U_{eg} \times 0.37)/1.0]_{\text{Double w/low-e}}$$

From Table 2, $U_{cg}$ and $U_{eg}$ for double-glazing are 0.52 and 0.62, respectively. Likewise, $U_{cg}$ and $U_{eg}$ for double-glazing with low-e are 0.43 and 0.55, respectively. Therefore, the equation becomes:

$$\text{Adjustment} = [(0.52 \times 0.63) + (0.62 \times 0.37)]_{\text{Double glazing}} - [(0.43 \times 0.67) + (0.55 \times 0.37)]_{\text{Double w/low-e}}$$
and Adjustment = [(0.557) - (0.4744)] = 0.0826. For more information on the influence of edge-effects on U-values, see Appendix C.

c. Calculate the corrected glazing heat loss by subtracting the correction factor from each of the four exposure directions in Line 4a. Subtract: (Line 4a-Line 4b). Enter the appropriate value for each exposure direction.

d. Calculate the conduction heat loss through the frame. Multiply: (Line 1a x 24 x Line 2f). Enter this value.

e. Calculate the combined heat loss through both glazing and frame. Calculate: (Line 4c x 0.70) + (Line 4d x 0.30). Enter this value. This equation assumes that for the entire window unit, the percentage of the glazing area is 70% and the percentage of the frame area is 30%. (For more information, see Appendix C)

f. Adjust for use of window covering in winter, if any. If none used, enter 0. If used, Calculate:((Line 2k-2o) x 24 x line 1a x 0.50.) This equation assumes that the window covering is used 50% of the time. Enter this value.

g. Calculate the corrected conduction heat loss by subtracting the adjustment factor from Line 4f from each of the four exposure directions in Line 4e. Subtract: (Line 4e- Line 4f). Enter the appropriate value for each exposure direction.

h. Enter the total window area @ each exposure direction from line 3d.

i. Calculate the conduction heat loss in MBtu/yr for each exposure. Multiply: (Line 4g x Line 4h). Enter the appropriate value for each exposure direction.

j. Add the values from N,S,E,W exposures in Line 4i and enter the sum of the conduction heat losses through the windows.

k. Calculate the total infiltration heat loss in MBtu/yr from all windows. Multiply: (Line 2n x Line 3g x Line 1a x 24 x 60 x 0.018). Enter this value. (For more information, see Appendix C)

l. Calculate the total window heat loss due to conduction and air infiltration. Add: (Line 4j + Line 4k). Enter this value.

5. **ANNUAL WINDOW HEAT GAIN (COOLING SEASON)** *(Fill out this section once for Before Retrofit and repeat again for After Retrofit.)*

a. Based on your latitude (line 1d), select either Figure 26 or 27 (pp. 84-87) to determine the annual solar heat gain through glazing for N,W,E, and W exposures. You will need the # of annual cooling degree hours (or dry-bulb degree hours 78F) (Line 1b) and the amount of solar radiation in Langleys (Line 1c) in order to use the figure.

For the Before Retrofit case, look up the glazing type specified in Line 2g to find the appropriate set of curves. For the After Retrofit case, use the set of curves for double-glazing. This will be adjusted in step b below to account for the lower shading coefficient of low-e glass.

b. Adjust for the glazing shading coefficient. If Line 2h $\geq$ 0.88 (0.88 is the shading coefficient of double-glazing), then enter 1.0. If Line 2h < 0.88, then enter (Line 2h/0.88).

c. Adjust for the window covering shading coefficient. If not used, enter 1. If used, enter (Line 2p/Line 2h).

d. Enter the corrected solar heat gain through glazing for each orientation. Multiply: (Line 5a x Line 5b x Line 5c)

e. Determine the annual conduction heat gain through the glass. Calculate:[ ((Line 2i x 0.63) + + (Line 2j x 0.37)) ] x Line 1b.

f. Enter the total heat gain (solar and conduction) through the glazing for all exposures. Add: (Line 5d + Line 5e).

g. Find the annual conduction heat gain due to the frame. Multiply: (Line 1b x Line 2f).

h. Calculate the combined heat gain through both the glazing and frame for all exposures. Add:(Line 5f x 0.70) + (Line 5g x 0.30).

i. Enter the total window area for each exposure from Line 3d.

j. Calculate the total annual heat gain in MBtu/yr for each exposure. Multiply: (Line 5h x Line 5i).

k. Add the total annual heat gain from N,S,E,W, exposures in line 5j and enter the sum.

| WORKSHEET II | Worksheet II is accompanied by General Instructions. Please read the instruction sheet carefully prior to filling out each corresponding line item on the worksheet form. |
|---|---|

## 1. SITE INFORMATION

| | Input | Source |
|---|---|---|
| **a. Annual Heating Degree Days:** | ________ F-day/yr | *Table 1* |
| **b. Annual Cooling Degree Hours:** | ________ F-hr/yr | *Figure 22* |
| **c. Annual Mean Daily Solar Radiation:** | ________ Langleys | *Figure 23* |
| **d. North Latitude:** | ________ ° | *Table 1* |
| **e. Heating Fuel Type:** *(circle one)* | Oil / Gas / None | *Field Data* |
| **f. Heating System Efficiency:** | ________% | *Field Data* |
| **g. Cost of Fuel:** | Oil ________\$/gallon<br>or Natl. Gas ________\$/therm | *Local Price* |
| **h. Is Building Air-Conditioned?** *(circle one)* | Yes / No | *Field Data* |
| **i. Cooling System Efficiency:** | EER Rating = ______ | *Field Data* |
| **j. Cost of Electricity:** | Electric ________\$/kwh | *Local Price* |

## 2. WINDOW INFORMATION

**a. Window type:** *(circle one)* Double-Hung / Casement / Horizontal Slider / Awning — *Field Data*

**b. Average Window Size:** Height: ________in. Width: ________ in. — *Field Data*

**c. Number of windows @ each exposure:** North __________ South__________ TOTAL # ________ East __________ West__________ — *Field Data*

**d. Window Covering Type most used:** Window Covering Type ______________________ — *Field Data*

| | (Before Retrofit) | (After Retrofit) | |
|---|---|---|---|
| **e. Window Frame Material:** *(circle one)* | Wood/ Alum./Alum. w/Th.Br. | *Vinyl* | *Field Data* |
| **f. Window frame U-Value:** | ________Btu/hr-ft$^2$-F | *0.40* *Btu/hr-ft$^2$-F* | *Table 2* |
| **g. Glazing Type:** *(circle one)* | Single / Double | *Double with Low-e* | *Field Data* |
| **h. Glazing shading coefficient:** | ____________ | *0.82* | *Table 2* |
| **i. Center of glass U-Value:** | ________Btu/hr-ft$^2$F | *0.43* *Btu/hr-ft$^2$-F* | *Table 2* |
| **j. Edge of glass U-Value:** | ________ Btu/hr-ft$^2$-F | *0.55* *Btu/hr-ft$^2$-F* | *Table 2* |
| **k. Overall glazing and frame U-Value:** | ________Btu/hr-ft$^2$-F | *0.45* *Btu/hr-ft$^2$-F* | *Table 2* |
| **l. Are windows weatherstripped?** *(circle one)* | Yes / No | *Yes* | *Field Data* |
| **m. Condition of fit:** *(circle one)* | Poor/ Average/ Excellent | *Excellent* | *Field Data* |
| **n. Air Infiltration Rate** | ____________ cfm/ ft. | ______*cfm/ ft.* | *Table 3* |
| **o. Combined glazing and covering U-Value:** | ________ Btu/hr-ft$^2$-F | ________*Btu/hr-ft$^2$-F* | *Table 4* |
| **p. Combined glazing and covering shading coefficient** | ________ | ________ | *Table 4* |

## 3. GENERAL CALCULATIONS

**Source**

**a. Calculate cost of fuel in $/MBtu** Oil: [(__________ $/gal.) / (139,600 Btu/gal.)] x $10^6$ = ______$/MBtu — *Line 1g*

or

Gas: [(__________ $/therm / (100,000 Btu/therm)] x $10^6$ = ______ $/MBtu

**b. Calculate cost of electricity in $/MBtu:** Electric: [(_____ $/kwh) / (3,413 Btu/kwh)] x $10^6$ = ______ $/MBtu — *Line 1j*

**c. Calculate area of representative window:** Area = [________ (in.) x ________(in.)] / 144 = ________$ft^2$ — *Line 2b*

(Height) (Width)

**d. Calculate window area @ ea. exposure:** — *Line 2c and Line 3c*

North: ________ x ________ = ________$ft^2$
(# Windows) (Area) North Area

South: ________ x ________ = ________$ft^2$
(# Windows) (Area) South Area

East: ________ x ________ = ________$ft^2$
(# Windows) (Area) East Area

West: ________ x ________ = ________$ft^2$
(# Windows) (Area) West Area

**e. Calculate crack length, $L_c$, for representative window type:** — *Line 2a and Line 2b*

$L_c$: (Double-Hung) = [(2 x _____) + (3 x ______)] / 12 = ______ft.
(Height) (Width)

$L_c$: (Casement) = [(2 x _____) + (2 x ______)] / 12 = ______ft.
(Height) (Width)

$L_c$: (Slider) = [(3 x _____) + (2 x ______)] / 12 = ______ft.
(Height) (Width)

$L_c$: (Awning) = [(2 x _____) + (2 ______ )] / 12 = ______ft.
(Height) (Width)

**f. Calculate total crack length for all windows in the building:** — *Line 2c and Line 3e*

TOTAL $L_c$ = __________ x ________ = _______ft.
(Total # of Windows) ($L_c$)

*Worksheet II - continued*

## 4. ANNUAL WINDOW HEAT LOSS (HEATING SEASON)

| BEFORE RETROFIT | North South East West | | Source |
|---|---|---|---|
| *(All values in this top section apply only to existing windows before retrofit)* | | | |
| a. Conduction heat loss through glazing | ____ ____ ____ ____ | Btu/ft$^2$-yr | *Fig. 24 or 25* |
| b. Adjust N,S,E,W for low-e glazing | 0 | Btu/ft$^2$-yr | *No Adjustment needed* |
| c. Corrected glazing heat loss | ____ ____ ____ ____ | Btu/ft$^2$-yr | *(Line 4a - Line 4b)* |
| d. Conduction heat loss through frame | ____ | Btu/ft$^2$-yr | *(Line 1a x Line 2f x 24)* |
| e. Combined heat loss through glazing and frame | ____ ____ ____ ____ | Btu/ft$^2$-yr | *[(Line 4c x 0.7) + (Line 4d x 0.3)]* |
| f. Adjust N,S,E,W for covering | ____ | Btu/ft$^2$-yr | *If not used, enter 0. If used: [(Line 2k -2o) x 24 x Line 1a x 0.5]* |
| g. Corrected window heat loss | ____ ____ ____ ____ | Btu/ft$^2$-yr | *(Line 4e - Line 4f)* |
| h. Window area @ea. exp. | ____ ____ ____ ____ | ft$^2$ | *Line 3d* |
| i. Conduction heat loss @ea. exp. | ____ ____ ____ ____ | MBtu/yr | *[(Line 4g x Line 4h)/ $10^6$]* |
| **j. Total conduction heat loss** | ____ | **MBtu/yr** | *(Add N,S,E,W in Line 4i)* |
| **k. Total infiltration heat loss** | ____ | **MBtu/yr** | *[(Lines 2n x 3f x 1a x 26.46)/$10^6$]* |
| **l. Total window heat loss before retrofit** | ____ | **MBtu/yr** | *(Line 4j + Line 4k)* |

| AFTER RETROFIT | North South East West | | |
|---|---|---|---|
| *(All values in this bottom section apply only to new vinyl replacement windows after retrofit)* | | | |
| a. Conduction heat loss through glazing | ____ ____ ____ ____ | Btu/ft$^2$-yr | *Fig. 24 or 25* |
| b. Adjust N,S,E,W for low-e glazing | ____ | Btu/ft$^2$-yr | *(Line 1a x 24 x 0.0826)* |
| c. Corrected glazing heat loss | ____ ____ ____ ____ | Btu/ft$^2$-yr | *(Line 4a - Line 4b)* |
| d. Conduction heat loss through frame | ____ | Btu/ft$^2$-yr | *(Line 1a x Line 2f x 24)* |
| e. Combined heat loss through glazing and frame | ____ ____ ____ ____ | Btu/ft$^2$-yr | *[(Line 4c x 0.7) + (Line 4d x 0.3)]* |
| f. Adjust N,S,E,W for covering | ____ | Btu/ft$^2$-yr | *If not used: enter 0. If used: . [(Line 2k-2o) x 24 x Line 1a x 0.5)]* |
| g. Corrected window heat loss | ____ ____ ____ ____ | Btu/ft$^2$-yr | *(Line 4e - Line 4f)* |
| h. Window area @ea. exp. | ____ ____ ____ ____ | ft$^2$ | *Line 3d* |
| i. Conduction heat loss @ea. exp. | ____ ____ ____ ____ | MBtu/yr | *[(Line 4g x Line 4h)/$10^6$]* |
| **j. Total conduction heat loss** | ____ | **MBtu/yr** | *(Add N,S,E,W in Line 4i)* |
| **k. Total infiltration heat loss** | ____ | **MBtu/yr** | *[(Lines 2n x 3f x 1a x 26.46)/$10^6$]* |
| **l. Total window heat loss after retrofit** | ____ | **MBtu/yr** | *(Line 4j + Line 4k)* |

## 5. ANNUAL WINDOW HEAT GAIN (COOLING SEASON)

| BEFORE RETROFIT | North | South | East | West | | Source |
|---|---|---|---|---|---|---|
| *(All values in this top section apply only to existing windows before retrofit)* | | | | | | |
| a. Solar heat gain through glazing | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *Fig. 26 or 27* |
| b. Adjust N,S,E,W for low-e S.C. | | 1.0 | | | | *No adjustment needed* |
| c. Adjust N,S,E,W for covering S.C. | ______ | | | | | *If not used, enter 1. If used enter: (Line 2p/Line 2h)* |
| d. Corrected solar heat gain | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *( Line 5a x Line 5b x Line 5c)* |
| e. Conduction heat gain through glazing | ______ | | | | $Btu/ft^2$-yr | *[(Line 2i x 0.63) + (Line 2j x 0.37) x Line 1b]* |
| f. Total solar and conduction heat gain through glazing | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *(Line 5d + Line 5e)* |
| g. Conduction heat gain through frame | ______ | | | | $Btu/ft^2$-yr | *(Line 1b x Line 2f)* |
| h. Combined heat gain through glazing and frame | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *[(Line 5f x 0.7) + (Line 5g x 0.3)]* |
| i. Window area @ea. exp. | ______ | ______ | ______ | ______ | $ft^2$ | *Line 3d* |
| j. Total window heat gain @ea. exp. | ______ | ______ | ______ | ______ | MBtu/yr | *[(Line 5h x Line 5i)/$10^6$]* |
| **k. Total window heat gain before retrofit** | ______ | | | | MBtu/yr | *(Add N,S,E,W in Line 5j)* |

| AFTER RETROFIT | North | South | East | West | | |
|---|---|---|---|---|---|---|
| *(All values in this bottom section apply only to new vinyl replacement windows after retrofit)* | | | | | | |
| a. Solar heat gain through glazing | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *Fig. 26 or 27* |
| b. Adjust N,S,E,W for low-e S.C. | ______ | | | | | *(Line 2h/0.88)* |
| c. Adjust N,S,E,W for covering S.C. | ______ | | | | | *If not used, enter 1. If used, enter: (Line 2p/Line 2h)* |
| d. Corrected solar heat gain | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *(Line 5a x Line 5b x Line 5c)* |
| e. Conduction heat gain through glazing | ______ | | | | $Btu/ft^2$-y | *((Line 2i x 0.63) + (Line 2j x 0.37) x Line 1b]* |
| f. Total solar and conduction heat gain through glazing | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *( Line 5d + Line 5e)* |
| g. Conduction heat gain through frame | ______ | | | | $Btu/ft^2$-yr | *(Line 1b x Line 2f)* |
| h. Combined heat gain through glazing and frame | ______ | ______ | ______ | ______ | $Btu/ft^2$-yr | *[(Line 5f x 0.7) + (Line 5g x 0.3)]* |
| i. Window area @ea. exp. | ______ | ______ | ______ | ______ | $ft^2$ | *Line 3d* |
| j. Total window heat gain @ea. exp. | ______ | ______ | ______ | ______ | MBtu/yr | *[(Line 5h x Line 5i)/$10^6$]* |
| **k. Total window heat gain after retrofit** | ______ | | | | MBtu/yr | *(Add N,S,E,W in Line 5j)* |

## 6. COST SAVINGS IN HEATING ENERGY:

*(Note: Subscript "br" refers to "before retrofit", and subscript "ar" refers to "after retrofit")*

**a.** Calculate heating cost **Before Retrofit**: — Source

Annual heating cost Before Retrofit = (______MBtu/yr) x (________$/MBtu) x (100 /______) = ________ $/yr — *Line 4l, Line 1f, and Line 3a*

( Line $4l_{br}$ ) ( Line 3a ) ( Line 1f )

**b. Calculate heating cost After Retrofit:**

Annual heating cost After Retrofit = (______MBtu/yr) x (________$/MBtu) x (100 /______) = ________ $/yr — *Line 4l, Line 1f, and Line 3a*

( Line $4l_{ar}$ ) ( Line 3a ) ( Line 1f )

**c. Calculate first year heating cost savings:**

First year heating cost savings = ____________$/yr - ____________$/yr = ____________ $/yr — *Line 6a and Line 6b*

( Line $6a_{br}$ ) ( Line $6b_{ar}$ )

## 7. COST SAVINGS IN COOLING ENERGY:

**a. Calculate annual cooling cost Before Retrofit:**

Annual cooling cost Before Retrofit = (____ MBtu/yr) / (______) x (3.414 Btu/Whr) x (_____$/MBtu) = ______ $/yr — *Line 5k, Line 1i, and Line 3b*

( Line $5k_{br}$ ) ( Line 1i ) ( Line 3b )

**b. Calculate annual cooling cost After Retrofit:**

Annual cooling cost After Retrofit = (____MBtu/yr) / (______) x (3.414 Btu/Whr) x (_____ $/MBtu) = ______$/yr — *Line 5k, Line 1i, and Line 3b*

( Line $5k_{ar}$ ) ( Line 1i ) ( Line 3b )

**c. Calculate first year cooling cost savings:**

First year cooling cost savings = ____________$/yr - ____________$/yr = ____________ $/yr — *Line 7a and Line 7b*

( Line $7a_{br}$ ) ( Line $7b_{ar}$ )

## 8. TOTAL COST SAVINGS IN HEATING AND COOLING ENERGY:

**a. Calculate total heating and cooling energy cost Before Retrofit:**

Annual heating and cooling energy cost Before Retrofit = ____________ $/yr + ____________$/yr = ____________ $/yr — *Line 6a and Line 7a*

( Line $6a_{br}$ ) ( Line $7a_{br}$ )

**b. Calculate total heating and cooling energy cost After Retrofit:**

Annual heating and cooling energy cost After Retrofit = ____________$/yr + ____________$/yr = ____________$/yr — *Line 6b and Line 7b*

( Line $6b_{br}$ ) ( Line $7b_{br}$ )

**c. Calculate first year heating and cooling energy cost savings:**

**First year heating and cooling energy cost savings** = ____________$/yr - ____________$/yr = ____________$/yr — *Line 8a and Line 8b*

( Line $8a_{br}$ ) ( Line $8b_{ar}$ )

# APPENDIX B

## Basic Economics

## GENERAL

This appendix section discusses some general economic procedures for conducting life-cycle cost analysis. Its reference source is the Navy Activity-Level Energy Systems Planning Procedure (A-LESP), pages 9 through 14. For more information on economics, refer to the Economic Analysis Handbook, NAVFAC P-442, June 1986. For determining discount factors for life-cycle cost analysis, refer to NISTIR 85-3273-3, "Energy Prices and Discount Factors for Life-Cycle Cost Analysis," Nov. 1988. This publication is updated annually as a supplement to NBS Handbook 135 and NBS Special Publication 709.

### Basic Economics

Money has value over time as expressed by the price it commands. We recognize that one dollar today is not equivalent to one dollar at a future date. Therefore all dollar amounts in the SIR equations are based on "present value" for use in comparisons. This is done by adjusting life cycle savings and costs with present value factors.

### Savings- to-Investment Ratio

SIR is a technique to determine whether an existing system should be retrofitted or replaced with another system on the basis of cost savings. It is cost-effective to implement a retrofit or a replacement if the expected lifetime savings exceed the initial investment required, that is, if the value for SIR is greater than 1.

### Present Value Factors

In order to make comparisons between SIRs they must first be on the same economic base. For our purposes, a facility/system life of 25 years will be used in all SIR analyses. During the analysis future periodic costs are adjusted (discounted) by means of present value factors. The factors differ if the payment is one time cost (e.g., a car is purchased with cash), or spread out over the lifetime in cumulative uniform payments (e.g., a car is purchased in installments). After all adjustments have been made, SIR can then be evaluated.

$$SIR = [ (\Delta E_1 \times DERF) + (\Delta E_2 \times DERF) + (\Delta O\&M \times PYDF) ] / ( C \times PIF)$$

where:

- $\Delta E_1$ = Change in annual heating energy cost savings due to retrofit/replacement system
- $\Delta E_2$ = Change in annual cooling energy cost savings due to retrofit/replacement system
- DERF = Differential Escalation Rate Factor
- $\Delta O\&M$ = Change in annual O&M cost savings due to retrofit/replacement (negative value if higher O&M costs result)
- PYDF = Project Year Discount Factor
- C = Startup cost of retrofit/replacement system
- PIF = Periodic Investment Factor

PYDF, DERF, and PIF are present value factors defined below.

**PROJECT YEAR DISCOUNT FACTOR (PYDF)**

- Annual operation and maintenance costs increase with time at the same rate as the general economy. This rate is commonly known as the annual discount (or inflation) rate. Table B-1 shows the project year discount factor (PYDF) at several annual interest rates.

Table B-1. Project Year Discount Factor (PYDF)for Project Year 25

| Annual Discount Rate R (%) | Project Year Discount Factor (PYDF) |
|---|---|
| 6 | 13.163 |
| 7 | 12.057 |
| 8 | 11.096 |
| 9 | 10.258 |
| 10 | 9.524 |

**DIFFERENTIAL ESCALATION RATE FACTOR (DERF)**

- Energy costs, unlike O&M costs, increase or escalate at a rate greater than the annual discount rate (see Table B-2). The "differential escalation rate" takes into account items whose prices are increasing at a rate faster than the general economy. DOD policy currently mandates the use of the following differential escalation rates
  Coal 5%
  Electricity 7%
  Fuel Oil 8%
  Natural Gas/LPG 8%

Since the rate of increase is greater, the present value factor for energy costs is correspondingly greater. Table B-2 shows the differential escalation rate factor (DERF) for different annual discount and escalation rates.

Table B-2. Differential Escalation Rate Factors (DERF) forProject Year 25

| Annual Discount | Differential Escalation Rate D (%) (Fuels) | | | | | |
|---|---|---|---|---|---|---|
| Rate (%) | 5 | 6 | 7 | 8 | 9 | 10 |
| 7 | 19.931 | 22.282 | 24.731 | 28.146 | 31.794 | 36.030 |
| 8 | 17.945 | 19.972 | 22.306 | 24.731 | 28.15 | 31.721 |
| 9 | 16.243 | 17.997 | 20.011 | 22.329 | 25.000 | 28.084 |
| 10 | 14.778 | 16.303 | 18.049 | 20.051 | 22.351 | 25.000 |

## PERIODIC INVESTMENT FACTOR (PIF)

- When the retrofit or replacement has a life of 25 years or more, the investment is just the startup cost, C. However, some energy options require periodic product replacement within the 25-year analysis period. These additional investment costs require use of the periodic investment factor (PIF). Table B-3 shows the PIF for 5-year increments of the stated 25-year lifetime

Table B-3. Periodic Investment Factor (PIF)

| Replacement Year | Annual Discount Rate (R) (%) 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|
| 5 | 3.095 | 2.906 | 2.739 | 2.593 | 2.463 |
| 10 | 1.896 | 1.793 | 1.104 | 1.627 | 1.561 |
| 15 | 1.430 | 1.375 | 1.328 | 1.287 | 1.251 |
| 20 | 1.321 | 1.267 | 1.223 | 1.186 | 1.156 |
| 25 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

# APPENDIX C

## How Energy is Lost Through Windows
## (Derivation of Annual Energy Losses)

# How Energy is Lost Through Windows

Windows transmit heat through conduction, convection, radiation, and by air infiltration. When there is a temperature difference across a window, heat will flow from the high temperature side of the window to the low temperature side. During the winter, heat will flow from the warm inside air to the cold outside air. Heat flow due to temperature difference is referred to as conductive heat flow. The rate of conductive heat flow from air to air through a window is determined by the thermal resistance of the glass and framing plus the air film resistance at the inner and outer surfaces of the glass and framing.

