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Stop the Energy Leaks at Your Windows

(In developing the Texas Home Energy Analysis Training series [HEAT] to instruct residential energy advisors, researchers at the Center for Energy Studies have developed a number of energy conservation strategies applicable to Texas homes and climatic conditions. The following discussion of window-related methods of saving energy are adapted from the HEAT Manual *[Governor's Office of Energy Resources, 1979] by Jim Broughton, Jerold Jones, and Carl Crow of the the CES Conservation Division. The Texas Governor's Office of Energy Resources [now the Texas Energy and Natural Resources Advisory Council] has sponsored the HEAT project as part of the federally funded state conservation plan.*

For more information about energy conservation, contact the customer service department of your local utility or the Texas Energy Extension Service, Center for Energy and Mineral Resources, Texas A&M University, College Station, Texas 77843.)

Windows can alter significantly the amount of energy consumed in a building. If poorly designed and numerous, the windows in a home can greatly increase the heating and air conditioning loads and therefore increase the homeowner's utility bills. Several different strategies exist for making the windows of a home more energy efficient.

Windows allow heat gain and heat loss in three ways:

1. Infiltration of air through cracks,
2. Heat gain from direct sunshine and loss by reradiation to the sky at night,
3. Heat loss or gain caused by the difference between inside and outside temperatures (often five to ten times greater through a window than through an insulated wall)

Many kinds of windows are used in residences, some of which are more energy conservative than others. Windows that contain numerous cracks and/or lengthy cracks around the sash and frame generally waste energy and may create comfort problems. For example, double-hung windows have approximately twice the crack length of single-hung windows and are therefore usually less energy efficient. Jalousie windows also have many cracks.

Caulking and Weatherstripping of Windows

Infiltration of air through cracks is one of the primary ways that heat is lost or gained through windows. Conditioned air is lost around the windows and is replaced by unconditioned outside air. This replacement air must then be conditioned, increasing the cost of heating or cooling the home. Modifications that reduce infiltration, then, can provide significant energy savings. For example, a tightly weatherstripped window may provide a 30 to 75 percent reduction of infiltration compared to one so loose it rattles.

Air leakage at a window occurs at three perimeter joints: between wall and window frame, between sash and frame, and between sash and glazing (glass). Each of these locations must be properly maintained in order to keep infiltration at windows to a minimum.

A large percentage of the infiltration at windows occurs through gaps and cracks between the wall and window frame. This problem can be overcome if care is taken to caulk or otherwise fill the perimeter voids during the construction process. Urethane foams or high-grade sealants can be used around the window during installation to provide air tightness.

For the existing home, the interior or exterior trim around the window must be removed to provide access for this type of sealing, but it is a messy, time-consuming job. The possible energy savings would not warrant the task in most cases.

A simple, but effective, method to seal the frames of windows is to caulk around the exterior trim (figure 1). This task is fairly inexpensive and can easily be done by the homeowner. Selection of a good-quality caulk or sealant and careful application (the bead of caulk should be drawn along the crack, not pushed) should provide long-lasting protection from infiltration around window frames. In order to seal the windows properly, the homeowner must carefully locate and fill all potential paths of air leakage at the frame—primarily those cracks where the frame butts the exterior siding, trim, or brick veneer.