In the case of single glass, the resistance to heat flow is due almost entirely to the resistance at the surfaces. This resistance from surface to air depends on surface emissivity and the velocity of air across the surface.

The total resistance to heat flow across the frame and glass area of a window is the sum of the inside surface to air resistance, the resistance of the frame and glass itself, and the outside surface to air resistance. The reciprocal of the sum of these resistances is the conductance. Unit air to air heat conductance is called heat transmittance. It is the heat which is conducted through one square foot of window area in one hour when the temperature difference across the winodw is one degree Fahrenheit. This is written as Btu/hr/sq.ft./F and is referred to as the U-value.

Convective losses are caused by air moving across the surfaces of the window. Total heat loss through windows that can be controlled through proper design involve conduction and convection heat transfer, as well as heat loss due to air infiltration. This is represented by the following equation:

$$Q = q_c + q_i$$

where:
- $Q$ = the total annual window heat loss
- $q_c$ = heat loss by conduction and convection heat transfer through a surface
- $q_i$ = heat loss by air infiltration. This is the energy required to warm outdoor air entering by infiltration to the temperature of the room.

By subtituting the appropriate equations for $q_c$ and $q_i$, the equation for Q becomes:

$$Q = (A \times U \times (t_i - t_o)) + (C_p \times V \times \rho \times (t_i - t_o))$$

where:
- $A$ = area of exposed surface, $ft^2$
- $U$ = overall coefficient of heat transfer, Btu/hr-$ft^2$-F
- $t_i$ = indoor temperature, F
- $t_o$ = outdoor temperature, F
- $C_p$ = specific heat of air (0.245 Btu/lb-F)
- $V$ = volume of outdoor air, $ft^3$/hr
- $\rho$ = density of standard air (0.075 lb/$ft^3$)

If the air infiltration rate of a window, I, is known (where I is expressed in $ft^3$/min-ft.), and if the crack length of the window, $L_c$, is also known (where $L_c$ is expressed in ft.), then the equation for Q becomes:

$$Q = (U \times A \times (t_i - t_o)) + (C_p \times I \times L_c \times \rho \times (t_i - t_o))$$

If the number of annual heating degree days, D, for a location were also known (where D is expressed as $^{o}$F-day/yr), then the total annual heat loss, Q (Btu/yr), can be further simplified. By substituting D for the temperature differential ($t_i$-$t_o$), the known values for specific heat of air and density of air, then the equation for Q can be calculated by:

$$Q = (24 \times U \times A \times D) + (0.245 \times 0.075 \times I \times L_c \times 60 \times D \times 24)$$

$$Q = (24 \times U \times A \times D) + (0.018 \times I \times L_c \times 60 \times D \times 24)$$

or

$$\boxed{Q = (24 \times U \times A \times D) + (26.46 \times I \times L_c \times D)}$$

where:

Q = heat loss through window in Btu/yr

U = overall coefficient of heat transfer in Btu/hr-$ft^2$-F

A = area of window, in $ft^2$

D = # of heating degree days > 65F in F-day/yr

24 = multiplier, 24 hr/day

$C_p$ = specific heat of air, 0.245 Btu/lb-F

I = air infiltration rate, $ft^3$/min-ft

$L_c$ = crack length, ft

$\rho$ = density of air at standard conditions 0.075 lb/$ft^3$

60 = multiplier, 60 min/hr

When calculating the annual energy losses through the window, the overall heat transfer coefficient of the window, or its U-value (1/R-value), must be known. This can be obtained through manufacturer data and verfied by thermal test reports, also obtainable from the manufacturer.

Windows consist of three basic areas of heat transfer: the glass center, the glass edge, and the frame/sash areas. The glass center area comprises the bulk of the total glass area (about 63%). The R-value of this area is affected by the number of glazing layers, the width of the airspace, and the emissivity of the glazing surfaces.

In a sealed insulating glass unit, the spacing between the panes is typically maintained by a hollow aluminum edge spacer. Because of aluminum's high thermal conductivity, the R-value at the edge of a sealed insulating glass unit is considerably lower than the R-value at the center of the glass. This is commonly referred to as the "edge effect". The edge of glass area is nominally 37% of the total glass area.

Frame and sash areas also contribute to the thermal performance of the window. In an overall window unit, frame and sash area typically comprise about 30% of the window unit, while the glass comprises about 70%. The overall U-value is estimated using area-weighted U-values for each contribution by:

$$U = [ (U_{cg} \times A_{cg}) + (U_{eg} \times A_{eg}) + (U_f \times A_f) ] / (A_{cg} + A_{eg} + A_f)^{*}$$

where the subscripts $_{cg}$, $_{eg}$, and $_{f}$ refer to the center-of-glass, edge-of-glass,and frame, respectively.

When considering the thermal performance of a window, it is important to verify that the U-value (or R-value) refers to the complete window unit, including the effects on U-value of both the frame and the glass. Manufacturer data can be supported by available thermal test reports from independent test facilities.

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* Source: "Window U-values," Michael E. McCabe, Ashrae Journal, June 1989

# Appendix D

## Performance Data for Some Whole Window Units (Without Window Coverings)

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ $hr\text{-}ft^2\text{-}F$ | R $hr\text{-}ft^2\text{-}F$/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Airtite Manufacturing Inc.<br>109-35 178 St.<br>St. Albans, NY 11433<br>(718)658-2822 | "Spectus System 710" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8"airspace | 0.46 | 2.17 | 0.04 | 10 | 5 |
| Alaska Window Co.<br>P.O. Box 61252<br>Fairbanks, AK 99706<br>(907)479-5874 | "Alaska Windows Series 400" | Vinyl | Tilt-Turn | Double | 3/4" IG; 1/2" airspace | 0.44 | 2.27 | .02 | Limited Lifetime | 5 to 10 |
| | | | Tilt-Turn | Double w/LowE(S) (Heat-Mirror 88) | 1-3/8" IG; 1-1/8" airspace | 0.21 | 4.76 | .02 | | |
| Andersen Corp.<br>100 4th Avenue, North<br>Bayport, MN<br>55003- 1096<br>(612) 770-7217 | "Andersen Perma-Shield" | Vinyl-Clad Wood | Casement | Double | 5/8" IG; 3/8" airspace | 0.52* | 1.9* | 0.04* | 5 | 20 |
| | | | Casement | Double w/LowE(S) (Andersen High Performance by Cardinal IG) | 5/8" IG; 3/8" airspace | 0.25* | 4.0* | 0.04* | | |
| Anpaul Window Co., Inc.<br>8741 Jennings Sta.<br>St. Louis, MO 63136<br>(800) 444-2675 | "Anpaul Fiberlux 950" | Vinyl | Double-Hung | Double | 1-3/16" IG; 9/16" airspace | 0.54 | 1.85 | 0.08 | 20 | 10 |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ hr-ft$^2$-F | R hr-ft$^2$-F/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Arrow Aluminum Industries, Inc. P.O. Box 528 Martin, TN 38237 (901)587-9528 | "Arrow Series 40" | Aluminum w/Thermal Break | Single-Hung | Double | 5/8" IG; 3/8" airspace | 0.69 | 1.45 | 0.07 | None | 5 |
| Arrowhead Vinyl Window Co. 518 E. 4th Street Duluth, MN 55805 (218) 722-2600 | "900" | Vinyl | Tilt-Turn | Double | 1-3/16" IG; 9/16" airspace | 0.43 | 2.32 | 0.03 | 25 | 10 |
| | | | | Double w/Low-E(H) | | | | | | |
| Baltimore Thermal Window 600 S. Catherine St. Baltimore, MD 21223 (301)947-6100 | "5000" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.50 | 2.0 | 0.10 | 25 | 15 |
| Best Built 3400 Tacoma Street Union Gap, WA 98903 (800) 322-8050 | "Best Built Windows" | Aluminum-Clad Wood | Casement | Double | 13/16" IG; 5/8"airspace | 0.45 | 2.22 | 0.08 | Limited Lifetime | 5 |
| | | | Casement | Double w/Low-E(H) (AFG-Comfort E) | 13/16" IG; 5/8"airspace | 0.38 | 2.63 | 0.06 | | |
| | | | Casement | Double w/Argon | 13/16" IG; 5/8" airspace | 0.38 | 2.63 | 0.06 | | |
| | | | Casement | Double w/Low-E and Argon | 13/16" IG; 5/8" airspace | 0.32 | 3.13 | 0.06 | | |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ $hr\text{-}ft^2\text{-}F$ | R $hr\text{-}ft^2\text{-}F$/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Biltbest Windows<br>175 Tenth Street<br>Ste. Genevieve, MO 63670<br>(314) 883- 3571 | "Bestclad" | Aluminum-Clad Window | Casement | Double | 5/8" IG; 3/8"airspace | 0.43* | 2.33* | 0.03* | 1 | 20 |
| | | | Casement | Triple | 1-1/8" IG; double 3/8" airspace | 0.32* | 3.13* | 0.03* | | |
| | | | Casement | Double w/Low-E(S) (PPG Sungate 100) | 5/8" IG; 3/8"airspace | 0.29* | 3.44* | 0.03* | | |
| | | | Double-Hung | Double | 5/8" IG; 3/8" airspace | 0.44* | 2.27* | 0.24* | | |
| | | | Double-Hung | Double w/Low-E (S) (100 Sungate) | 5/8" IG; 3/8"airspace | 0.30* | 3.33* | 0.24* | | |
| Diamond Manufacturing Corp.<br>168 Railroad Street<br>Huntington Station,,L.I. NY 11746-1598<br>(516) 423-4700 | "Diamond Windows" | Vinyl | Casement | Double-Hung | 7/8" IG; 5/8" airspace | 0.54 | 1.85 | 0.08 | 10 | 5 |
| Fiberlux, Inc.<br>1634 S. Franklin Street<br>South Bend, IN 46613<br>(219) 233-6603 | "Fiberlux 950" | Vinyl | Double-Hung | Double | 1-3/16" IG; 9/16" airspace | 0.54 | 1.85 | 0.08 | 25 | 10 |
| | | | Double-Hung | Double w/Low-E (H) (Ford Sunglas HR) | 1-3/16" IG; 9/16" airspace | 0.45 | 2.22 | 0.08 | | |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ hr-ft$^2$-F | R hr-ft$^2$-F/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Galaxy Manufacturing Co. of CNY, Inc. 109 Monarch Drive Liverpool, NY 13088 (315) 451-5353 | "Poly Tex" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.51 | 1.96 | 0.05 | 40 | 40 |
| | | | Double-Hung | Double w/Low-E (H) AFG Comfort-E | 7/8" IG· 5/8" airspace | 0.45 | 2.22 | 0.03 | | |
| H&M Vinyl Windows 475 Babylon Turnpike Freeport, NY 11520 (516) 623-5555 | "Certainteed Vinyl" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.48 | 2.08 | 0.12 | 10 | 5 |
| | | | Double-Hung | Double w/Low-E (H) (Comfort-E) | 7/8" IG; 5/8" airspace | 0.40 | 2.50 | 0.12 | | |
| | | | Double-Hung | Triple | 1-5/8" IG; double airspace, 5/8" each | 0.35 | 2.86 | 0.12 | | |
| House of Aluminum and Glass, Inc. 5414 E. Broadway Avenue Spokane, WA 99212 (509) 535-3015 | | Aluminum w/Thermal Break | Slider | Double | 3/4" IG; 1/2" airspace | 0.54 | 1.85 | 0.02 | 1 | 10 |
| | | | Slider | Double w/Low-E (S) (Heat Mirror) | 3/4" IG; 1/2" airspace | 0.40 | 2.5 | 0.06 | | |
| | | | Slider | Double w/Int. Storm | 3/4" IG; 1/2" airspace | 0.33 | 3.0 | 0.06 | | |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING | | U | R | I | WARRANTY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Type | Thickness | Btu/ hr-ft$^2$-F | hr-ft$^2$-F/ Btu | cfm/ft | Frame (Yrs.) | Glass Unit (Yrs.) |
| Hurd Millwork Co. 520 S. Whelen Avenue Medford, WI 54451 (715) 748-2011 | "Hurd Windows" | Aluminum-Clad Wood | Double-Hung | Double | 3/4" IG; 9/16" airspace | 0.44* | 2.27* | 0.09* | 1 | 10 |
| | | | Casement | Double | 1" IG; 3/4" airspace | 0.43* | 2.31* | .02* | | |
| | | | Casement | Double w/Low-E (S) (Heat-Mirror 88) | 1" IG; 3/4" airspace | 0.25* | 4.05* | .02* | | |
| | | Wood | Double-Hung | Double | 5/8" IG; 7/8" airspace | 0.46* | 2.17* | .08* | | |
| | | | Casement | Double | 3/4" IG; 9/16" airspace | 0.44* | 2.27* | .02* | | |
| | | | Casement | Double w/Low-E (S) (Heat-Mirror 88) | 1" IG; 3/4" airspace | 0.25* | 4.05* | .02* | | |
| Kasson & Keller, Inc. School Lane Fonda, NY 12068 (518) 853-3421 | "Vinyl Building Products Series 500" | Vinyl | Double-Hung | Double | 3/4" IG; 1/2" airspace | 0.55 | 1.82 | 0.15 | 15 | 10 |
| | | | Double-Hung | Triple | 7/8" IG; double airspace, 1/4" each | 0.40 | 2.50 | 0.07 | | |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ hr-ft$^2$-F | R hr-ft$^2$-F/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Kensington Manufacturing Co. P.O. Box 571 Rte. 66 South Leechburg, PA 15656-0571 (412) 845-8133 | "Energy-saver" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.47 | 2.13 | 0.06 | Lifetime Limited | 20 |
| | | | Double-Hung | Double w/Low-E (H) PPG Sungate 200 | 7/8" IG; 5/8" airspace | 0.40 | 2.50 | 0.07 | | |
| Marvin Windows Warroad, MN 56763 (218) 386-1430 | "Marvin Windows" | Wood | Casement | Double | 1/2" IG; 1/4" airspace | 0.51* | 1.96* | 0.06* | 1 | 10 |
| | | | Casement | Double | 3/4" IG; 1/2" airspace | 0.43* | 2.32* | 0.06* | | |
| | | | Casement | Double w/Low-E (S) (Sungate 100) | 3/4" IG; 1/2" airspace | 0.28* | 3.57* | 0.06* | | |
| | | | Double-Hung (Tilt) | Double | 1/2" IG; 1/4" airspace | 0.49* | 2.04* | 0.14* | | |
| | | | Double-Hung (Tilt) | Double w/Low-E (S) (Sungate 100) | 1/2" IG; 1/4" airspace | 0.39* | 2.56* | 0.14* | | |
| | | Aluminum-Clad Wood | Double-Hung (Tilt) | Double | 3/4" IG; 1/2" airspace | 0.42* | 2.38* | 0.17* | | |
| | | | Double-Hung (Tilt) | Double w/Low-E (S) (Sungate 100) | 3/4" IG; 1/2" airspace | 0.28* | 3.57* | 0.17* | | |

## Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ $hr\text{-}ft^2\text{-}F$ | R $hr\text{-}ft^2\text{-}F$/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Master Windows and Doors, Inc.<br>801 Chase Avenue<br>Elk Grove Village, IL 60007<br>(312) 593-0220 | "Trocal 750" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.55 | 1.82 | .05 | 20 | 20 |
| Metro Manufacturing<br>480 Wildwood Avenue<br>Woburn, MA 01801<br>(617) 935-8893 | "Poly-Tex III/III" | Vinyl | Double-Hung | Double w/Low-E (H) Ford Sunglas | 7/8" clear IG; 5/8" airspace | 0.45 | 2.22 | 0.03 | Limited Lifetime | 10 |
| NAPCO<br>Rte. 8 at McFann Rd<br>Valencia, PA 16059<br>(800) 245-1934 | "NAPCO Double-Gard V" | Vinyl | Double-Hung | Double | 3/4" IG; 5/8" airspace | 0.51 | 1.96 | 0.07 | 1 | 10 |
| Northwest Aluminum Products, Inc.<br>1015 E. Lincoln Avenue<br>Yakima, WA 98901<br>(509) 248-4346 | "525" | Aluminum | Slider | Double | 3/4" IG; 1/2" airspace | 0.64 | 1.57 | 0.06 | 1 | 10 |
| | "825" | Aluminum | Single-Hung | Double | 3/4" IG; 1/2" airspace | 0.65 | 1.54 | 0.20 | | |
| | "4530" | Aluminum w/Thermal Break | Slider | Double | 3/4" IG; 1/2" airspace | 0.54 | 1.85 | 0.10 | | |
| | "V-1080" | Vinyl | Single-Hung | Double | 3/4" IG; 1/2" airspace | 0.47 | 2.13 | N/A | 10 | 10 |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ $hr\text{-}ft^2\text{-}F$ | R $hr\text{-}ft^2\text{-}F$/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Northwest Aluminum cont. | | Vinyl | Single-Hung | Double w/Low-E (S) (PPG Sungate 100) | 3/4" IG; 1/2" airspace | 0.34 | 2.94 | N/A | | |
| Peachtree Windows & Doors<br>Box 5700<br>Norcross, GA 30091<br>(404) 497-2000 | "Peachtree Windows" | Aluminum-Clad Wood | Double-Hung | Double | 3/4" clear or bronze tinted IG; 1/2" airspace | 0.42* | 2.38* | N/A | 2 | 10 |
| | | | Double-Hung | Double w/Low-E (S) (PPG Sungate 100) | 3/4" clear or t ronze tinted IG; 1/2" airspace | 0.29* | 3.45* | N/A | | |
| Pella Windows & Doors<br>102 Main Street<br>Pella, IA 50219<br>(515) 628-1000 | "Pella Windows" | Aluminum-Clad Wood | Double-Hung | Double | 5/8" IG; 3/8" airspace | 0.50* | 2.00* | N/A | 1 | 10 |
| | | | Double-Hung | Double w/Low-E (H) (Heatlock by Glaverbel) | 5/8" IG; 3/8" airspace | 0.34* | 2.94* | N/A | | |
| | | | Double-Hung | Double w/Tinted Ext. Glass (Sunblock by Glaverbel) | 5/8" IG; 3/8" airspace | 0.44* | 2.27* | N/A | | |
| Stanley Building Products<br>7160 Krick Road<br>Walton Hills, OH 44146<br>(216) 439-3232 | "250" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.53 | 1.89 | 0.06 | Limited Lifetime | 30 |

**Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS**

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING Type | GLAZING Thickness | U Btu/ hr-ft$^2$-F | R hr-ft$^2$-F/ Btu | I cfm/ft | WARRANTY Frame (Yrs.) | WARRANTY Glass Unit (Yrs.) |
|---|---|---|---|---|---|---|---|---|---|---|
| Stormaster Door & Windows<br>P.O. Box 260<br>Ballston Spa, NY 12020<br>(518)885-9000 | "Vinyl-master" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | 0.53 | 1.89 | 0.14 | 20 | 10 |
| | | | Double-Hung | Double w/Low-E (H) (AFG Comfort-E) | 7/8" IG; 5/8" airspace | 0.43 | 2.33 | 0.15 | 20 | 10 |
| Sugarcreek Window & Door Corp.<br>425 S. Broadway Street<br>P.O. Box 500<br>Sugarcreek, OH 44681 | "DH-001" | Vinyl | Double-Hung | Double | 7/8" IG; 5/8" airspace | .53 | 1.89 | 0.03 | | |
| The Window Factory<br>21600 Alexander Road<br>Cleveland, OH 44146<br>(216) 439- 8000 | "Euro-Weld 80" | Vinyl | Double-Hung | Double w/Low-E (H) AFG Comfort- E) | 7/8" IG; 5/8" airspace | 0.42 | 2.38 | 0.04 | 40 | 15 |
| Vinyl Therm, Inc.<br>321 W. 83rd Street<br>Minneapolis, MN 55420<br>(612) 884- 4329 | "620" | Vinyl | Double-Hung | Double | 1-3/16" IG; 9/16" airspace | 0.54 | 1.85 | 0.09 | N/A | N/A |
| | "630-CSP" | Vinyl | Slider | Double | 1-3/16" IG; 9/16" airspace | 0.51 | 1.96 | 0.03 | | |
| | "310-RW" | Vinyl | Casement | Double | 1" IG; 3/4" airspace | 0.45 | 2.22 | 0.01 | | |
| | "310-RW" | Vinyl | Casement | Double w/Low-E (H) (AFG Comfort-E) | 1" IG; 3/4" airspace | 0.30 | 3.33 | 0.01 | N/A | N/A |

Table D-1. PERFORMANCE DATA FOR SOME WHOLE WINDOW UNITS

| MANUFACTURER | SERIES/ MODEL | SASH TYPE | WINDOW TYPE | GLAZING | | U | R | I | WARRANTY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Type | Thickness | Btu/ hr-ft²-F | hr-ft²-F/ Btu | cfm/ft | Frame (Yrs.) | Glass Unit (Yrs.) |
| Wenco Windows Industrial Park Mt. Vernon, OH 43050 (614) 397-1144 | "Wenco JX-7" | Aluminum-Clad Wood | Casement | Double | 7/16" IG; 1/4" airspace | 0.51* | 1.97* | .02* | 1 | 5 |
| | | | Double-Hung (Tilt) | Double | 7/16" IG; 1/4" airspace | 0.51* | 1.97* | .05* | | |
| | | | Double-Hung (Tilt) | Double w/Low-E (H) (PPG Sungate 200) | 7/16" IG; 1/4" airspace | 0.35* | 2.85* | .05* | | |

* refers to a Calculated U-value.

U = Overall Coefficient of Heat Transmission (Btu/hr-ft$^2$-F)

R = 1/U (hr-ft$^2$-F/Btu)

I = Air Infiltration rate (cfm/ft)

IG = Insulating glass unit

# APPENDIX E

## Performance Data for Some Window Coverings

**Table E-1. PERFORMANCE DATA FOR SOME WINDOW COVERING UNITS**

| MANUFACTURER | COVERING TYPE & DESCRIPTION | PRODUCT NAME | U Btu/hr-ft$^2$-F | R hr-ft$^2$-F/Btu | SC | COMMENTS |
|---|---|---|---|---|---|---|
| Sun Control Products, Inc.<br>431 Fourth Avenue, S.E.<br>Rochester, MN 55904 | Shades (Roller shade w/heat reflective film. Transparent interior, mirror-like exterior, edge-sealed) | "Stainless Steel" | 0.28* | 3.57 | 0.42 | 10-15 yrs. est. useful life; 7 yrs. mfr. warranty. Shade also available as edge-sealed unit. |
| | | "Solar Bronze" | 0.25* | 4.00 | 0.24 | |
| | | "Bronz/Silver/Bronze" | 0.48* | 2.08 | 0.29 | |
| Dirt Road Co.<br>RD 1 - Box 260<br>Waitsfield, VT 05673 | Shades (Edge-sealed, double loop roller shade, 4-layers overall with airspaces; mylar int. layers, white vinyl ext. layers.) | "Comfort Shade" | 0.13** | 7.69 | N/A | 10-15 yrs. est. useful life; 1-2 yrs. warranty |
| T.W. Raftery, Inc.<br>1055 Broad Street<br>P.O. Box 6809<br>Hartford, CT 06106 | Drapes (Double-drapes made of woven fiberglass) | "Thermo-Fold" | 0.56* | 1.78 | 0.33 | 15 yrs. est. useful life; 1 yr. mfr. warranty |

## Table E-1. PERFORMANCE DATA FOR SOME WINDOW COVERING UNITS

| MANUFACTURER | COVERING TYPE & DESCRIPTION | PRODUCT NAME | U Btu/hr-ft$^2$-F | R hr-ft$^2$-F/Btu | SC | COMMENTS |
|---|---|---|---|---|---|---|
| Plastic-View<br>Box 25<br>VanNuys, CA 91409 | Shades (Roller shade made of heat-reflective mylar.) | "Dusk" | 0.16* | 6.25 | 0.17 | 10-12 yrs. est. useful life; 3 yr. mfr. warranty |
| | | "Bronze" | 0.20* | 5.0 | 0.32 | |
| | | "Smoke" | 0.49* | 2.04 | 0.51 | |
| Graber Ind.<br>7549 Graber Road<br>Middleton, WI 53562 | Blinds (Horizontal) | Aluminum | 1.06* | 0.94 | 0.74 | 20 yrs. est. useful life; 3 yr. mfr. warranty |
| | | Satin Black | 0.90* | 1.11 | 0.68 | |
| | Blinds (Vertical) | Flat PVC | 0.80* | 1.25 | 0.22 | 10 yr. mfr. warranty |
| | Shades (pleated fabric shades) | "Mirage" | 0.71* | 1.41 | 0.60 | 3 yr. mfr. warranty |
| | | "Metallized Mirage" | 0.65* | 1.53 | 0.52 | |
| Aeroshade, Inc.<br>P.O. Box 559<br>Waukesha, WI 53187 | Shades (Roller shade made of wooden slats, 7/8" wide) | "Temlite Loomwood" | 0.83* | 1.21 | N/A | 20-30 yr. est. life |

**Table E-1. PERFORMANCE DATA FOR SOME WINDOW COVERING UNITS**

| MANUFACTURER | COVERING TYPE & DESCRIPTION | PRODUCT NAME | U Btu/hr-ft$^2$-F | R hr-ft$^2$-F/Btu | SC | COMMENTS |
|---|---|---|---|---|---|---|
| Rolscreen Co.<br>102 Main Street<br>Pella, IA 50219 | Blinds (Narrow-slat aluminum blinds or pleated fabric shades enclosed between 2 panes of glass) | "Slimshade White" | 0.31** | 3.23 | 0.19 | 1 yr. mfr. warranty |
| | | "Slimshade Type E" | 0.23** | 4.35 | 0.19 | |
| | | "Almond Pleated Shade" | 0.27** | 3.70 | 0.24 | |
| Koolshade Corp.<br>722 Genevieve Street<br>Solana Beach, CA 92075 | Blinds (Aluminum horizontal louvers) | "Black Koolshade" | 0.85** | 1.18 | 0.23 | N/A |
| Hunter Douglas, Inc.<br>601 Alter Street<br>Broomfield, CO 80020 | Shades (Translucent, dual-pleated "cellular" shades in non-woven polyester fabric) | "Duette Classic" (3/8" pleats) | 0.45* | 2.22 | 0.49 | 15 yrs. est. useful life; 3 yr. mfr. warranty |
| | Shades (Polyester "celllular" shades with a metallized polyester film case to block out light | "Duette Eclipse" (3/4" pleats) | 0.322* | 3.1 | N/A | 15 yrs. est. useful life; 3 yr. mfr. warranty |

**Table E-1. PERFORMANCE DATA FOR SOME WINDOW COVERING UNITS**

| MANUFACTURER | COVERING TYPE & DESCRIPTION | PRODUCT NAME | U Btu/hr-ft$^2$-F | R hr-ft$^2$-F/Btu | SC | COMMENTS |
|---|---|---|---|---|---|---|
| Appropriate Technology Corp. 7 Technology Drive Brattleboro, VT 05301 | Shades (5 layers of bonded material-a 1/4 in. layer of fiberfill on each side of a mylar vapor barrier, and 2 outer layers of polycotton cloth, edge-sealed.) | "Window Quilt" | 0.26* | 3.85 | 0.23 | 10 yrs. est. useful life; 3 yr. mfr. warranty |
| | | "Window Showcase" (Quilt with exterior cover sheet) | 0.24* | 4.17 | | |

* Refers to calculated U-value for single glazing w/covering
** Refers to calculated U-value for double-glazing w/covering
U = Overall Coefficient of Heat Transmission (Btu/hr-ft$^2$-F)
R = 1/U (hr-ft$^2$-F/Btu)
SC = Shading Coefficient
N/A = Not available

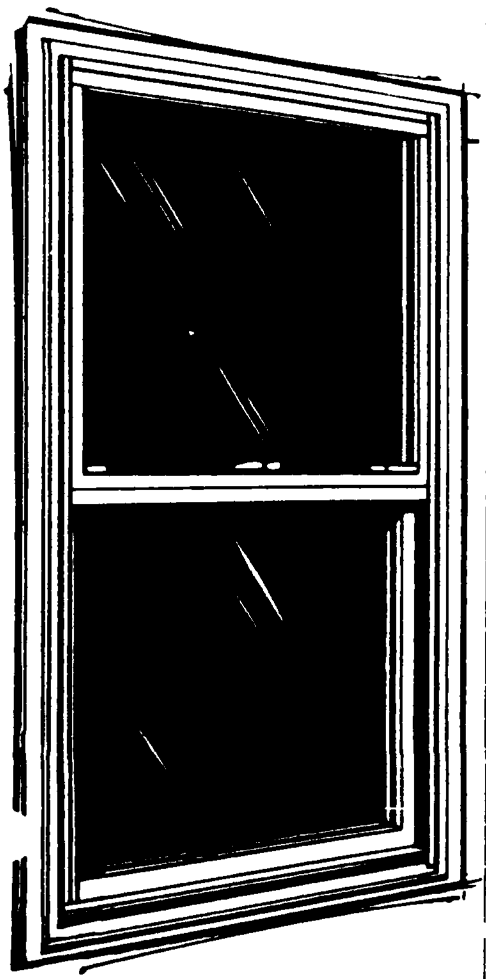
# APPENDIX F

## Sample Manufacturer Installation Instructions for Vinyl Window Units

# How to install CertainTeed Vinyl Double Hung Window into plaster or drywall opening.

Read instructions completely before work begins

**Caution:**
**Do not remove old window until dimensions of CertainTeed Vinyl Window and old window have been checked and are correct.**



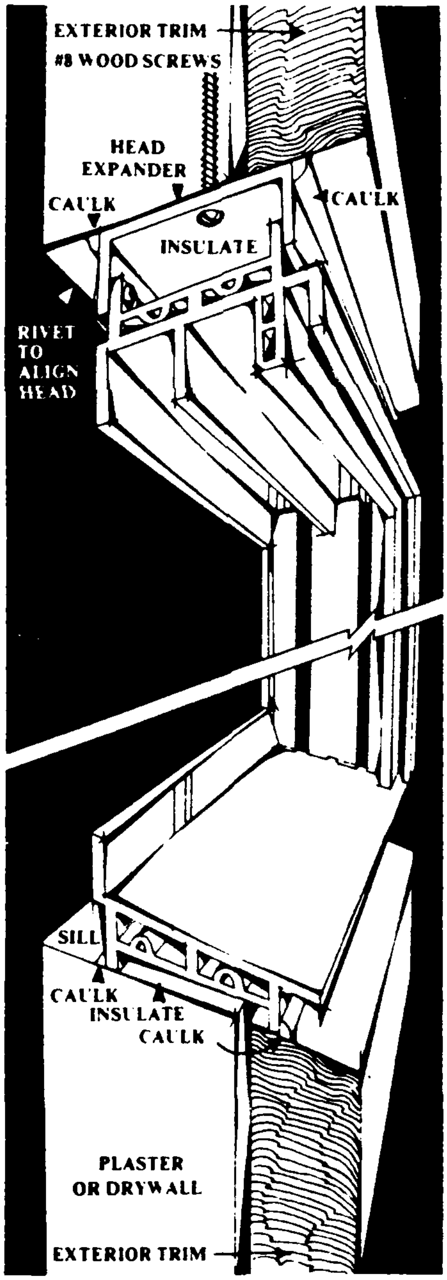
**Prepare opening of old window.**

1. Remove old window carefully to prevent damage to structure.

2. Clean opening before installing CertainTeed window.

**Installing the new window.**

Double hung window can be installed with or without head expander and still angle, depending on how window was measured and ordered.




**INSTALLING WITH HEAD EXPANDER STEPS 1-10**

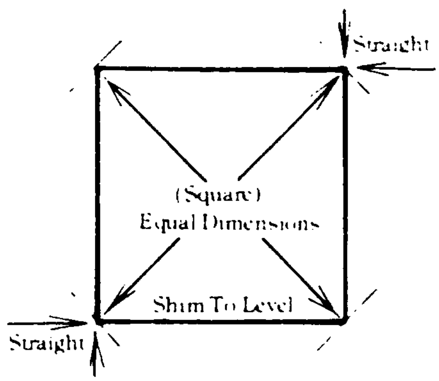
1. Determine proper location of head expander. Seal under expander, and fasten with nails or screws to penetrate minimum 3/4" solid lumber. CertainTeed Double Hung window should be installed as far into the opening as possible for best support and performance.

2. Trim jamb interior vinyl lips with block plane for snug fit at jambs. Note: head expander may have to be trimmed so window will clear sill.

3. Insulate all four sides of CertainTeed Window.

4. Do not remove center shipping strap. Lift CertainTeed Window into head expander, rotate into place and set firmly on old window sill.

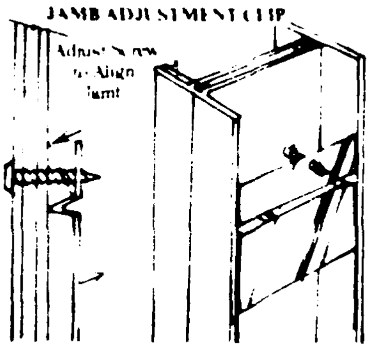
5. Sill of CertainTeed Window must be shimmed to be perfectly straight for proper operation. Note: Sill interior lip can be trimmed with block plane to accomplish straightness instead of shimming.




6. Center and square CertainTeed Window. Fasten both jambs at top and bottom with #8 wood screws through pre-drilled holes to penetrate minimum 3/4" solid lumber. Do not over-tighten screws.

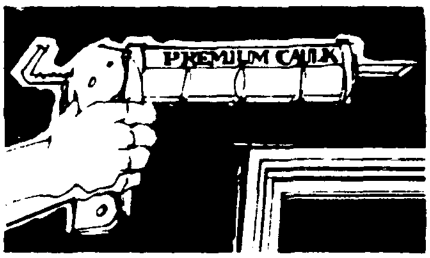
7. Remove center shipping strap. Adjust center alignment clips to provide straight jamb and install center instal-

lation screws.

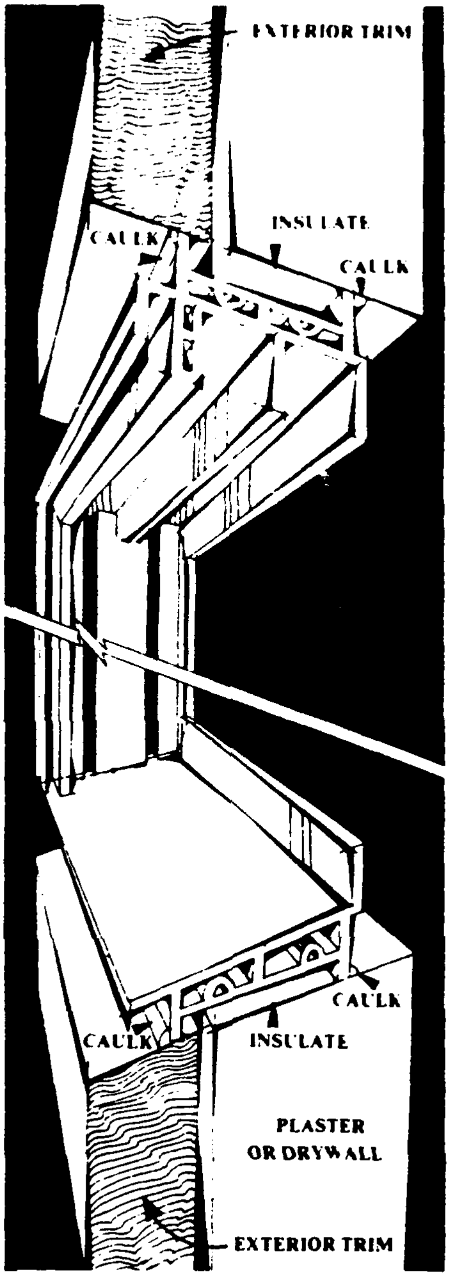


8. In windows over 52" high, adjust alignment clips located center of both sash to provide straight jambs.

9. Caulk between CertainTeed Window and old window frame material with non-hardening sealant compatible with vinyl in sufficient quantities to provide air tight seal




10. Complete necessary exterior trim and caulk to provide weathertight seal.




**INSTALLING WITHOUT HEAD EXPANDER STEPS 2-10**

11. If head expander is not used, trim interior sill lip of CertainTeed Window to fit opening and install as described steps 2 thru 10.

**Cleaning-up after installation.**

Customer satisfaction is IMPORTANT.

1. Make sure window operates properly:
a) Both sashes operate up and down. b) Both sashes tilt in. c) Lock works. d) Screen fits.

2. Clean both glass surfaces with glass cleaner and vinyl parts with soap and water.

3. Remove all debris from job.

4. Demonstrate proper window operation for homeowner.



CertainTeed

CertainTeed Corporation
Vinyl Building
Products Division
PO Box 860
Valley Forge, PA 19482

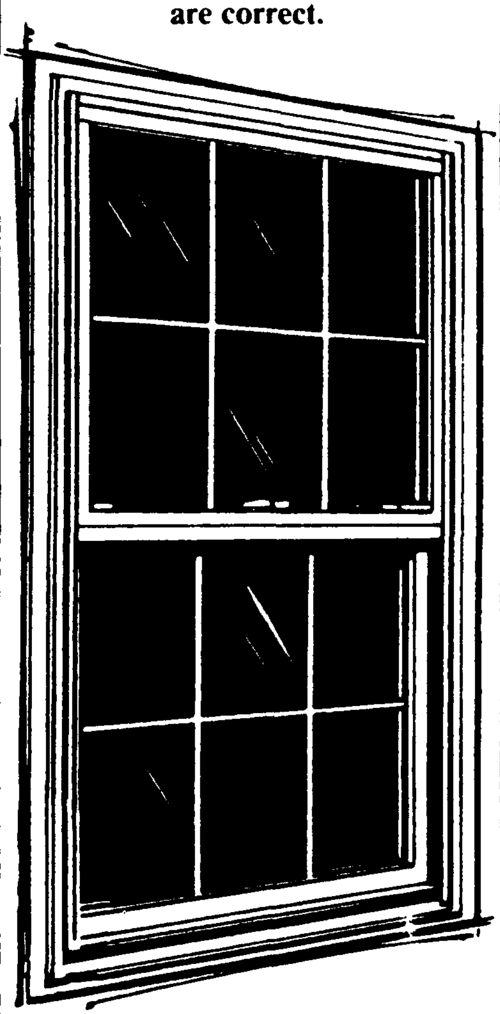


Pub. No. 20-50-282

# How to install CertainTeed Vinyl Double Hung Window into Wood frame opening.

Read instructions completely before work begins

**Caution:**
**Do not remove old wood sashes until dimensions of new replacement window and old window have been checked and are correct.**



**Prepare opening of old wood frame.**

1. Remove inside stops at top and both sides. To prevent damage use wide putty knife. If trim was painted, score with utility knife between stop and frame.

2. Cut sash cords or chains and remove lower sash to inside.

3. Remove center parting stop at top and both sides.

4. Lower top sash, cut cords or chains and remove sash to inside.

5. Remove pulleys, jab liners, weatherstripping, and fasteners from head, sill and jambs to provide clear surface for new window.

6. Replace rotten wood and clean opening with brush.

**Installing the new window.**

Double hung window can be installed with or without head expander, depending on how window was measured and ordered. See Form 20-50-284.

1. Caulk under head expander and fasten in place with screws or nails. Note: head expander may have to be trimmed so window will clear stool.

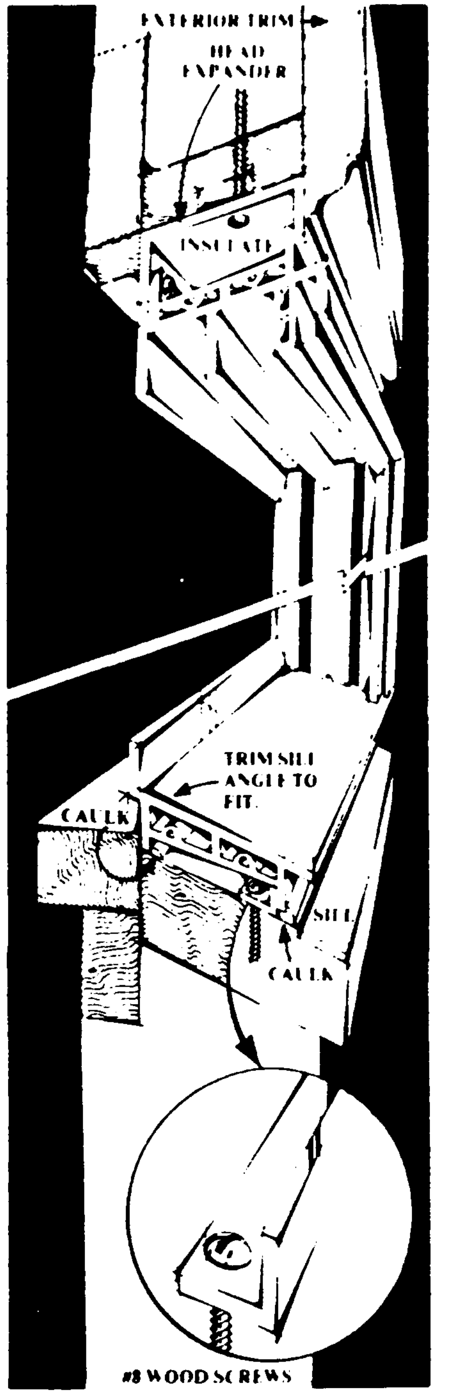
2. Trim sill angle along trim line to support and fit under CertainTeed Window and fasten to sill against blind stops with nails or screws.

3. Caulk jambs at exterior blind stops.

4. Install insulation on all four sides of CertainTeed Window.

5. Do not remove center shipping strap or shipping clips. Lift window into place and set down over sill angle.

6. Center and square the window in the opening by taking diagonal measurements. Make sure the sill is level. See Fig. #1.




**INSTALLING WITH HEAD EXPANDER STEPS 1-10**

7. Use ½" blocks of wood and shingle points to square and level window in the opening. Fasten both jambs at top and bottom with #8 wood screws through pre-drilled holes. Do not overtighten screws.

FIG. #1

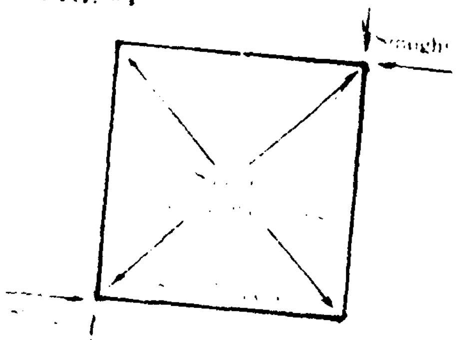
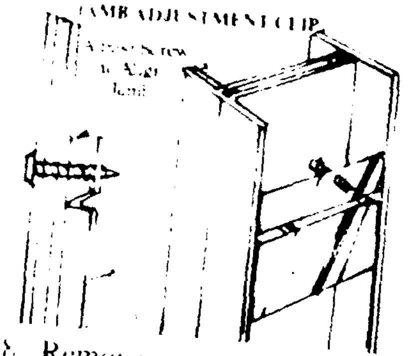
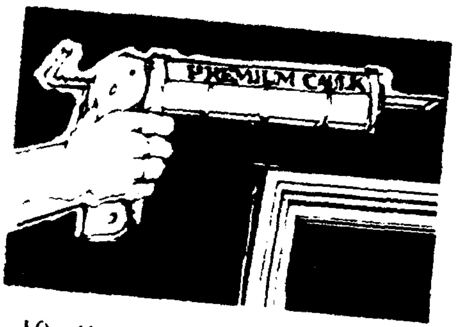



FIG. #2

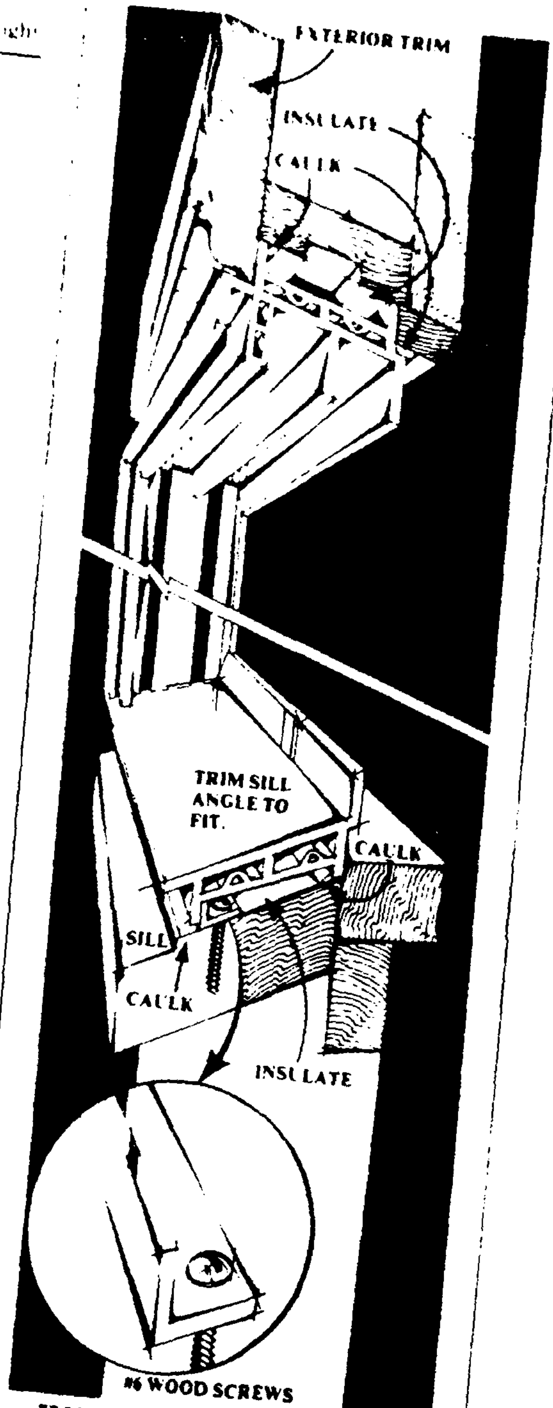



8. Remove center shipping strap or shipping clips (located on bottom rail top sash). Adjust center alignment clips to provide straight jamb (See Fig. #2) and install center installation screws. Make sure all installation screw heads are snug, flush with the jamb wall. This will provide proper clearance for the balance mechanism.

9. Replace inside stops. Stops can be sealed to the window with small bead of silicone caulk. This will provide a weathertight seal.




10. Caulk exterior between CertainTeed Window and frame with non-hardening sealant in sufficient quantity to provide weathertight seal.




**INSTALLING WITHOUT HEAD EXPANDER STEPS 2-10**

11. If head expander is not used, trim interior sill lip of CertainTeed Window, set in opening over sill angle, rotate in place and follow steps 2 thru 10.

## Cleaning-up after installation

Customer satisfaction is IMPORTANT.

1. Make sure CertainTeed Window operates properly, both sashes operate up and down, sashes tilt in, sashes lock, and screens fit.

2. Clean both glass surfaces with glass cleaner and vinyl parts with soap and water.

3. Remove all debris from job

4. Demonstrate proper window operation for homeowner.

CertainTeed

CertainTeed Corporation
Vinyl Building
Products Division
PO Box 860
Valley Forge, PA 19482



Pub. No. 20-80-281

# CHELSEA
## BUILDING PRODUCTS
565 CEDAR WAY • OAKMONT, PA 15139

## Prime Replacement Window
# INSTALLATION INSTRUCTIONS

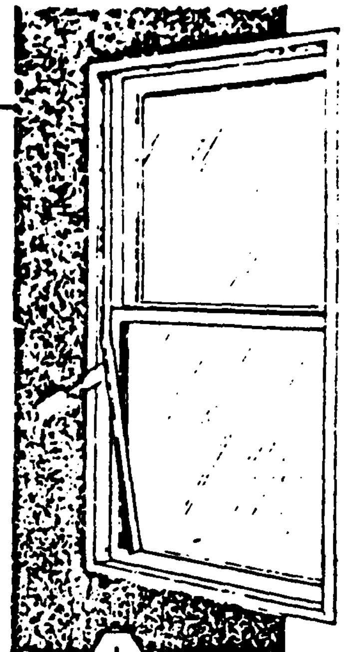
1.Prior to installation-recheck the overall height and width of the Retrofit unit and the overall height and width of opening to be sure they are compatible. If window (in some cases) is too large on the width or height, the fins may be trimmed accordingly to insure proper fit with a utility knife.

2.Various fabricators will have various cutting charts for their overall dimensions, but generally they will all fall into the area of 1/4" to 1/2" on the width and 1/2" to 1" on the height.

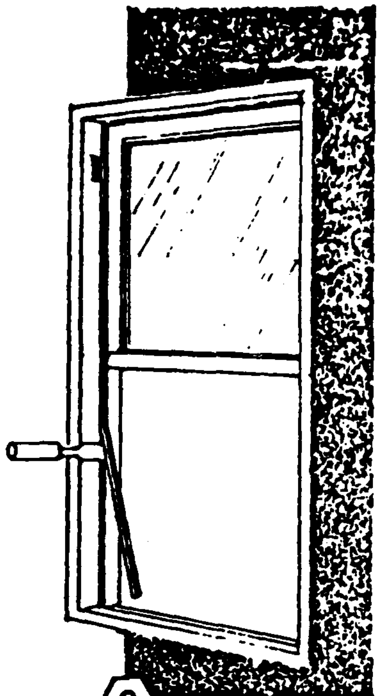
3.The first step for removal of the lower sash will be to remove interior trim. (See figure #1) If you wish to re-use existing interior trim, be sure to score with a utility knife where painted trim meets the actual jamb. This will minimize paint splintering and insure a neat finished interior appearance. Upon removing interior trim on both sides of jamb and header, the lower sash may be removed by cutting the balance ropes.

4.To remove the upper sash-remove the parting bead as illustrated in figure #2. This may be achieved with simple hand tools. (Hammer and wood chisel.) After removing the parting bead on the jambs and header, the top sash can now be removed by simply cutting the balance cords

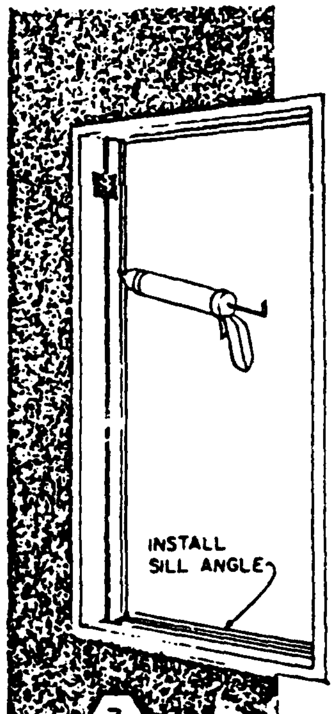
5.All pulleys and sash weights should be removed from the opening to prevent "hanging up" upon placement of new unit into the opening.



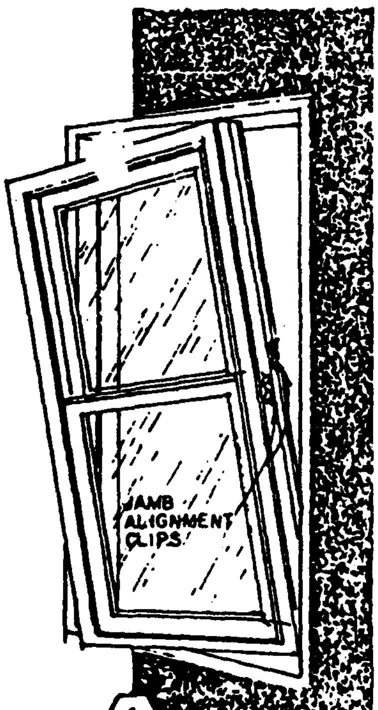
1



2




3




4

6. Leave the exterior stop (blind stop) intact. This will prevent the new unit from falling through the opening to the outside. (See fig.#3)

7. Place a fine bead of caulking around the exterior stop, with the exception of the bottom sill. (See fig.#3)

8. Place the sill angle (usually supplied with each unit) on the window sill inside the exterior stop allowing 1/8" clearance between the sill angle and the blind stop. This will allow the actual replacement window master frame to butt firmly against the exterior stop on the sides (jambs) and top (header). (See fig.#3)

9. Each unit is usually fitted with four (4) jamb alignment clips as shown in figure #4. The purpose of the jamb alignment clips is to keep the window centered in the opening and insure proper fit between master frame and sash frame.

10. The unit is now ready to be set by inserting the bottom into the opening allowing the outside of the sill member to fit into the 1/8" opening between the sill angle and the blind stop.

11. The next step is to slide the head expander into place and secure with either screws or pop rivets. This step will close the gap at the top of the replacement unit and the opening.

12. Secure the window to the opening with the screws provided at the prepunched installation jamb screw holes.

13. Avoid over tightening the installation screws, snugging is more than adequate. Most important at this point is to determine that the master frame corners are perfectly square to insure proper fit and ride of sashes.

14. Lock up the window and check for squareness - adjust as required.

15. You may elect to stuff openings between master frame and rough opening with insulation to insure draught free installation. Some manufacturers' perimeter band with poly foam to save this step.

16. Replace interior stop.

NOTE: Do <u>not</u> remove "belly band" around the center of the window until after the window is installed in the opening. Simply snip the band and slide it out.

PRIME REPLACEMENT WINDOW

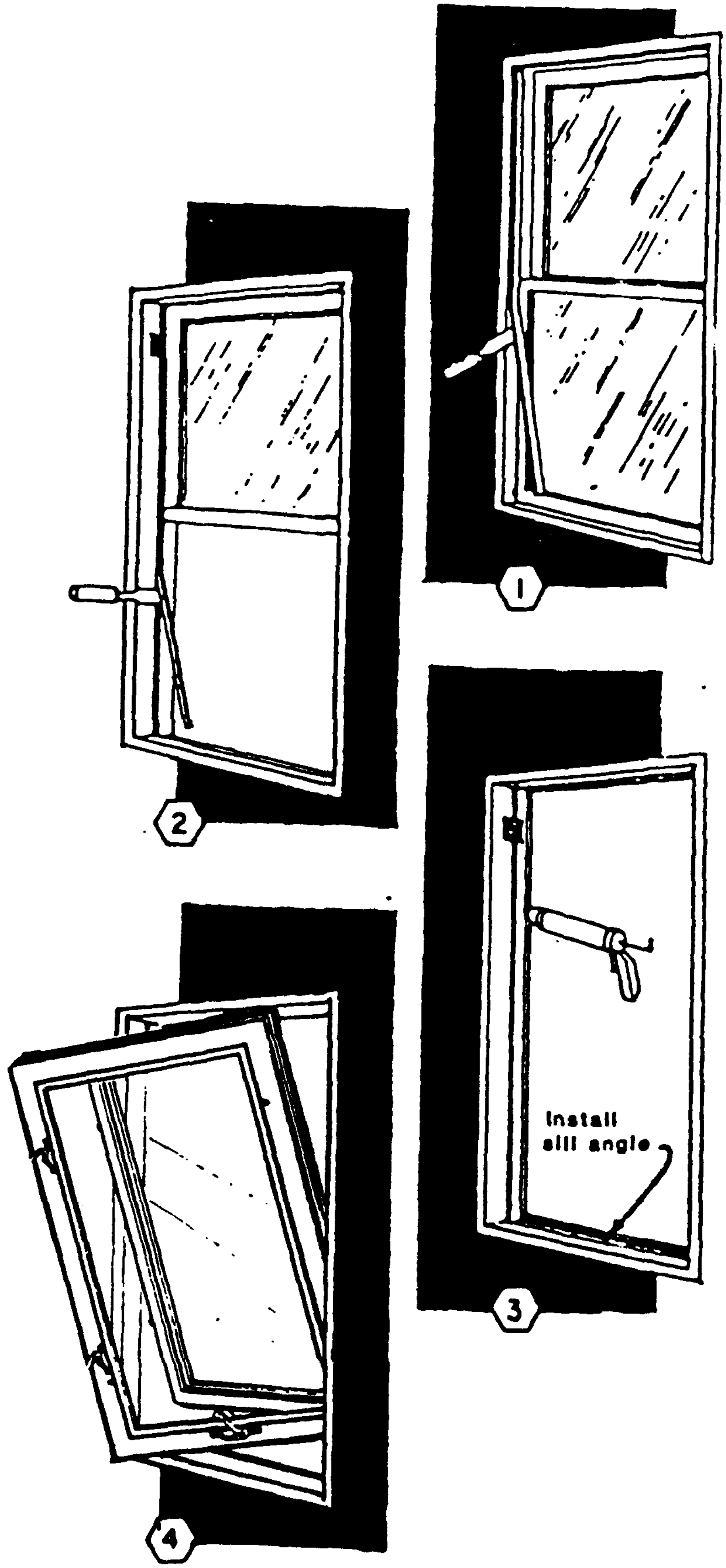
# INSTALLATION INSTRUCTIONS

1. Prior to installation-recheck the overall height and width of the Retrofit unit and the overall height and width of the opening to be sure they are compatible.

2. The first step for removal of the lower sash will be to remove interior trim. (See figure #1) If you wish to re-use existing interior trim, be sure to score with a utility knife where painted trim meets the actual jamb. This will minimize paint splintering and insure a neat finished interior appearance. Upon removing interior trim on both sides of jamb and header, the lower sash may be removed by cutting the balance ropes.

3. To remove the upper sash, remove the parting bead as illustrated in figure #2. This may be achieved with simple hand tools. (Hammer and wood chisel.) After removing the parting bead on the jambs and header, the top sash can now be removed by simply cutting the balance cords.

4. All pulleys and sash weights should be removed from the opening to prevent "hanging up" upon placement of new unit into the opening. We recommend filling this void with insulation.



5. Leave the exterior stop (blind stop) intact. This will prevent the new unit from falling through the opening to the outside. (see fig. #3)

6. Place a fine bead of caulking around the exterior stop, with the exception of the bottom sill. (See fig. #3)

7. Place the sill angle on the window sill inside the exterior stop allowing 1/16" clearance between the sill angle and the blind stop. This will allow the actual replacement window master frame to butt firmly against the exterior stop on the sides (jambs) and top (header). (See fig. #3)

8. The unit is now ready to be set by inserting the bottom into the opening allowing the outside of the sill member to fit into the 1/16" opening between the sill angle and the blind stop.

9. The next step is to slide the head expander (optional) into place and secure with either screws or pop rivets. This step will close the gap at the top of the replacement unit and the opening. We recommend this header to be used only if opening is out of square.

10. Secure the window to the opening with the screws provided at the prepunched installation jamb screw holes.

11. Avoid over tightening the installation screws, snugging is more than adequate. Most important at this point is to determine that the master frame corners are perfectly square to insure proper fit and ride of sashes.

12. Lock up the window and check for squareness - adjust as required.

13. You may elect to stuff opening between master frame and rough opening with insulation to insure draft free installation.

14. Replace interior stop.

---

## INSTALLATION

### INSTALLATION FROM OUTSIDE

1. Remove Blind Stop with recriprocating saw.
2. Remove Top Sash.
3. Remove Parting Stop and then Bottom Sash leaving inside trim in position.
4. Remove pullers in windows (if there) and seal.
5. Remove any old caulking or paint that might keep the unit from sealing good and place a fine bead of caulking around the inside trim.
6. Place sill angle.

Continue with same instructions as inside installation.

FOR A BETTER INSTALLATION. CAULK INSTALLATION AND JAMB ALIGNMENT HOLES.

## INSTALLATION IF CAPPING WINDOWS

Before installing sill, angle cap sill back to stool, caulk for a water-tight fit.

Install window as usual.

Cap jambs and header.

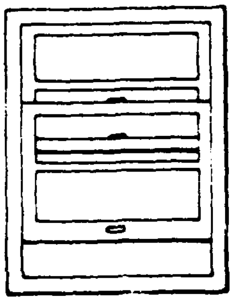
## INSTALLATION - METAL TEAROUT
(Buck Frame Recommended)

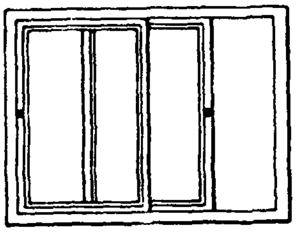
After removing metal window it is sommetimes better to build a new casing with 1 X 6 and install window as if wood tearout with new trim inside and outside.

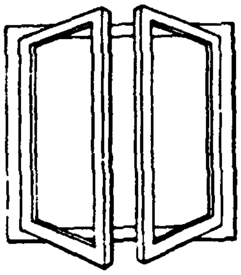
## USING HEAD EXPANDER

This is used when there is an out of square window opening. It is possible to expand as much as 1" with this use.

VINYL WINDOW
AND DOOR INSTITUTE
THE SOCIETY OF THE PLASTICS INDUSTRY, INC







# RECOMMENDED PROCEDURE FOR INSTALLATION OF VINYL WINDOWS

This procedure applies to the installation of vinyl-framed replacement windows, from pre- through post-installation procedures. Consistently followed, the procedure helps to ensure the installation of replacement windows, in a safe and effective manner. Actual conditions in existing buildings vary greatly, and in some cases substantial additional care and precaution may have to be taken.

Improper installation of units may reduce their thermal effectiveness, lead to excessive air and water leakage, condensation, and may promote the deterioration of wall constructions, windows, and their finishes.

## PRE-INSTALLATION PROCEDURES

1. Measure the opening and the new window to insure proper fit before you begin removal.
2. Check for signs of decay, air leakage or water leakage that the replacement window alone will not solve. Do not install a replacement window without correcting these problems.
3. Use a drop cloth and collect all debris.

## METAL WINDOW REMOVAL

The objective in removing a metal window and preparing the opening is to create a jamb with a stop that will serve the same purpose as a blind stop on a wooden window. Exterior capping and head flashing are necessary to making a proper installation.

### ALUMINUM REMOVAL

Aluminum Fin Windows are generally nailed to the studs in frame construction with siding run over the fin on the outside, and a dry wall return from the interior wall to the window frame.

For removal, first remove the inserts. Then pry up the aluminum sill in the middle, and cut the frame with a hack saw, using care not to damage the interior of the opening. Break each half of the sill away from the corners, and pry out the jamb heights starting from the bottom, cutting nails where practical. Then remove the header.

### STEEL REMOVAL

Steel casements are generally found in homes of masonry construction, and consist of the casement frame itself, plus an interior steel pan. Removal of the pan can create major complications, such as damage to interior walls.

The casement frame is usually screwed or bolted into a steel flange, which is nailed to the rough-in framing. To remove the casement, first remove the screws or bolts (whose heads may be embedded in putty). Then pry the frame to the center of the opening to give the clearance necessary to remove it. You may have to break glass and/or cut part of the frame in this process. You may also have to chisel off the heads of bolts or screws.

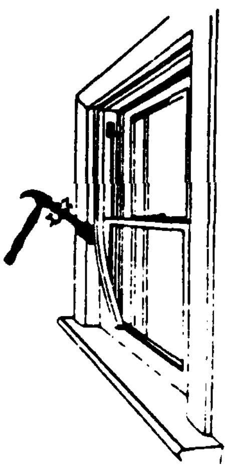
# OPENING PREPARATION AFTER METAL REMOVAL

Whether the window removed was steel or aluminum frame the opening to match, as closely as is reasonable, a flush jamb at least 4" in depth with a stop such as you will find in a standard wood opening. The framing lumber may provide only part of the jamb, with a steel pan or dry wall providing the rest, as long as the jamb is flush from the inside to the stop. Move the stop as far to the outside of the opening as possible, to allow a reasonable amount of exposed inside sill.

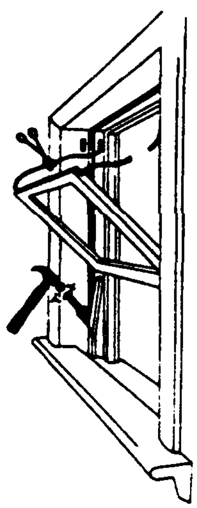
Caulk and cover with trim coil the exposed exterior framing, and flash the head.

Follow the instructions for a standard installation in a wood opening.

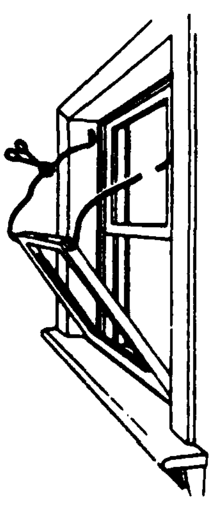
# WOOD REMOVAL



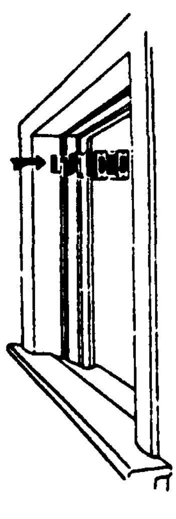
1. Remove sash bead. Score first with a razor knife and use special care in removal if the existing sash bead is to be reinstalled.



3. Remove parting bead, cut cords, and remove upper sash.



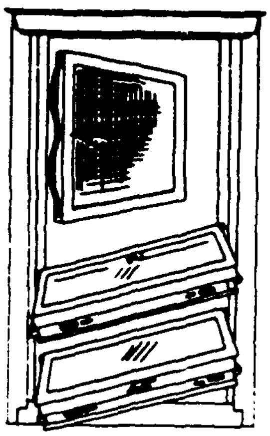
2. Cut cords and remove lower sash.



4. Remove or pound in pulley on both sides of opening.

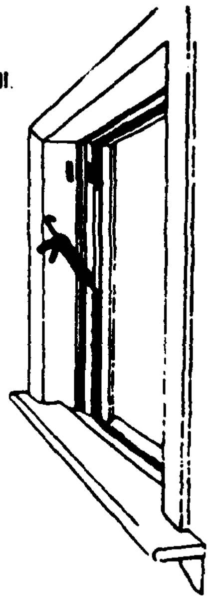
# INSTALLATION PROCEDURES

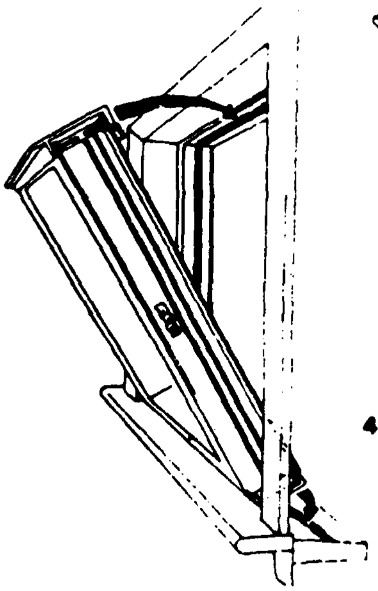
1. Remove both sash and screen from the master frame. You may install small windows with sash in place, but do not allow the master frame to spread far enough for the sash to come loose from the balance shoes.



2. Mount the head expander, if used, and sill angle, both cut to the same width as the master frame. Insert the short side of the sill angle into the slot, unless the longer side is needed to raise the window in the opening, or compensate for a steeply-sloped sill. If necessary, check the fit of the master frame in the opening.

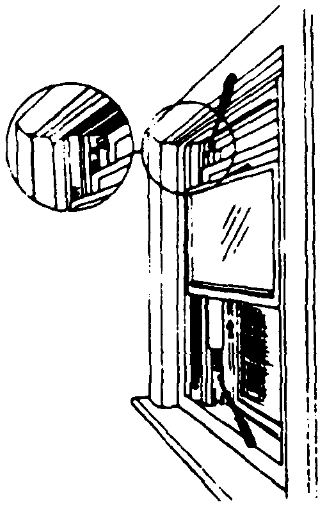
3. Clean the opening of dirt and debris, then caulk the stops and sill.





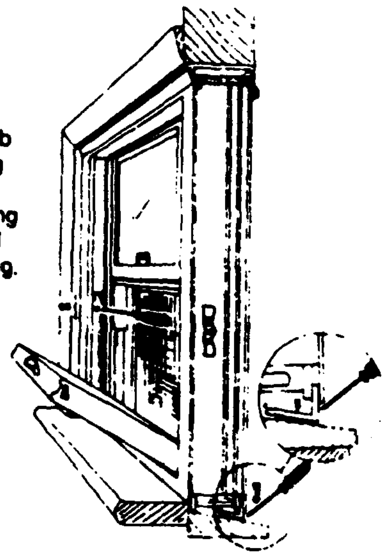
4. Insert the window frame into the opening and compress it tightly against the caulked stops and sill.

5. Use a level and square to make sure the frame is level, square, and plumb, regardless of the squareness of the opening.



6. Run until just snug all four installation screws, first the top two, then the bottom two, centering the frame from side to side and checking to be sure the frame remains square. Temporarily shimming each corner as you run the screws helps to keep the frame centered and square.

7. Turn the center alignment clip screws in the center of each side of the jamb height until each jamb height is straight and the opening at the center of the main frame measures the same as the opening at the top or bottom. Force the sill angle down firmly into the caulking.

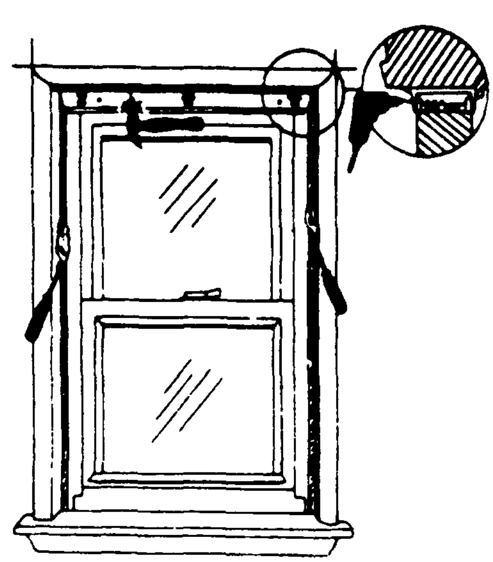


*continued*

8. Install the screen and both sashes. Check for proper operation, locking, and fit, and make adjustments as necessary.

9. Raise the head expander and first nail the flange into the header jamb. Then pop rivet the head expander to the master frame. Stuff fiberglass insulation into the cavities between the master frame and the opening, and caulk the window to the opening.

10. Reinstall the sash bead or mount new sash bead.



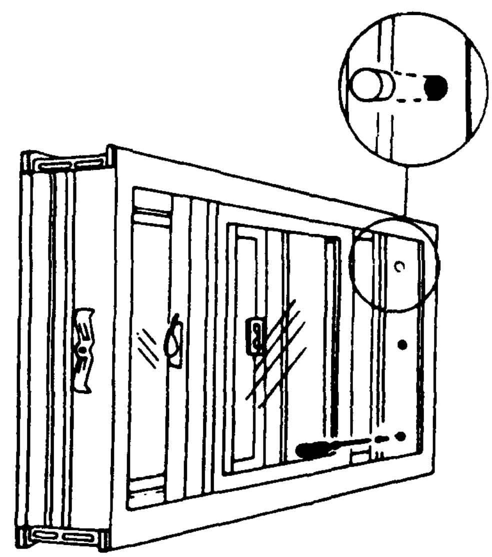
## SLIDING WINDOWS: SPECIAL INSTRUCTIONS

a) One sash is fixed in place, and the other can be removed by pushing it into the header and lifting it out.

b) Make sure that the sill is level and firmly supported—use shims if necessary.

c) Secure the header with F channel or by running screws through the header into the jamb. Measure the height of the main frame while securing the header to insure that it neither sags down nor bows up.

d) Place the cover buttons supplied in the installation screw packs into the installation holes.



VINYL WINDOW AND DOOR INSTITUTE

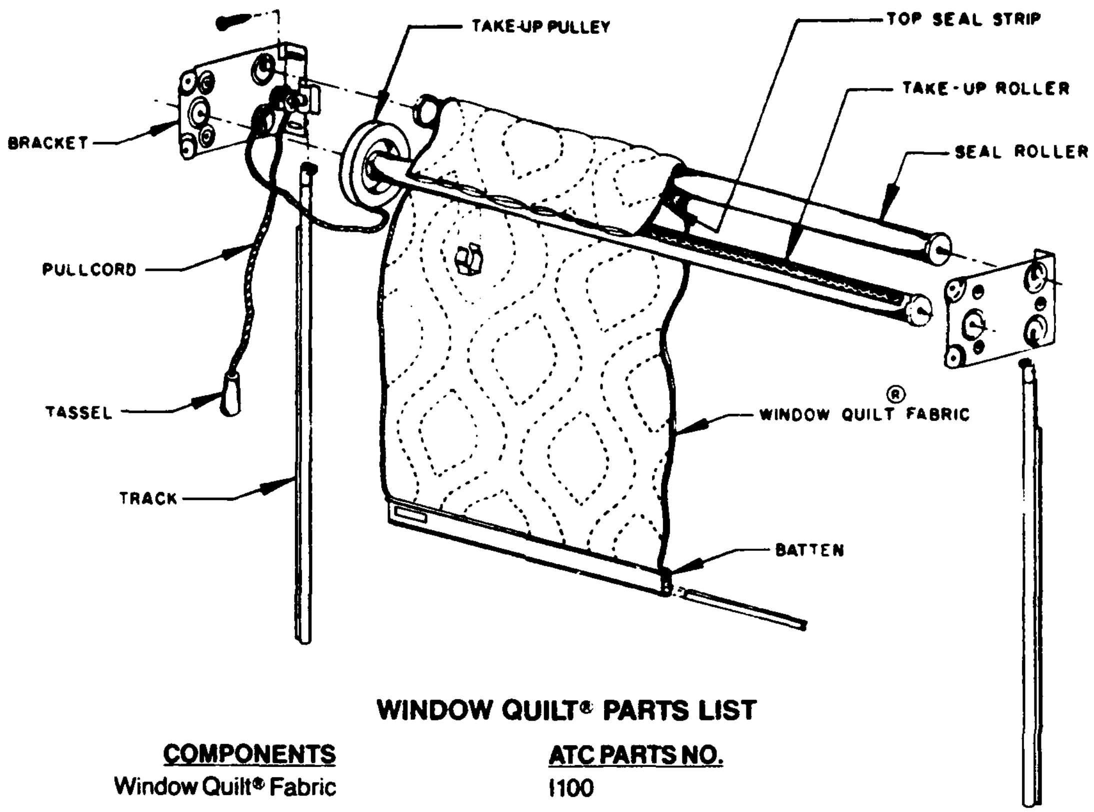
For more information, write or call:
Vinyl Window and Door Institute
A division of
The Society of the Plastics Industry, Inc.
355 Lexington Avenue
New York, NY 10017
212/503-0600

# APPENDIX G

## Sample Manufacturer Installation Instructions for Window Covering Units

# INSTALLATION INSTRUCTIONS

# Window Quilt®




**WINDOW QUILT® PARTS LIST**

| COMPONENTS | ATC PARTS NO. |
|---|---|
| Window Quilt® Fabric | I100 |
| Batten | KW013 |
| Top Seal Strip | CWA29 |
| Take-Up Pulley | CWA24—White, CWA35—Bronze, |
| Take-Up Roller | KW017—White, KW014—Bronze, KW016—OS White, KW015—OS Bronze |
| Seal Roller | KW012 |
| Brackets, 1 pair | KW003 |
| Hardware Kit, 1 | KW001—White, KW002—Bronze, |
| Tassel<br>Lubricant<br>Jam Roller<br>Clevis Pin<br>Hair Pin Clip<br>Screws (4) | |
| Tracks, 1 pair w/guides | KW008—White, KW009—Bronze |
| Pullcord | CWA61—White, CWA67—Bronze |

Your **Window Quilt®** insulating shades have been cut to meet your specifications. Their installation is not difficult but does require care. Please take the time to read and understand all instructions prior to starting the installation.

APPROPRIATE TECHNOLOGY CORPORATION • TECHNOLOGY DRIVE • BRATTLEBORO, VT 05301
802-257-4500

# Installation Procedure

1. **Preparation**
Check all components received against those on the parts list and diagram. If you have any questions, contact your dealer.

Washing of the mounting surface is highly recommended. (Make sure that the surface is dry and clear of detergent residue prior to track application.)

If your mounting surface is unfinished, very porous or has an oil stain, it is imperative that it be sealed — shellac works well in this instance.

Certain basic tools will be required in the installation. They include the following:

| | | | |
|---|---|---|---|
| Tape Measure | Pencil | Hacksaw | Drill with ⅛" bit |
| Philipshead Screwdriver | Scissors | Silicone spray | Level |

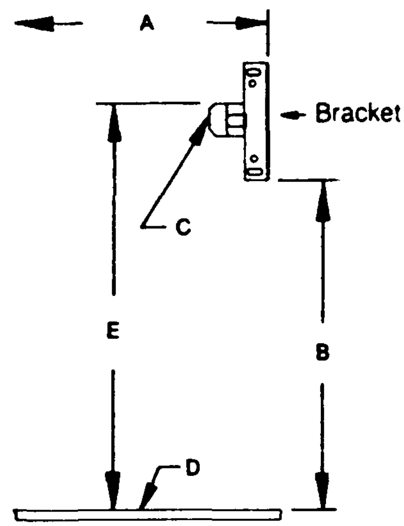
The screws provided are 1" long and self-tapping. (For installations on surfaces other than wood or metal, hollow wall fasteners are suggested.)

2. **Measurements**
The ordered width and height measurements of the Window Quilt are indicated on the yellow cutting ticket. Transfer these measurements into the following simple formulas to determine the *bracket location.*

a. Outside bracket width = Window Quilt width + ⅞" (See A)
b. Height from bottom of bracket to sill = Window Quilt height (See B)

3. **Bracket Position**
a. Using the sum from Step 2a., center the brackets on the window opening.
b. Use the dimension in Step 2b. to determine the height of the bracket.

With the bracket position laid out on the mounting surface, check the levelness of the brackets and make any necessary adjustments. On the mounting surface, mark the final location of the outside of the bracket as well as the oval hole locations.

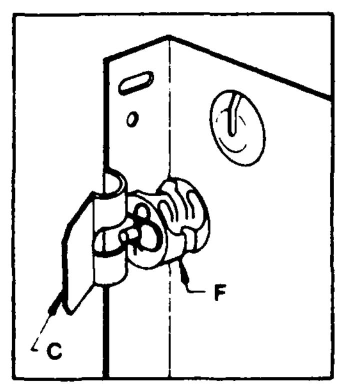



4. **Mounting Brackets**
At the center of the oval holes (Step 3), drill starter screw holes using the ⅛" bit. Fasten the brackets to the mounting surface aligning the outside and bottom edges with marks determined in Step 3. With brackets in place, determine pull side desired (right or left) and install the jam roller into the bracket. The jam roller is correctly installed when a **W** appears when viewed from room side. The pin holding the jam roller should be lubricated with silicone spray. (See F) If High Light Valances are to be used, install their mounting screws in the brackets at this time. See valance instructions for proper placement.

| Key Description | Step |
|---|---|
| A — Outside Bracket Dimension | (2a) |
| B — Bracket Height | (2b) |
| C — Batten Stop | (5) |
| D — Sill | (5) |
| E — Measurement for Track | (5) |
| F — Jam Roller Assembly | (4) |

5. **Track Measurements**
The track length to be cut is that distance from the top of the batten stop of the bracket to the sill plus ⅛". The track is measured from the top of the track guide. Cut track off with the hacksaw, or PVC track cutter.

TRACK LENGTH = SILL TO TOP OF BATTEN STOP + ⅛"



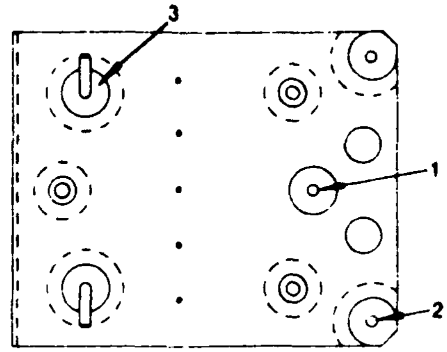

6. **Shade and Roller Assembly**
The Window Quilt is pre-attached to the take-up roller with pull as ordered. If you desire a change, complete the following steps.

Hold the take-up roller with the fabric rolling away from you. Unroll Quilt until attachment clips are visible. Remove clips, turn roller end for end and reattach the fabric. Reroll fabric.

With Window Quilt rolled properly, attach pull cord to the take-up pulley. Insert one end of the pull cord through the hole in the pulley and knot it on the inside.

**7. Roller Installation**

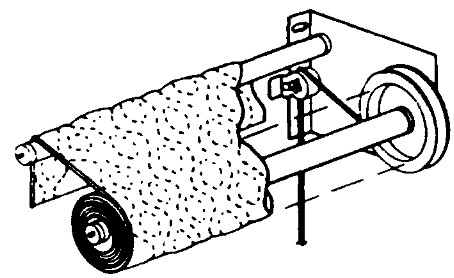
To install your take-up roller, wind pull cord around take-up pulley 2 times opposite in direction to Quilt and insert the free end of pull cord over, then down and behind the jam roller. Pull through all slack.




Insert ends of the take-up roller into their proper location in the brackets. (Middle holes for heights to 84" (position 1), outer (lower) holes for heights over 84" (position 2)). Using the pull cord, lower the Quilt about 12 inches. To lock, pull cord to the center of the window, engaging jam roller.

The seal roller is placed into the upper slotted holes of the brackets with the Quilt falling between it and the wall (position 3). Install the seal roller from underneath and behind the take-up roller. Insert the end at pull side first.

With the seal roller in place, check to make sure that the brackets are still in the proper position. Move the seal roller side-to-side. You should have ⅛" of play.

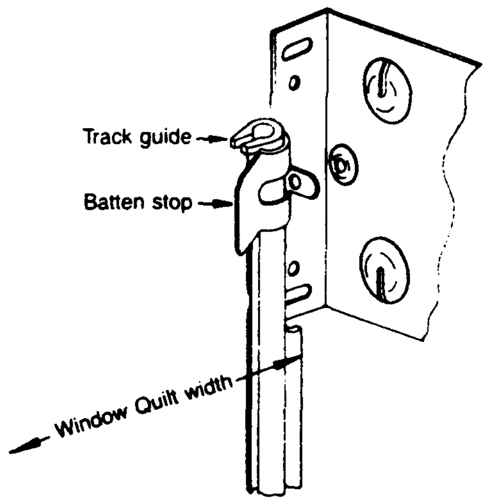


With the rollers in place, and the Quilt behind the batten stops of the bracket, lower and raise the Quilt with the pull cord to insure rollers move freely.

**8. Track Installation**

To install the tracks, you must first mark their position on the window frame, under the brackets. The outside dimension of these tracks equals Window Quilt width ordered.

Next lower the Window Quilt 12 inches and slide the left track on the corded edge until the track guide butts up to the batten stop of the bracket. With your fingers or blunt tool, open the batten stop and slide the track guide under, so that the plastic peg on the back of the track guide snaps into the upper of the two small holes in the stop. The function of the batten stop is to prevent the Quilt from being raised too high, lifting it out of its track guide. The stop should be bent away from the track guide just enough for it to catch the batten lip when the Quilt is raised. **NOTE:** Do not bend batten stop too far inward as it could pinch the track guide and prevent proper Quilt tracking.




Repeat these steps with the right hand track. *DO NOT* adhere tracks at this point. You should operate the shade to insure free movement prior to track adhesion.

**9. Track Attachment**

The tracks are attached to the mounting surface with a foam adhesive tape. Starting at the bottom of the left hand track, peel off the plastic backing from the foam adhesive. Align the outside edge of this track with the location determined at the beginning of Step 8. Lightly adhere the track to the mounting surface in a few places; do not apply pressure, which bonds the tracks instantly.

Repeat these steps with the right hand track.

**10. Cord & Tassel**

With the Window Quilt down, insert the pull cord through the tassel and tie off at the height desired. Cut off the excess cord.

**11. Lubrication**

Using grease capsules provided, lubricate end pins of rollers. Using silicone spray, lubricate tracks and track guides to facilitate easier Quilt movement.

**12. Top Seal**

With Window Quilt down, use pencil to draw a light line under the seal roller on the Quilt. Raise the Quilt until this line appears above the seal roller. Peel the backing off the foam seal strip and apply to Quilt above the line. Trim excess and operate Quilt to make sure placement is correct.

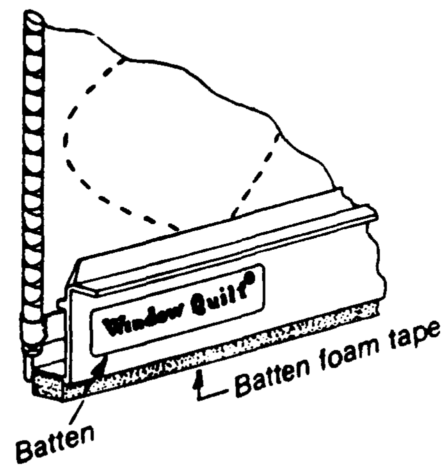
**13. Operation**

Try raising your Window Quilt a few times. When you are satisfied that the Quilt will drop of its own weight, permanently adhere your tracks with firm pressure. To insure a long trouble-free life, the attachment must be supplemented with panel nails every 18". If your shade does not operate smoothly, continue with the following checks prior to setting tracks.

a. Check the brackets to be sure they did not move when you tightened them. You should have ⅛" of lateral play in the seal roller.

b. Check the width measurement of the tracks. Spacing which is either too wide or too narrow will hinder operation. If you have not applied pressure to adhere the tracks permanently, you can probably remove them by gently and slowly pulling them out from the bottom. If this does not work, try to remove tracks by sliding a thin metal blade behind them as you pull gently forward.

c. The Quilt should be centered on the take-up roller, and clipped to it. If it is not centered properly the side cords may rub against the track guides. To reposition, remove the clips and then reclip the fabric to the roller.




d. The bottom batten should be centered on the Quilt with approximately ¼" clearance to the corded edge on each side. If the batten is off center, pry the batten open with a screwdriver (starting at one end), reposition it correctly, and squeeze it together again with pliers which have been lined with 6-8 layers of tape to prevent scratching.

**NOTE:** The batten foam tape, located at the bottom of the batten, provides the seal at the window sill or floor. ATC has left this tape uncut at its edges. For a finished look, trim the batten foam tape with a pair of scissors flush with the batten extrusion.

e. The window trim itself may be causing the problem. If it is not flat and level it may inhibit quilt movement.

If the trim is not flat where you mounted the brackets, the brackets may be squeezing the rollers so tightly that they cannot turn freely. If so, bend the brackets out slightly with hand pressure. If the window top trim bows slightly, it may bind the fabric where the seal roller holds it against the wall. It may be possible, if the bow is slight, to plane the center of the trim to increase clearance. If this can't be done, remove the brackets and place small wood shims or steel washers behind them as spacers. To do this, you will have to pull the top six inches of the track gently away from the wall so that the track guides align with the new bracket position. Caulk the gap behind the tracks to seal against drafts.

**14. Install Valance**

Refer to valance instructions.

**15. Warranty Card**

Please fill out the warranty card and return it to ATC. This card also insures your notification of future product developments and special discounts.

*If you have any questions about the installation, please contact your authorized dealer or* ***Appropriate Technology Corporation.*** *We stand by to help in any way we can, and we also welcome your suggestions and comments.*

ENJOY THE USE OF YOUR WINDOW QUILT

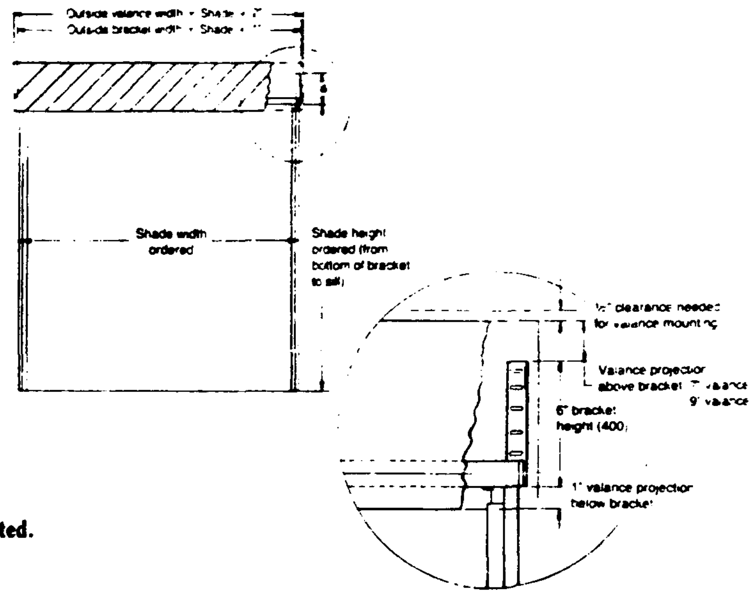
# Measuring Instructions

# Window Quilt® and Window Showcase®

Window Quilt® and Window Showcase® insulating shades are cut in whole inch increments to meet your individual requirements. The following instructions will guide you through the measuring process to determine the shade size best suited to your needs. Please follow these directions. Should you need any assistance, do not hesitate to contact your authorized dealer.

## It's as easy as 1, 2, 3!

## 1. Choose Your Model




We recommend the 400 series for most applications.

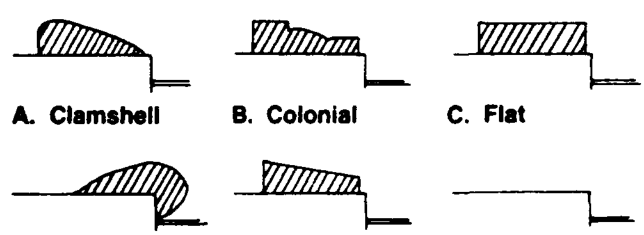
Order
- **410** if the Window Showcase® cover is not desired at this time.
- **420** if you plan to add a Window Showcase® cover.
- **430** if you plan to send Window Showcase® cover material to ATC for fabrication.*

*See COM service and custom front cover guide for instructions on fabric purchase.

Use the 100 series (no front cover option) if there is insufficient stack height available for 400 series application.

**All shades will be shipped with a right hand pull unless otherwise requested.**

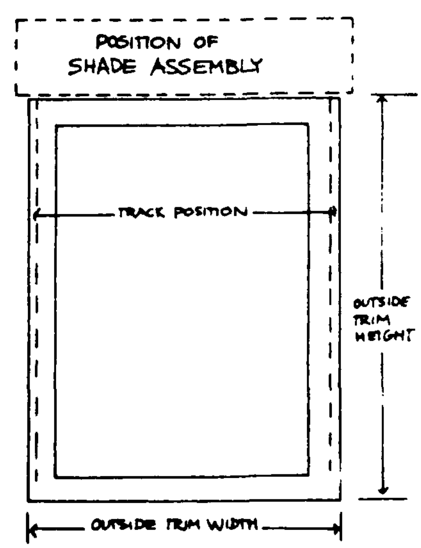
## 2. Choose Your Trim




**Which window trim most closely represents yours?**

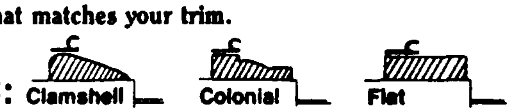
Window Quilt® and Window Showcase® are designed for outside surface installation. The tracks must be applied to flat surfaces. If your window trim is not flat, see instructions for trim choices D and E.

## 3. Take Measurements (Use a metal tapemeasure only!)




**Use the instruction that matches your trim.**

### For A, B or C:




**Shade Width:**

Measure outside trim width and round *down* to nearest inch.

**Shade Height:**

Measure outside trim height and round *to* nearest inch.

- **The shade assembly is installed above trim on a board — for convenience order premount option.**
- **The tracks are installed along outside edge of trim.**
- **The window sill must project a minimum of ¾". Add if needed. For convenience, order ATC Easy Frame™ sill stock from your dealer.**

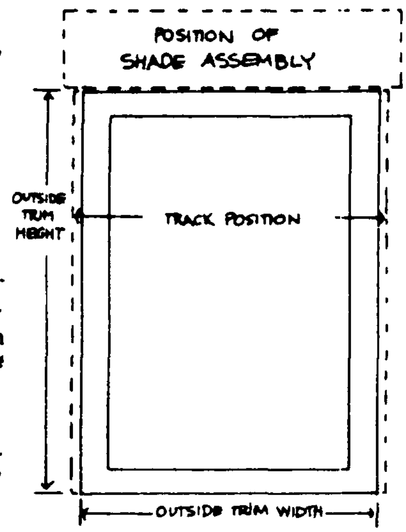
## For D and E: 



**Shade Width:**
Take outside trim width, add 2" and round *to* nearest inch.

**Shade Height:**
Take outside trim height and round *to* nearest inch.

- The shade assembly is installed above trim on board — for convenience order premount option.
- The tracks are installed off trim on wood strips. Use ATC part # KWO 67/69/76 for convenience.
- The window sill must project a minimum of ¾". Add if needed. For convenience, order ATC Easy Frame Track Mounting Strip.





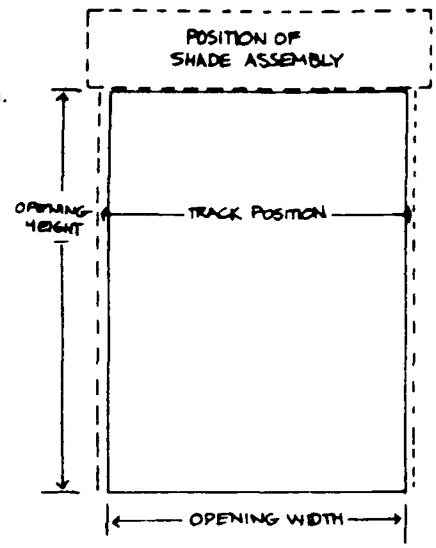
## For F: 



**Shade Width:**
Take the opening width, add 2" and round *up* to nearest inch.

**Shade Height:**
Take the opening height and round *to* nearest inch.

- The shade assembly is installed on wall above opening (do not order premount).
- The tracks are installed along sides of opening on wall.
- The window sill must project a minimum of ¾". Add if needed. For convenience, order ATC Easy Frame Track Mounting Strip.



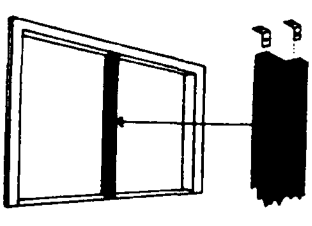


# Special Situations

### Other Window Coverings:
Draperies, curtains and top treatments may be easily installed with your Window Quilt®. Your authorized dealer can give you details on these applications.

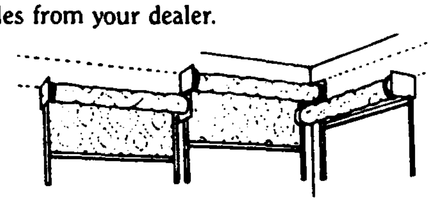
### Not Enough Clearance Space Above Trim?
Your Window Quilt® or Window Showcase® brackets may be lowered to partially or fully install on the top trim. You may also order your 100 series shade one inch narrower on trim style A, B or C and install the entire shade assembly on the trim.

### Wide Windows:
Windows wider than 105" (some sliding glass doors), may require the abutting of shade units. In this case a 2¼" mullion will be needed to mount tracks. When High Light™ valances are used we require a minimum mullion width of 3⅛". Ask your authorized dealer for details.



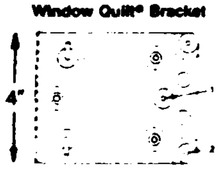
### Protruding Crank Handles and Door Knobs:
It may be necessary to "build out" the Window Quilt® or Window Showcase® to accommodate any obstructions. Thin tapered wood strips (shims) under track and bracket may suffice. Sometimes the handles of a casement window can be turned out of the way or replaced with one of our low-profile T-handles. Specify the window manufacturer if ordering the T-handles from your dealer.

### Corner Windows:
Depending on the height of the window, at least 8" of space from corner on each side of Window Quilt® and 5" of space from corner on each side of Window Showcase® will be needed for adjacent WQ/WS installations (add an additional inch if High Light™ valances are to be ordered). If this space is not available, units may be staggered. The first WQ/WS shade bracket can be positioned 1" from the corner and the overlapping shade 1" from the corner and at least 6" higher for Window Quilt® and at least 7" higher for Window Showcase®. A cornice or drapes will finish the installation.



# Technical Information

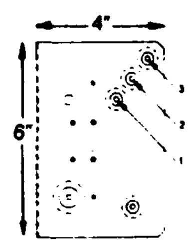
Window Quilt® Bracket



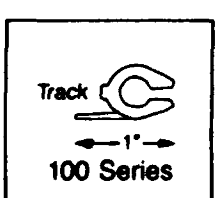


| Term: | Measurement: | Order Width: |
|---|---|---|
| Round up | If your measurement includes a fraction, | go to the next whole inch. |
| Round down | If your measurement includes a fraction, | drop the fraction. |
| Round to | If your measurement is ½" or greater, | go to the next whole inch. |
| Round to | If your measurement is less than ½", | drop the fraction. |

Window Showcase® Bracket







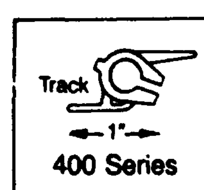


### 100 Series Clearances

| Bracket position | Window height up to | Bracket to ceiling clearance | Projection into room |
|---|---|---|---|
| 1 | 48" | ½" | 6¼" |
| 1 | 72" | 1½" | 6¾" |
| 1 | 84" | 1¾" | 7" |
| 2 | 120" | 1" | 8¼" |
| 2 | 144" | 1" | 8½" |

### 400 Series Clearances

| Bracket position | Window height up to | Bracket to ceiling clearance | Projection into room |
|---|---|---|---|
| 1 | 52" | 1" | 5¼" |
| 2 | 72" | 1½" | 5¾" |
| 2 | 84" | 1¾" | 6" |
| 3 | 108" | 2¾" | 6¾" |
| 3 | 144" | 3¼" | 7¼" |





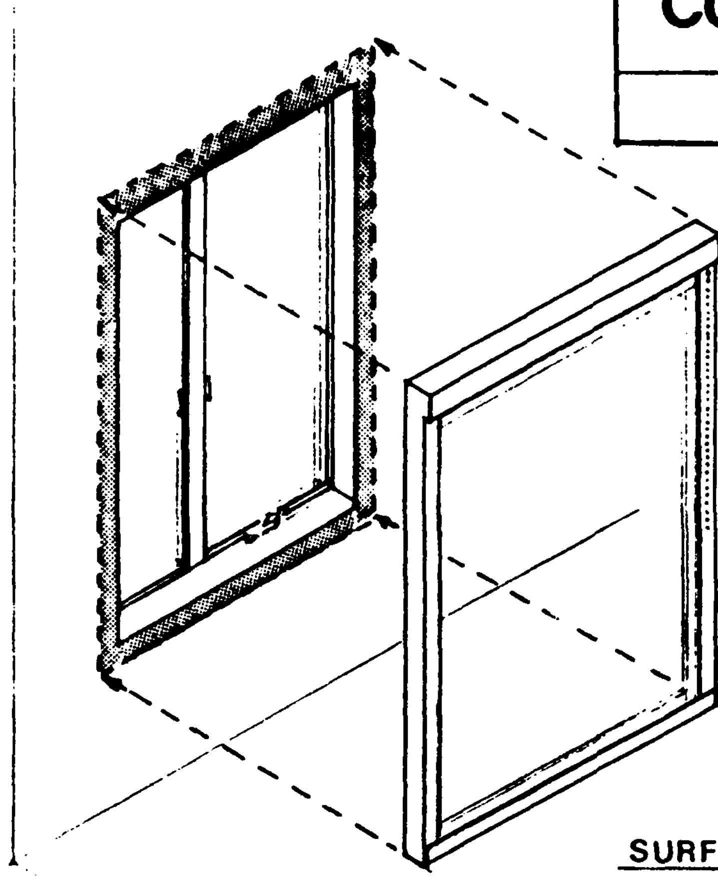
**Appropriate Technology Corporation ▪ Technology Drive ▪ Brattleboro, Vermont 05301**



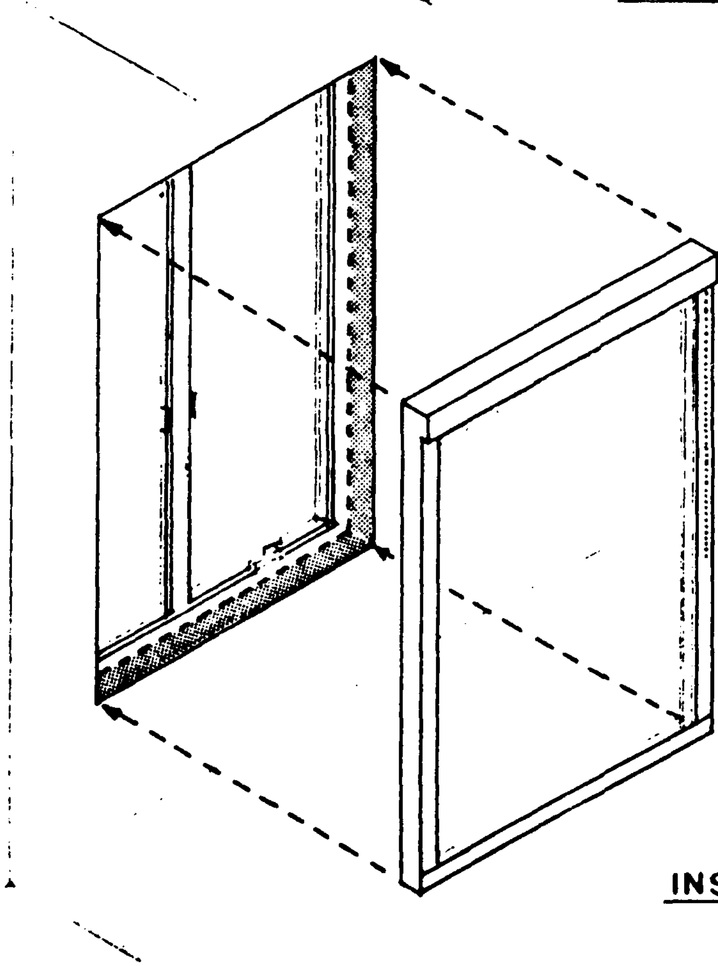
LW162 - 6/22/87

# COMFORT SHADE

INSTALLATION OPTIONS



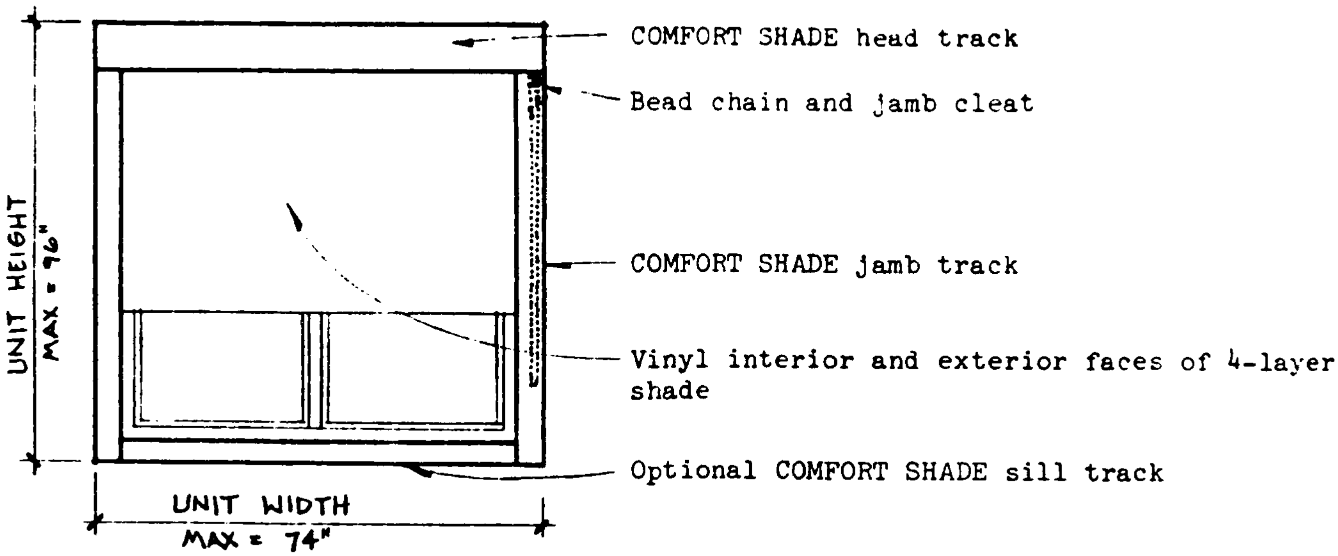
SURFACE MOUNTED INSTALLATION



INSET MOUNTED INSTALLATION

# COMFORT SHADE

TYPICAL INSTALLATIONS | 1




## ELEVATION

Shade shown partially drawn

## NOTES

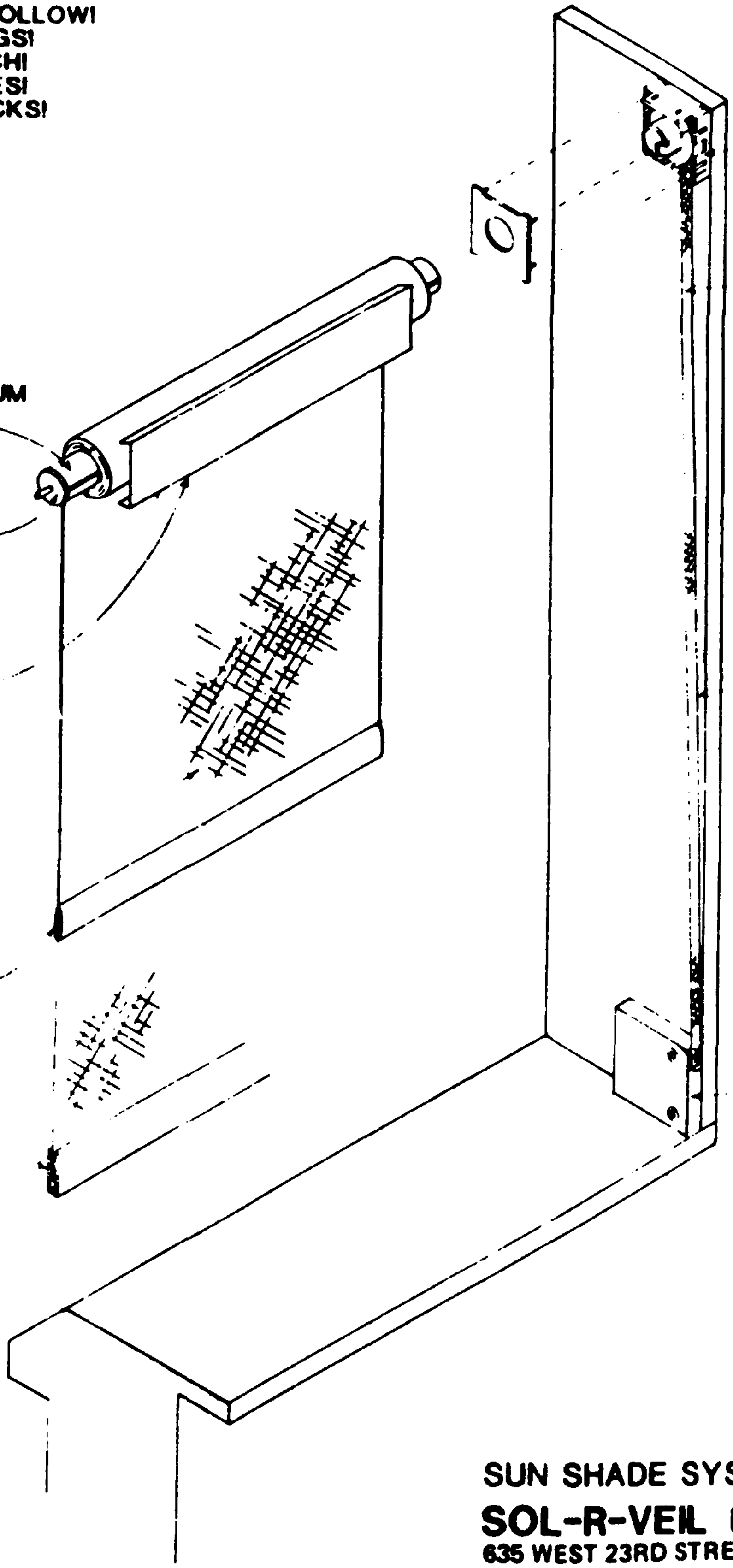
1. Bead chain operator may be placed on the right or the left hand side.
2. Length of bead chain loop is adjustable to suit job conditions.
3. Frames can be pre-fabricated to shop drawings or cut to length in the field.
4. Design solutions are endless, and we encourage you to develop your own.
5. Dirt Road Company reserves the right to change specifications without notice.


**DIRT ROAD**
**rural delivery 1, box 122**
**waitsfield, vermont 05673**

# SURE SHADE®

PATENT PENDING "It Surely 'Works'"

NOTES: TUBE IS HOLLOW!
NO SPRINGS!
NO CLUTCH!
NO BRAKES!
NO GIMMICKS!



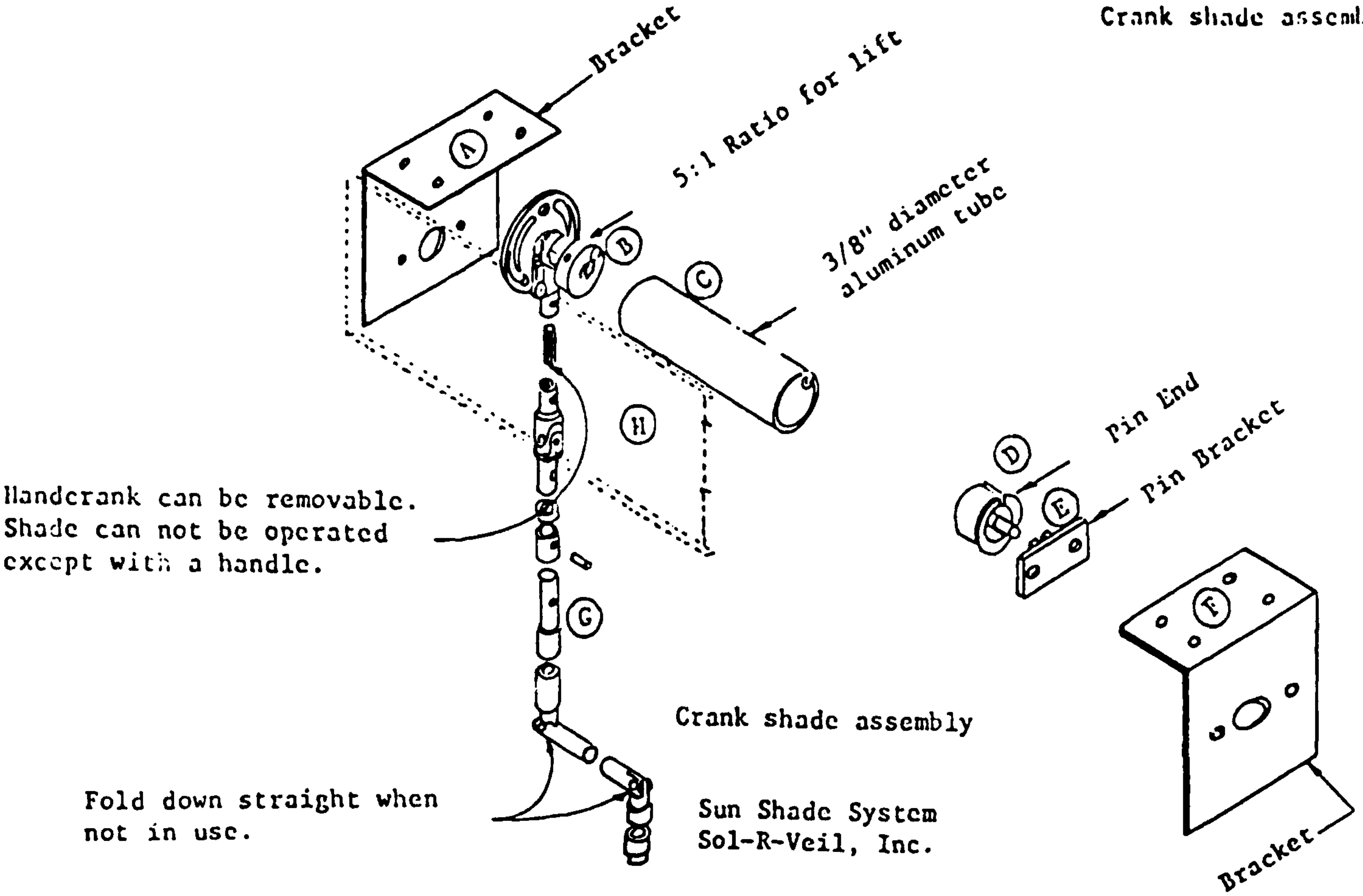

*CAN BE INSTALLED BELOW SILL.

*FABRIC AVAILABLE IN 14 COLORS.

SUN SHADE SYSTEMS

**SOL-R-VEIL INC.**

635 WEST 23RD STREET, NEW YORK, N.Y. 10011




Parts that are preassemble in the factory are as follows.

A and B

C and D

E and F

C As one unit.

Points to consider before placing an order.

1. Left or right side crandk handle.
2. Wall, ceiling or flush mount.
3. Fascia or valance box.
4. Removable or sationary crank.
5. Fabric type and color.
6. Multiple bands can also be on one system.

Installation Instruction

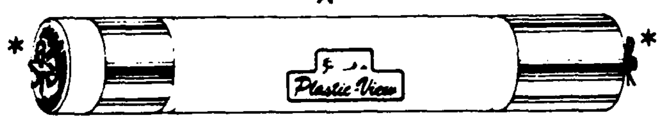
1. Mount A and F at the head of the window horizontally and it must be level.
2. Take tube with fabric and slip C into B at an angle.
3. Take D up and drop it into E
4. Release fabric and let hang.
5. Snap facia onto A and F if required.

# INSTALLATION INSTRUCTIONS

## SPRING OPERATED ROLLERS

1. Do not remove wrapping until step #4.
2. Mount brackets in the desired location.
3. Place the shade into the brackets. Minor adjustments for tip widths include (A) slightly pulling out end pin (done only on wood spring rollers), (B) using washers to build out brackets, (C) see drawing "H".
4. Remove wrapping and adjust spring tension by (A) pulling the shade down halfway, then lifting the shade out of the bracket and rolling it up manually, (B) flipping the bottom K-bar over the roller or, (C) manually turning spring motor end pin.
5. After installation and spring tension adjustments have been completed, place safety cotter keys* through end pins whenever possible, as shown in Illustration A.
6. Review operational and upkeep instructions.

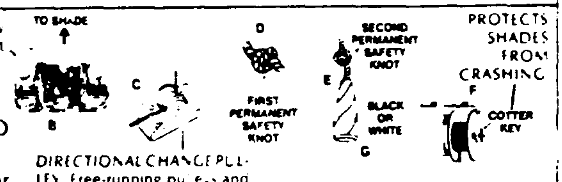
A




PLASTIC-VIEW metal spring rollers are a... specially designed for silent efficiency and safety. Pre-drilled end pins accept our own safety cotter keys* that lock the roller into the brackets.

## CORD & REEL OPERATED ROLLERS

Never consider Lock Pulley 100% efficient. Safety slip knot to be used after cord is "Locked".




DIRECTIONAL CHANGE PULLEY. Free-running pulleys and cleats also may be ordered for excessive cord and directional changes.

This 2" x 3" bracket does 80% of all work. (See adjustments below.)

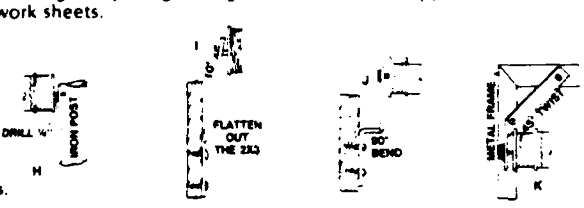
1. Do not remove wrapping until step #6.
2. Mount brackets in the desired location.
3. Place the shade into the brackets, prying the brackets slightly if necessary. DO NOT PRY ON THE REEL.
4. Secure the lock pulley (B) in the desired position, usually about eye or shoulder height. Make certain that the lock pulley is aligned so that the cord is guided straight into the reel, either directly or through directional guide (C).
5. Release the cord to full length, then place the first permanent knot (D) in the cord approximately 2" to 3" above the lock pulley. (This permanent safety knot will prevent the K-bar from being pulled over the top of the roller and will also put the stress and tension on the lock pulley rather than on the brackets & cord attachment to roller.)
6. With cord in the locked position, remove the shade wrapping.
7. Use the cord to lower the shade to within approximately 1" of the floor or desired length, then place a second permanent knot in the cord immediately below the lock pulley. (This knot will prevent the shade from crashing onto the floor or pulling the material off of the roller.)
8. When the shade is rolled up, leave the bottom K-bar approximately 6" lower than the roller.
9. After these steps have been completed, place the safety cotter keys through the pre-drilled holes in the end pins. This will lock the roller into the brackets, eliminating potential accidents.
10. Cut the cord to the desired length and place tassel (G) on the end.
11. Review operational and upkeep instructions.

NOTE: Test, rolling the shade up and down. If shade "veers" to left side of the roller, place 2" to 4" of tape around roller on the right end or vice versa.

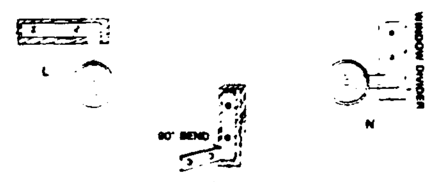
## SLIGHT ADJUSTMENTS FOR DIFFICULT INSTALLATIONS

Diagrammed below are bracket variations that handle virtually every type installation. These are accomplished by bending or adjusting the regular stock brackets supplied with order, as designated on order work sheets.

Occasionally it is recommended to simply drill a hole into a post, beam, etc., and use that hole as a bracket. (Keep this in mind whenever any shade is ordered up to ¼" too wide.) **Do not do this in airport cabs.**




The above diagrams show positions that the 2x3 regular brackets may be adjusted 80% of these shades will use the 2" x 3" regular bracket without any adjustments necessary.




The above diagram shows the flat bracket which is mostly used in metal installations. It may be mounted horizontally or vertically, and/or bent to any desire angle. (Bending should be done prior to mounting—slight adjustments may be made after mounting.)

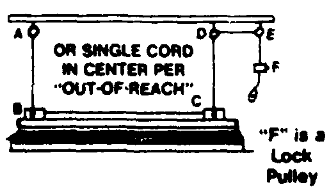
## BOTTOM-UP ROLLERS (Also for Skylights)

NOTE: This type of shade is not recommended. Dust, insects, water, etc. may fall into the shade roll. However, the job can be done.

1. Secure cord at eye-screw (A) then run the cord through directional pulleys B & C. Continue through eye-screws D & E, finally through lock pulley F.
2. The roller will be "single notch", so final installation procedure is to place roller in bracket to permanently release the only "dog" or "latch", which will result in constant tension.

If the roller is placed into the brackets upside down, there will be a "double locking" action. To correct this, simply remove the roller from the brackets and turn it 180°.

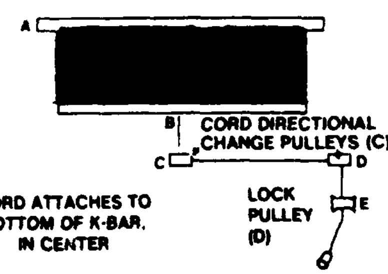
On small shades (4' wide and less), the shade may be operated by one cord attached to the center of the K-bar, then routed through directional change pulleys. For "veering" see note in "cord-&-reel" section.




## OUT-OF-REACH ROLLERS

1. Follow normal spring roller instructions, but also follow #2 of the "BOTTOM-UP" instructions regarding "constant tension" and "veering".

NOTE: This was the procedure utilized in the FAA spec. WE-13...




PLASTIC-VIEW supplies #8 self-tapping "pan head" HEX metal screws (¾") long, which are also excellent in wood installations. Drills for metal installations range from 7/64" to 9/64" depending on the type and gauge of metal. Small spring roller operated shades, lock pulleys and directional change pulleys receive #6 screws. Some installations, such as concrete, brick, wall board may require toggle bolts, lead inserts, rawl plugs, etc. and ¼" drills (not supplied by PLASTIC-VIEW).

# MEASURING INSTRUCTIONS

Please use factory order forms to expedite your order and avoid ambiguous data.

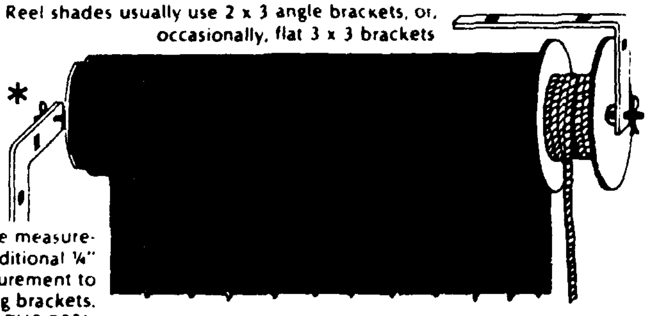
**ALL SHADES ARE CUSTOM-MADE TO EXACT SPECIFICATIONS. THINK "TIP" MEASURE.**

Determine:
1. TYPE OF ROLLER (A) spring operated (wood or metal), or (B) cord and reel gravity operated, etc.
2. IF USING CORD AND REEL ROLLER which side of roller should the reel be on and does the material come off roller TOWARDS OR AWAY from the glass. (If not stated on order sheet, reel will be on the right side and material will roll toward the glass.)
3. SELECT BRACKET LOCATIONS AND TYPE OF BRACKET TO BE USED (outside, inside, ceiling, etc.).
4. What extra hardware is needed. Factory always includes plated #8 self tapping one inch metal screws.
5. STATE FOR EACH SHADE IF COMMERCIAL OR RESIDENTIAL to insure proper label. (If left unspecified, residential label will be used . . . this minimizes free dealer advertising.)

OBTAIN CUSTOMER APPROVAL FOR EXACT POSITIONING WHERE BRACKETS WILL INSTALL—FILL OUT ORDER FORMS COMPLETELY—DO NOT MAKE THE FACTORY GUESS . . . THIS CAUSES UNNECESSARY DELAYS.

## CORD & REEL GRAVITY OPERATED SHADES

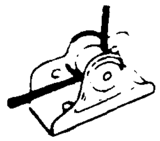
Cord & Reel shades usually use 2 x 3 angle brackets, or, occasionally, flat 3 x 3 brackets




The cloth measurement on cord & reel shades is approximately 2½" less than tip measure.

On cord & reel inside measurements, deduct an additional ¼" off of the "TIP" measurement to allow prying brackets. DO NOT PRY THE REEL.

Cord may be routed through direction guides to increase operational convenience.

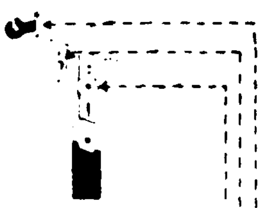


*PLASTIC-VIEW cotter keys prevent shades from crashing out of the brackets or if one bracket of installation fails.

Cord & Reel rollers are recommended for:
1. Very large shades
2. Shades that are difficult to reach (such as very high or behind a couch, etc.)
3. On shades designed to reach the floor, floor to ceiling

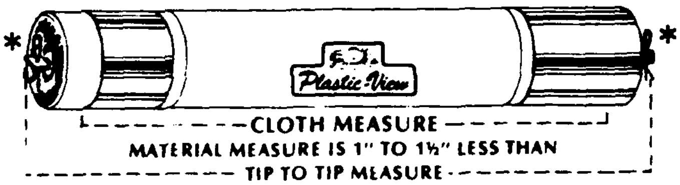
## SPRING OPERATED ROLLERS

**WHERE TO MEASURE BASIC TYPES OF BRACKETS FOR SPRING OPERATED ROLLERS**



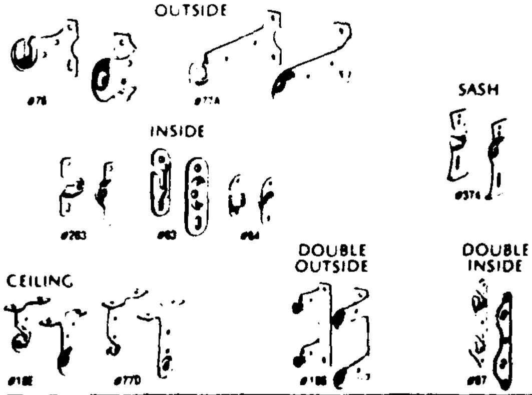
SASH RUN BRACKET
INSIDE BRACKET
OUTSIDE BRACKET

CEILING OR UPSIDE DOWN BRACKET




Roller diameter will be supplied as indicated in the Color Code of price charts, unless specified otherwise.
Utilize cotter keys in end pins whenever possible.

## STANDARD PLASTIC-VIEW BRACKETS




| BRACKET NUMBER | BRACKET POSITION | ROLLER TYPE | DEALER PRICE (per pair) |
|---|---|---|---|
| 76/18 | Outside | 1" to 1¼" wood or metal | .15 |
| 77A | Outside | 1½" to 1¾" metal | .41 |
| 263 (63) | Inside | 1" to 1¼" wood or metal | .15 |
| 64 | Inside | 1½" to 1¾" metal | .32 |
| 18E | Ceiling | 1" to 1¼" wood or metal | .22 |
| 77D | Ceiling | 1½" to 1¾" metal | .98 |
| 374 | Inside (sash) | 1" to 1¼" | .39 |
| 186 | Double Outside | 1" to 1¼" wood or metal | 1.48 |
| 87 | Double Inside | 1" to 1¼" wood or metal | 1.48 |

OTHER AVAILABLE: Outside—#276, #276A, #77 Ceiling—#77C, #205
SPECIAL BRACKETS Footless—#62F, #76F Reverse—#76R, #63R Bottom-Up #376

BRACKETS INCLUDED WITH EACH PLASTIC-VIEW CUSTOM MADE SHADE
BRACKETS NOT INCLUDED ON SUNFILTER "READY-MADE" SHADES

## MINIMUM "TIP" WIDTHS FOR SHADES WITH SPRING ROLLERS (before cutting into spring)

| | | | | | |
|---|---|---|---|---|---|
| 1" wood | 14" | 1¼" wood | 17" | 1½" metal | 26" |
| 1⅛" wood | 15" | 1¼" metal | 26" | 1¾" metal | 30" |

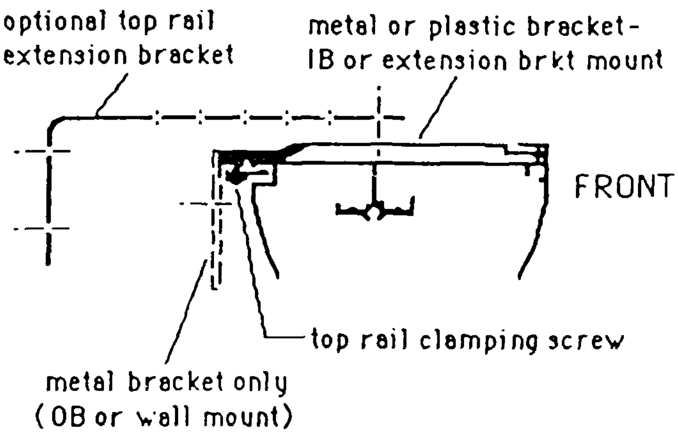
# DUETTE VERTIGLIDE™
# INSTALLATION INSTRUCTIONS

1. Clear a work space in front of the opening that is to be covered by the new Duette Vertiglide™ shade. This area should be at least as large as the shade outside dimensions, and must be clean to avoid the possibility of soiling the shade. Use a drop cloth if needed.

2. Carefully unwrap the shade and check the hardware against the order for completeness. All shades will include handles (1 for Left Stack [LS] or Right Stack [RS]; 2 for Center Stack [CS] or Center Opening [CO]), with color-matched screws. All IB mount and CO include a Steel Pull Strip and Magnetic Strip for each opening, to be installed on the shade at the customer's option. End caps are used for OB mount only. A Center Pull Plate is used on CO only. Stationary rails will have one bottom bracket (optional: and one wall mount bracket) each. Top Rail Mounting Brackets (optional: and extension brackets) are used at 72" maximum separation. A valance (optional) will include matching flat fabric, returns, and brackets for attachment to the top rail.

3 Check the mounting area to be sure there are no obstructions that would interfere with the moving vertical rail(s). If top rail extension brackets were included, these will be used to clear any projecting door handles, window cranks, etc. Attach these to the mounting brackets first, using the screws and speed nuts provided.

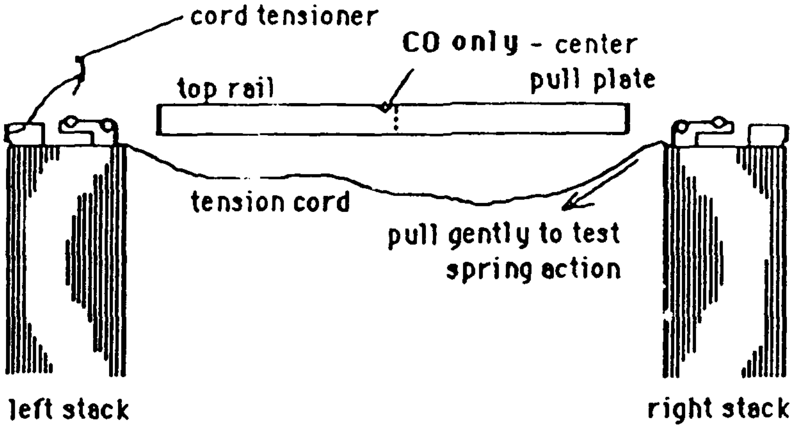
4. Install the top rail mounting brackets, screwing directly into the wooden header or studs if possible. Fasten two brackets within 8" from the ends of the top rail. Additional brackets are equally spaced at 72" maximum separation.



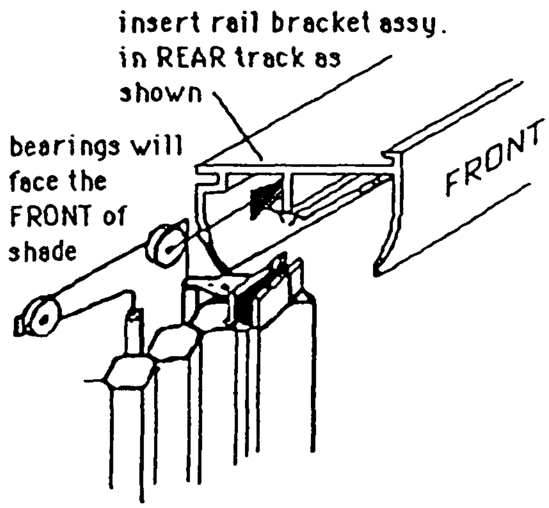

NOTE: If the top rail is in two pieces (W>16 ft.), the middle bracket must be located at the split in the rails to align the rails accurately.

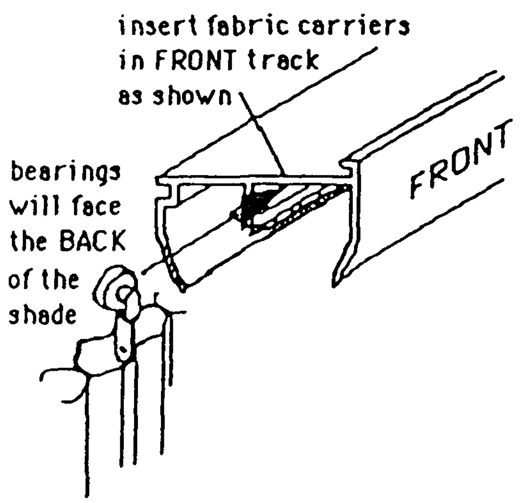
5. Lay the top rail in front of the opening, with the front of the rail facing up. Place the vertical rails at the end of the top rail in the shade configuration- left side for left stack, etc. The top of the vertical rail (the end with cords) must be next to the top rail, with the tension cord moving freely through the shade.

<u>NOTE:</u> CO shown. Other types similarly assembled with only one stack present.



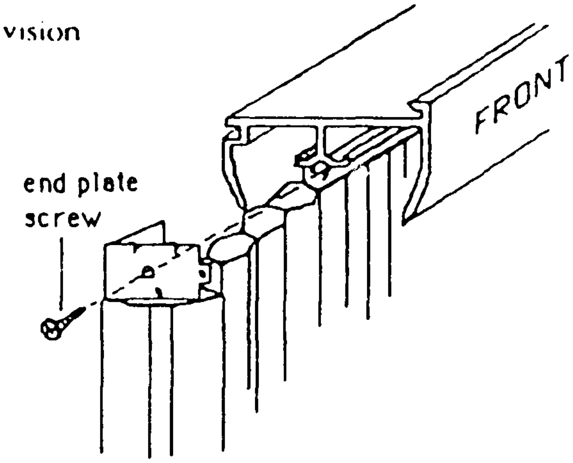

6. With all rails flat on the floor, insert the moving rail into the top rail. Make sure the bearings locate properly in the <u>rear track</u> (on the bottom in this orientation). The rails must remain relatively square with each other during this procedure. Keep the cord clear of the bracket.

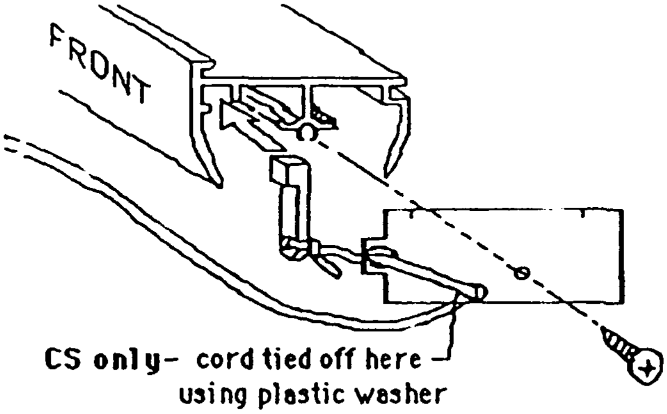



7 Insert the fabric carrier bearings into the top rail, making sure they go in the <u>front track</u> (on top in this orientation). Keep the cord from getting tangled in the carriers.

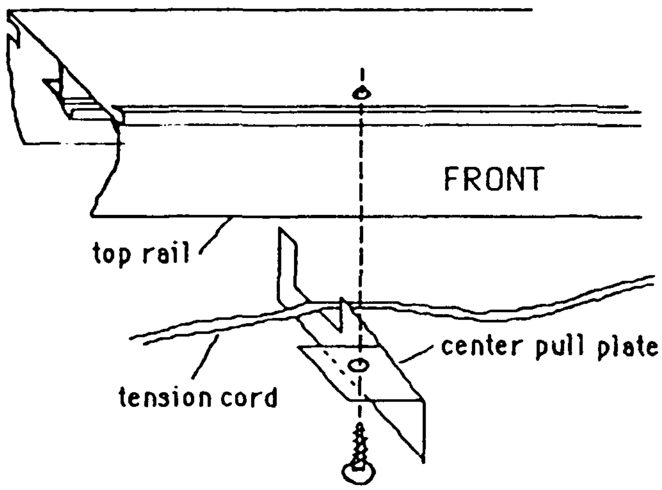
8. Place the stationary rail bracket in place and secure with an end plate screw to retain the fabric assembly.



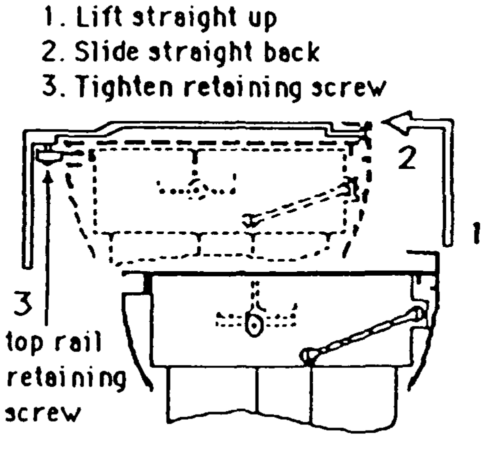




9. At the opposite end of the top rail, thread the cord tensioner into the top rail from 6-12", then attach the other end plate as shown.

*NOTE:* *For Center* Opening shades, attach center pull plate with cord captured between the plate and top rail.




10. Carefully lift the assembled shade into place and install by lifting <u>straight</u> up under the bracket and sliding <u>straight</u> back to engage the front lip and the retainer in the back. Center the top rail in the opening (IB Mount), or check the overlaps for outside mounts.

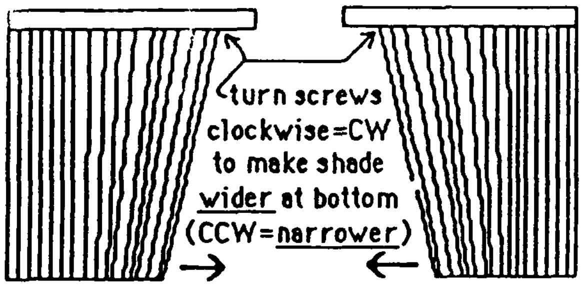



11. Tighten the retaining screws to lock the top rail in place.

12. Adjust the stationary rails by moving the bottom end of the rail into alignment and fastening to the floor (or wall, if the optional wall mount brackets are used). Note the stationary rail bottom brackets may be reversed in the rail to face the back or front as needed.

13. Check operation of the shade, moving the rails from side to side through the extremes of the operating range. The rail should be easily repositioned, and should just hold its position when moved. Adjust tension in the cord by holding the tensioner between two fingers and sliding to the left or right as needed. Increase tension if the rail doesn't hold its position, and decrease if it moves too stiffly.

14. Adjust the angle of the moving rail by turning the exposed adjusting screw to bring the rail(s) into alignment with the vertical, the jamb, or each other (center opening). Do not unscrew more than 8 or 9 turns from the end of travel. To adjust the rail to make the shade wider at the bottom, turn the screw clockwise (as if tightening the screw). To make the shade narrower at the bottom, turn the screw counterclockwise (as if loosening the screw).




<u>NOTE:</u> When adjusting the shade narrower at the bottom (loosening the screw), keep pressure against the screw head to force it in against the bracket for the best results. <u>Do not exceed 9 turns</u> from the full clockwise stop when loosening the screw.

15. Install end caps (outside mount only), handles, magnetic strip and steel pull strip (if included and if customer so requests), and valance (if present). Be sure to clean the area following completion of the installation, and suggest other applications for additional Duette® shades.

Duette® by HunterDouglas

# DISTRIBUTION LIST

AF 1004 SSG/DE, Onizuka AFB, CA; 18 CESS/DEEEM, Kadena, JA; 314 CES/DEEE (Kinder), Little Rock AFB, AR; 438 ABG/DEE (Wilson) McGuire AFB, NJ; 6550 ABG/DER, Patrick AFB, FL; 92d CES/DCME, Fairchild AFB, WA; AFIT/DET (Hudson), Wright-Patterson AFB, OH; AFIT/DET, Wright-Patterson AFB, OH; AFSC/DEEE, Andrews AFB, DC; CES/DEMC (Neal), Sheppard AFB, TX; LEEEU, Bolling AFB, DC; WR-ALS/QL (McCabe), Robins AFB, GA

AF HQ ESD/AVMS, Hanscom AFB, MA; ESD/DEE, Hanscom AFB, MA

AFB 314 CSG/DEEE, Little Rock AFB, AR; 42 CES/DEMU (Drechsel), Loring AFB, ME; 443 ABG/DEI/34, Altus AFB, OK; 82nd ABG/DEMCA, Williams AFB, AZ; HQ MAC/DEEE, Scott AFB, IL; HQ SAC/DEMM, Offutt AFB, NE; SAMSO/DEC (Sauer), Vandenberg AFB, CA

AFESC DEB, Tyndall AFB, FL; DEMM/Ius, Tyndall AFB, FL; RDVS (Hathaway), Tyndall AFB, FL

AFSC DEEQ (P. Montoya), Peterson AFB, CO

ARMY 416th ENCOM, Akron Survey Tm, Akron, OH; AETV-DMT-EM, Darmstadt, GE; Asst Ch of Engrs, DAEN-ZCF, Washington, DC; CECOM R&D Tech Lib, Ft Monmouth, NJ; CEHSC-FU-N (Krajewski), Ft Belvoir, VA; Ch of Engrs, DAEN-CWE-M, Washington, DC; Ch of Engrs, DAEN-MPU, Washington, DC; FESA-EM (Karney), Ft Belvoir, VA; HQ Europe Cmd, AEAEN-FE-U, Heidelberg, GE; HQ, FEAK, EAFE-E-UE, Yongsan, Korea; HQDA (DAEN-ZCM), Washington, DC; POJED-O, Okinawa, Japan; R&D Cmd, STRNC-WSA (Kwoh Hu), Natick, MA

ARMY BELVOIR R&D CEN ATSE-DAC-LB, Ft Leonard Wood, MO

ARMY CERL CERL-ES (DL Johnson), Champaign, IL; CERL-ES (Lawrie), Champaign, IL; CERL-ESD (D Chu), Champaign, IL; Energy Sys Div, Champaign, IL; Library, Champaign, IL

ARMY CORPS OF ENGRS A. Azares, Sacramento, CA; Ch Joseph Dam Proj, Bridgeport, WA

ARMY CRREL CRREL-EA, Hanover, NH; CRREL-EC (Flanders), Hanover, NY

ARMY DEPOT Letterkenny, SDSLE-EF, Chambersburg, PA; Letterkenny, SDSLE-EN, Chambersburg, PA

ARMY EHA HSHB-EA-S, Aberdeen Proving Grnd, MD; HSHB-EW, Aberdeen Proving Grnd, MD

ARMY ENGR DIST LMVCO-A/Bentley, Vicksburg, MS; Library, Portland, OR; Library, Seattle, WA

ARMY EWES WESCD-P (Melby), Vicksburg, MS

ARMY LMC Fort Lee, VA

ARMY MISSILE R&D CMD Ch, Docs, Sci Info Ctr, Arsenal, AL

ARMY MMRC DRXMR-SM (Lenoe), Watertown, MA

ARMY MTMC MTT-CE, Newport News, VA

ARMY TRADOC ATEN-FE, Ft Monroe, VA

ADMINSUPU PWO, Bahrain

ASO PWO, Philadelphia, PA; PWP-A, Philadelpia, PA

ASST SECRETARY OF THE NAVY RE&S, Washington, DC

BUREAU OF RECLAMATION D-1512 (GS DePuy), Denver, CO

CBC CO, Port Hueneme, CA; Code 10, Davisville, RI; Code 15, Port Hueneme, CA; Code 155, Port Hueneme, CA; Code 430, Gulfport, MS; Code 470.2, Gulfport, MS; Code 84, Port Hueneme, CA; Library, Davisville, RI; PWO (Code 400), Gulfport, MS; PWO (Code 80), Port Hueneme, CA; PWO, Davisville, RI; Tech Library, Gulfport, MS

CBU 402, OIC, Pensacola, FL; 403, OIC, Annapolis, MD; 407, OIC, Corpus Christi, TX; 408, OIC, Newport, RI; 409, OIC, Long Beach, CA; 410, OIC, Jacksonville, FL; 412, OIC, Charleston, SC; 413, OINC, Pearl Harbor, HI; 414, OIC, Groton, CT; 415, OIC, Virginia Bch, VA; 416, OIC, Alameda, Ca; 419, OIC, Orlando, FL; 422, OIC, Washington, DC; 423, OIC, Brooklyn, NY

CG FMF Pac, SCIAD (G5) Camp HM Smith, HI

CG FOURTH MARDIV Base Ops, New Orleans, LA

CINCLANTFLT CE Supp Plans Offr, Norfolk, VA

CINCPACFLT Pearl Harbor, HI

COGARD ACADEMY Util Sect, PWD, New London, CT

COGARD ARSC CO, Elizabeth City, NC

COGARD ATC CO, Mobile, AL

COGARD AVTECHTRACEN CO, Elizabeth City, NC

COGARD NSF LANTAREA, Mobile, AL

COGARD R&DC CO, Groton, CT; Library, Groton, CT

COGARD RESTRACEN CO, Yorktown, VA

COGARD TRACEN CO, Cape May, NJ; CO, Petaluma, CA

COGARD YARD CO, Baltimore, MD

COMCOGARD FDDC East, Norfolk, VA; West, Seattle, WA

COMDT COGARD Library, Washington, DC

COMFLEACT PWO, Kadena, Japan; PWO, Sasebo, Japan

COMNAVACT PWO, London, UK

COMNAVAIRSYSCOM Code 422, Washington, DC

COMNAVFOR Korea, Ch RE

COMNAVLOGPAC SCE, Pearl Harbor HI

COMNAVMARIANAS Code N4, Guam

COMNAVMILPERSCOM Code 4413, Washington, DC
COMNAVRESFOR Code 08, New Orleans, LA; Code 823, New Orleans, LA
COMNAVSUPPFORANTARCTICA DET, PWO, Christchurch, NZ; PWO
COMOCEANSYS Lant, Code N9, Norfolk, VA; Pac, SCE, Pearl Harbor, HI
COMSPAWARSYSCOM SPARWAR 05, Washington, DC; SPAWAR 005-03A, Washington, DC
COMSUBDEVGRU ONE Ops Offr, San Diego, CA
DEFENSE DEPOT E. Fronk, Engr Tech, Ogden, UT; PWO, Ogden, UT
DEPT OF LABOR Job Corps, (Mann), Imperial Beach, CA
DEPT OF STATE Foreign Bldgs Ops, BDE-ESB, Arlington, VA
DESC PWO, Dayton, OH
DFSC DFSE-F, Alexandria, VA
DNA Tech Svcs Lib, Mercury, NV
DOD DEH-EP&S, Frankfurt, GE; DFSC-FE, Cameron Station, Alexandria, VA
DODDS Pac, FAC, Okinawa, Japan
DOE Fed Energy Mgt Program, Wash, DC; INEL Tech Lib Reports Sta, Idaho Falls, ID; Knolls Atomic Pwr Lab, Lib, Schenectady, NY; Wind/Ocean Tech Div, Tobacco, MD
DTIC Alexandria, VA
DTRCEN Code 2705, Annapolis, MD; Code 4111, Bethesda, MD; Code 4120, Annapolis, MD; Code 421.1, Bethesda, MD; Code 522, Annapolis, MD; PWO, Bethesda, MD
EPA Reg I, Library, Boston, MA; Reg II Lib, New York, NY; Reg III Lib, Philadelphia, PA; Reg VIII, Lib, Denver, CO
FAA Code APM-740 (Tomita), Washington, DC
FCTC LANT, PWO, Virginia Bch, VA
FLDSUPPACT SCE, Washington DC
NSAP Science Advisor SCIAD (G5), Camp HM Smith, HI
GIDEP OIC, Corona, CA
GSA Ch Engrg Br, PQB, Washington, DC; Code PCDP, Washington, DC; PBS (Iaconis), Washington, DC; Reg III, Energy Coord, Philadelphia, PA
LIBRARY OF CONGRESS Sci & Tech Div, Washington, DC
MAG 16, CO, MCAS Tustin, CA
MARCORBASE Base Maint Dept, Camp Lejeune, NC; Code 4.01, Camp Pendleton, CA; Code 405, Camp Lejeune, NC; Code 406, Camp Lejeune, NC; MARCORBASE/Facilities Coordinator, Camp Pendleton, CA; Maint Offr, Camp Pendleton, CA; PAC, PWO, Camp Butler, JA; PWD, Camp Lejeune, NC; PWO, Camp Pendleton, CA; Pac, FE, Camp Butler, JA
MARCORDIST 12, Code 4, San Francisco, CA
MARCORPS 1st Dist, Dir, Garden City, NY
MARCORPS AGCC PW Maint Offc, Twentynine Palms, CA
MARITIME ADMIN MMA, Library, Kings Point, NY
MCLB Code 555, Albany, GA
MCAS Code 3JA2, Yuma, AZ; Code 3JD, Yuma, AZ; Code 44, Cherry Point, NC; Code 6EDD, Iwakuni, Japan; Code LCU, Cherry Point, NC; El Toro, 1JF, Santa Ana, CA; El Toro, Code 1JD, Santa Ana, CA; El Toro, Code 1JE11, Santa Ana, CA; Fac Offr (Code 6FAC), Iwakuni, Japan; PWO, Kaneohe Bay, HI; PWO, Yuma, AZ
MCLB Maint Offr, Barstow, CA; PWO, Barstow, CA
MCRD PWO, San Diego, CA
MCRDAC AROICC, Quantico, VA; Base Maint Offr, Quantico, VA; Mech Engrg Mgr, PWO, Quantico, VA; NSAP Rep, Quantico, VA; PWD, Quantico, VA
NAF AROICC, Midway Island; Detroit, PWO, Mount Clemens, MI; Dir, Engrg Div, PWD, Atsugi, Japan; PWO, Atsugi, Japan; PWO, Misawa, Japan
NALF OIC, San Diego, CA
NAS CO, Norfolk, VA; Chase Fld, Code 18300, Beeville, TX; Chase Fld, PWO, Beeville, TX; Code 110, Adak, AK; Code 163, Keflavik, Iceland; Code 183, Jacksonville, FL; Code 18300, Kingsville, TX; Code 183P, Corpus Christi, TX; Code 18700, Brunswick, ME; Code 22, Patuxent River, MD; Code 70, Marietta, GA; Code 725, Marietta, GA; Code 8, Patuxent River, MD; Dir, Engrg Div, PWD, Keflavik, Iceland; Dir, Maint Control, Adak, AK; Fac Mgmt Offc, Alameda, CA; Memphis, Code 18200, Millington, TN; Memphis, Dir, Engrg Div, Millington, TN; Memphis, PWO, Millington, TN; Miramar, Code 1821A, San Diego, CA; Miramar, PWO, San Diego, CA; NI, Code 183, San Diego, CA; Oceana, PWO, Virginia Bch, VA; PW Engrg (Branson), Patuxent River, MD; PWD (Graham), Lemoore, CA; PWO (Code 182) Bermuda; PWO (Code 6200), Point Mugu, CA; PWO, Adak, AK; PWO, Bermuda; PWO, Cecil Field, FL; PWO, Corpus Christi, TX; PWO, Dallas, TX; PWO, Fallon, NV; PWO, Glenview, IL; PWO, Jacksonville, FL; PWO, Keflavik, Iceland; PWO, Key West, FL; PWO, Kingsville TX; PWO, New Orleans, LA; PWO, Sigonella, Italy; PWO, South Weymouth, MA; SCE, Alameda, CA; SCE, Barbers Point, HI; SCE, Cubi Point, RP; SCE, Norfolk, VA; SCE, Pensacola, FL; Whidbey Is, PWEU, Oak Harbor, WA; Whidbey Is, PWO, Oak Harbor, WA; Whiting Fld, PWO, Milton, FL

NAVAIRDEVCEN Code 832, Warminster, PA; Code 8323, Warminster, PA
NAVAIRENGCEN Code 18232 (Collier), Lakehurst, NJ; PWO, Lakehurst, NJ
NAVAIRPROPCEN CO, Trenton, NJ
NAVAIRTESTCEN PWO, Patuxent River, MD
NAVAMPHIB BASE Naval Amphib Base - LC, Norfolk, VA
NAVAUDSVCHQ Director, Falls Church VA
NAVAVIONICCEN PWO, Indianapolis, IN
NAVAVNDEPOT Code 61000, Cherry Point, NC; Code 640, Pensacola, FL; SCE, Norfolk, VA
NAVCAMS MED, SCE, Naples, Italy; PWO, Norfolk, VA; WestPac, SCE, Guam, Mariana Islands
NAVCOASTSYSCEN CO, Panama City, FL; Code 2360, Panama City, FL; PWO (Code 740), Panama City, FL; Tech Library, Panama City, FL
NAVCOMM DET MED, SCE, Sigonella, Italy
NAVCOMMSTA Code 401, Nea Makri, Greece; Library, Diego Garcia; PWO, Exmouth, Australia; PWO, Nea Makri, Greece; PWO, Thurso, UK
NAVCONSTRACEN CO, Gulfport, MS; Code 00000, Port Hueneme, CA; Code B-1, Port Hueneme, CA
NAVDIVESALVTRACEN CO, Panama City, FL
NAVELEXCEN DET, OIC, Winter Harbor, ME
NAVEODTECHCEN Tech Library, Indian Head, MD
NAVFAC Centerville Bch, PWO, Ferndale, CA; Code 183, Argentia, NF; PWO (Code 50), Brawdy Wales, UK; PWO, Oak Harbor, WA
NAVFACENGCOM Code 03, Alexandria, VA; Code 03R (Bersson), Alexandria, VA; Code 03T (Essoglou), Alexandria, VA; Code 04A, Alexandria, VA; Code 04A1, Alexandria, VA; Code 04B3, Alexandria, VA; Code 051A, Alexandria, VA; Code 083, Alexandria, VA; Code 09M124 (Lib), Alexandria, VA; Code 163, Alexandria, VA; Code 1651, Alexandria, VA; Code 1653 (Hanneman), Alexandria, VA; Code 18, Alexandria, VA
NAVFACENGCOM - CHES DIV. Code 112.1, Washington, DC; FPO-1PL, Washington, DC
NAVFACENGCOM - LANT DIV. Br Ofc, Dir, Naples, Italy; Code 111, Norfolk, VA; Code 1632, Norfolk, VA; Code 403, Norfolk, VA
NAVFACENGCOM - NORTH DIV. Code 04, Philadelphia, PA; Code 04AL, Philadelphia, PA; Code 11, Philadelphia, PA; Code 111, Philadelphia, PA; Code 202.2, Philadelphia, PA; Code III/WFT, Philadelphia, PA
NAVFACENGCOM - PAC DIV. Code 09P, Pearl Harbor, HI; Library, Pearl Harbor, HI
NAVFACENGCOM - SOUTH DIV. Code 04A3, Charleston, SC; Code 1112, Charleston, SC; Code 403 (Gaddy), Charleston, SC; Code 406, Charleston, SC; Library, Charleston, SC
NAVFACENGCOM - WEST DIV. 09P/20, San Bruno, CA; Code 04A2.2 (Lib), San Bruno, CA; Code 04B, San Bruno, CA; Code 09B, San Bruno, CA; Code 408.2 (Jeung) San Bruno, CA; Pac NW Br Offc, Code C/50, Silverdale, WA; Pac NW Br Offc, Dir, Silverdale, WA
NAVFACENGCOM CONTRACTS AROICC, Cherry Point, NC; AROICC, Coleville, CA; AROICC, Quantico, VA; AROICC, San Vito, Italy; Code 922, Everett, WA; DROICC, Adak, AK; DROICC, Lemoore, CA; DROICC, Santa Ana, CA; Mid Pac, OICC, Pearl Harbor, HI; North Bay, Code 1042.AA, Vallejo, CA; OICC (Code 04A), Madrid, Spain; OICC, Guam; OICC, Nea Makri, Greece; OICC/ROICC, Norfolk, VA; OICC/ROICC, Virginia Beach, VA; ROICC (Code 495), Portsmouth, VA; ROICC, Columbus, OH; ROICC, Corpus Christi, TX; ROICC, Crane, IN; ROICC, Keflavik, Iceland; ROICC, Twentynine Palms, CA; ROICC, Warminster, PA; SW Pac, OICC, Manila, RP; Trident, OICC, St Marys, GA
NAVFUEL DET OIC, Yokohama, Japan
NAVHOSP Hd, Fac Mgmt, Camp Pendleton, CA; Lt Barron, Yokosuka, Japan; PWO, Camp Lejeune, NC; ROICC Offc (Watson), Beaufort, SC; SCE (Knapowski), Great Lakes, IL; SCE, Great Lakes, IL; SCE, Guam, Mariana Islands; SCE, Long Beach, CA; SCE, Newport, RI; SCE, Pensacola, FL; SCE, Yokosuka, Japan
NAVMAG SCE, Subic Bay, RP
NAVMARCORESCEN LTJG Davis, Raleigh, NC
NAVMEDCOM NWREG, Fac Engr, PWD, Oakland, CA; NWREG, Head, Fac Mgmt Dept, Oakland, CA; PACREG, Code 22, Barbers Point, HI; SCE, Jacksonville, FL; SWREG, SCE, San Diego, CA
NAVMEDRSCHU Three, PWO, Cairo, Egypt
NAVOCEANCOMCEN Code EES, Guam, Mariana Islands
NAVOCEANSYSCEN Code 524 (Lepor), San Diego, CA; Code 811, San Diego, CA
NAVORDMISTESTSTA Code 40, White Sands, NM
NAVORDSTA Code 0922B1, Indian Head, MD; MDS-25, Louisville, KY
NAVPACEN Dir, San Diego, CA
NAVPETOFF Code 40, Alexandria, VA
NAVPETRES Director, Washington DC
NAVPGSCOL Code 1424, Library, Monterey, CA; Code 69 (T. Sarpkaya), Monterey CA; PWO, Monterey, CA
NAVPHIBASE PWO, Norfolk, VA; SCE, San Diego, CA
NAVRADSTA Whidbey Is, PWO, Oak Harbor, WA

NAVSCSCOL PWO, Athens, GA
NAVSECGRUACT PWO (Code 40), Edzell, Scotland; PWO, Adak, AK; PWO, Sabana Seca, PR; PWO, Sonoma, CA
NAVSECSTA Code 60, Washington, DC
NAVSHIPREPFAC SCE, Guam; SCE, Subic Bay, RP
NAVSHIPYD CO, Pearl Harbor, HI; Code 108.1, Pearl Harbor, HI; Code 202.5 (Library), Bremerton, WA; Code 244.13, Long Beach, CA; Code 308.05, Pearl Harbor, HI; Code 308.3, Pearl Harbor, HI; Code 382.3, Pearl Harbor, HI; Code 440, Portsmouth, NH; Code 440.1 (R. Schwinck), Long Beach, CA; Code 443, Bremerton, WA; Code 444, Philadelphia, PA; Code 450.4, Charleston, SC; Library, Portsmouth, NH; Mare Island, Code 453, Vallejo, CA; Mare Island, Code 457, Vallejo, CA; Mare Island, PWO, Vallejo, CA; Norfolk, Code 380, Portsmouth, VA; Norfolk, Code 440, Portsmouth, VA; Norfolk, Code 450-HD, Portsmouth, VA; Norfolk, Code 453-HD, Portsmouth, VA; PWO (Code 400), Long Beach, CA; PWO, Bremerton, WA; PWO, Portsmouth, NH
NAVSTA CO, Brooklyn, NY; CO, Long Beach, CA; Code 4216, Mayport, FL; Code 423, FPBO Guantanamo Bay; Code N4214, Mayport, FL; Design Sec, Brooklyn, NY; Dir, Engr Div, PWD, Guantanamo Bay, Cuba; Engrg Dir, PWD, Rota, Spain; Maint Div, PWD, Rota, Spain; PWO, Mayport, FL; SCE, San Diego, CA; SCE, Subic Bay, RP; Util Engrg Offr, Rota, Spain; WC 93, Guantanamo Bay, Cuba
NAVSUPPACT CO, Naples, Italy; PWO, Naples, Italy; PWO, New Orleans LA; PWO, Souda Bay, Greece
NAVSUPPFAC Contract Admin Tech Library, Diego Garcia; PWO, Antigua, The West Indies; PWO, Thurmont, MD
NAVSUPSYSCOM Code 0622, Washington, DC
NAVSWC CO, Dahlgren, VA; Code E211 (Miller), Dahlgren, VA; Code G-34, Dahlgren, VA; DET, White Oak Lab, Code W50 (Okonski) Silver Spring, MD; DET, White Oak Lab, PWO, Silver Spring, MD; PWO, Dahlgren, VA
NAVTECHTRACEN SCE, Pensacola FL
NAVTRASTA PWO, Orlando, FL; SCE, San Diego, CA
NAVTRASYSCEN Code N-213, Orlando, FL
NAVUSEAWARENGSTA Code 073, Keyport, WA; PWO, Keyport, WA
NAVWARCOL Code 24, Newport, RI
NAVWPNCEN AROICC, China Lake, CA; Code 2637, China Lake, CA; PWO (Code 266) China Lake, CA
NAVWPNSTA Code 092, Concord, CA; Code 092A, Seal Beach, CA; Code 093, Yorktown, VA; Dir, Maint Control, PWD, Concord, CA; Earle, Code 0922, Colts Neck, NJ; Earle, PWO (Code 09B), Colts Neck, NJ; PWO, Charleston, SC; PWO, Seal Beach, CA; PWO, Yorktown, VA
NAVWPNSUPPCEN Code 0931, Crane, IN; PWO, Crane, IN
NETC Code 42, Newport, RI; Code 46, Newport, RI; PWO, Newport, RI
NCR 20, Code R31, Gulfport, MS; 31, Code R00, Port Hueneme, CA
NEESA Code 111C (Hickenbottom), Port Hueneme, CA; Code 111E (McClaine), Port Hueneme, CA; Code 113M2, Port Hueneme, CA
NMCB 1, CO; 133, CO; 3, CO; 3, Ops Offr; 4, CO; 5, CO; 5, Ops Dept; 62, CO; 7, CO,
NOAA Joseph Vadus, Rockville, MD; Library, Rockville, MD
NORDA Code 1121SP, Bay St. Louis, MS; Code 352, Bay St. Louis, MS
NRL Code 2511, Washington, DC
NSC Code 54.1, Norfolk, VA; Code 70, Oakland, CA; Code 703, Pearl Harbor, HI; Puget Sound, SCE, Bremerton, WA; SCE, Charleston, SC; SCE, Norfolk, VA
NSD SCE, Guam, Mariana Islands; SCE, Subic Bay, RP
NTIS Lehmann, Springfield, VA
NUSC PWO, Newport, RI
NUSC DET AUTEC W Palm Bch, OIC, W Palm Beach, FL; Code 2143 (Varley), New London, CT; Code 4123, New London, CT; Code 44 (RS Munn), New London, CT, Code 5202 (S Schady), New London, CT; PWO, New London, CT
OCNR Code 1113, Arlington, VA; Code 1114SE, Arlington, VA; Code 1234, Arlington, VA; NRL (Prout), Alexandria, VA
OFFICE OF SECRETARY OF DEFENSE DDR&E, Washington, DC; Dir, Qlty Fac Acq, Washington, DC; OASD (P&L), M. Carr, Washington, DC; OASD, (P&L)E (Wm H. Parker), Washington, DC
PACMISRANFAC HI Area, PWO, Kekaha, HI
PHIBCB 1, CO, San Diego, CA; 1, P&E, San Diego, CA; 2, CO, Norfolk, VA
PMTC Code 5041, Point Mugu, CA

PWC ACE (Code 110), Great Lakes, IL; ACE Office, Norfolk, VA; Code 10, Great Lakes, IL; Code 10, Oakland, CA; Code 100E, Great Lakes, IL; Code 101 (Library), Oakland, CA; Code 101, Great Lakes, IL; Code 102, Oakland, CA; Code 110, Oakland, CA; Code 110C, Oakland, CA; Code 120, San Diego, CA; Code 123C, San Diego, CA; Code 30, Norfolk, VA; Code 400, Great Lakes, IL; Code 400, Pearl Harbor, HI; Code 420, Great Lakes, IL; Code 420, Oakland, CA; Code 420, San Diego, CA; Code 420B (Waid), Subic Bay, RP; Code 421, San Diego, CA; Code 422, San Diego, CA; Code 423, San Diego, CA; Code 423/KJF, Norfolk, VA; Code 424, Norfolk, VA; Code 430 (Kyi), Pearl Harbor, HI; Code 4450A (T. Ramon), Pensacola, FL; Code 50, Pensacola, FL; Code 500, Great Lakes, IL; Code 500, Norfolk, VA; Code 506, Oakland, CA; Code 505A, Oakland, CA; Code 600, Great Lakes, IL; Code 610, San Diego, CA; Code 614, San Diego, CA; Code 615, Guam, Mariana Islands; Code 616, Subic Bay, RP; Code 700, Great Lakes, IL; Library (Code 134), Pearl Harbor, HI; Library, Guam, Mariana Islands; Library, Norfolk, VA; Library, Pensacola, FL; Library, Yokosuka, Japan; PWC, C-422, Pearl Harbor, HI; Tech Library, Subic Bay, RP

RNCB Lant, CO, Norfolk, VA; Pac, CO, Santa Barbara, CA

RNCFSU Four, CO, Granite City, IL; One, CO, Manor, PA; Three, CO, Charleston, SC; Two, CO, Ft Carson, CO

RNCR Eight, CO, Philadelphia, PA; Five, CO, San Francisco, CA; Nine, CO, Dallas, TX; One, CO, Los Alamitos, CA; Seven, CO, Davisville, RI; Six, CO, Glenview, IL; Three One, CO, Santa Barbara, CA; Three, CO, Atlanta, GA; Two One, CO, Davisville, RI; Two Zero, CO, Gulfport, MS; Two, CO, Glenview, IL

RNMCB Eighteen, CO, Seattle, WA; Fifteen, CO, Richards-Gebaur AFB, MO; Fourteen, CO, Jacksonville, FL; Seventeen, CO, Port Hueneme, CA; Sixteen, CO, Los Alamitos, CA; Thirteen, CO, Peekskill, NY; Twelve, CO, Davisville, RI; Two Eight, CO, Barksdale AFB, LA; Two Five, CO, Glenview, IL; Two Four, Redstone Arsenal, AL; Two One, CO, Lakehurst, NJ; Two Seven, CO, Brunswick, ME; Two Six, CO, Mt Clemens, MI; Two Three, CO, Ft Belvoir, VA; Two Two, CO, Dallas, TX; Two Zero, CO, Columbus, OH; Two, CO, San Francisco, CA

SPCC Code 082, Mechanicsburg, PA; PWO (Code 08X), Mechanicsburg, PA

SUBASE Bangor, PWO (Code 8323), Bremerton, WA; PWO, Groton, CT

SUPSHIP Tech Library, Newport News, VA

US GOVT PRINTING OFFC Library Prgms Svcs, SLLC, Washington, DC; Supt Docs, SLLA, Washington, DC; Supt Docs, SLLA, Washington, DC

USAF RGNHOSP SGPM, Fairchild AFB, WA

USAFE DE-HFO, Ramstein AB, GE

USDA For Svc Reg 1, (Dittmer), Missoula, MT; For Svc Reg 1, Tech Engrs, Missoula, MT; For Svc Reg 10, Tech Engrs, Juneau, AK; For Svc Reg 2, Engr Tech Staff, Lakewood, CO; For Svc Reg 3, Engr Tech Staff, Albuquerque, NM; For Svc Reg 4, Tech Engrs, Ogden, UT; For Svc Reg 5, San Francisco, CA; For Svc Reg 5, Tech Engrs, San Francisco, CA; For Svc Reg 6, Tech Engrs, Portland, OR; For Svc Reg 8, (Bowers), Atlanta, GA; For Svc Reg 8, Tech Engrs, Atlanta, GA; For Svc, Reg 4, Ogden, UT; For Svc, Tech Engrs, Washington, DC; Forest Prod Lab (Fac Engr), Madison, WI; NE For Exp Sta, Broomall, PA; No Cen Forest Exper Sta, St Paul, MN; Rocky Mtn For & Rng Exper Sta, Fac Engrg, Ft Collins, CO; SE Forest Exp Sta, Asheville, NC

USNA Ch, Mech Engrg Dept, Annapolis, MD; Mech Engr Dept (C Wu), Annapolis, MD; Mech Engrg Dept (Power), Annapolis, MD; Rsch Dir, Annapolis, MD; Sys Engrg (Tuttle), Annapolis, MD

USPS Mgr, Plant Maint, Albany, GA

USS USS FULTON, Code W-3

ARIZONA STATE UNIVERSITY Design Sci (Kroelinger), Tempe, AZ; Energy Prog Offc, Phoenix, AZ

BALLSTATE UNIVERSITY Arch Dept (Meden), Muncie, IN

CALIFORNIA STATE UNIVERSITY C.V. Chelapati, Long Beach, CA

CITY OF AUSTIN Gen Svcs Dept (Arnold), Austin, TX

CITY OF EAST LANSING N. King, East Lansing, MI

CITY OF LIVERMORE Dackins, PE, Livermore, CA

CITY OF RIVERSIDE Bldg Svcs Dept, Riverside, CA

CITY OF SACRAMENTO Gen Svcs Dept, Admin, Sacramento, CA

CITY OF WINSTON-SALEM RJ Rogers, PWD, Winston-Salem, NC

CONNECTICUT Policy & Mgmt, Energy Div, Hartford, CT

CORNELL UNIVERSITY Library, Ithaca, NY

DRURY COLLEGE Physics Dept, Springfield, MO

FOREST INST FOR OCEAN & MT Library, Carson City, NV

FRANKLIN RSCH CEN Library, Norristown, PA

GEORGIA INSTITUTE OF TECHNOLOGY Arch Col (Benton), Atlanta, GA

INSTITUTE OF MARINE SCIENCES Library, Port Aransas, TX

IOWA STATE UNIVERSITY Arch Dept (McKrown), Ames, IA

KEENE STATE COLLEGE Sci Dept (Cunningham), Keene, NH

LAWRENCE LIVERMORE NATL LAB FJ Tokarz, Livermore, CA; Plant Engrg Lib (L-654), Livermore, CA

LEHIGH UNIVERSITY Linderman Library, Bethlehem, PA
LOUISIANA Nat Res Dept, R&D, Baton Rouge, LA
MAINE Energy Rscs Ofc, Augusta, ME
MAINE MARITIME ACADEMY Lib, Castine, ME
MICHIGAN TECH UNIVERSITY CE Dept (Haas), Houghton, MI
MISSOURI Nat Res Dept, Energy Div, Jefferson City, MO
MIT Engrg Lib, Cambridge, MA
MONTANA Energy Offc (Anderson), Helena, MT
NATL ACADEMY OF SCIENCES BRB (Smeallie), Washington, DC; NRC, Naval Studies Bd, Washington, DC
NE OHIO REG SEWER DIST Bldg Maint (Scherma), Cleveland, OH
NEW HAMPSHIRE Gov Energy Ofc, Asst Dir, Concord, NH
NEW YORK Energy Offc, Albany, NY; Energy Office, Lib, Albany, NY
NEW YORK STATE MARITIME COLLEGE Longobardi, Bronx, NY
NY CITY COMMUNITY COLLEGE Library, Brooklyn, NY
OKLAHOMA STATE UNIV Ext Dist Offc, Tech Transfer Cen, Ada OK
PURDUE UNIVERSITY Engrg Lib, W. Lafayette, IN
SEATTLE PORT W Ritchie, Seattle, WA
SEATTLE UNIVERSITY CE Dept (Schwaegler), Seattle, WA
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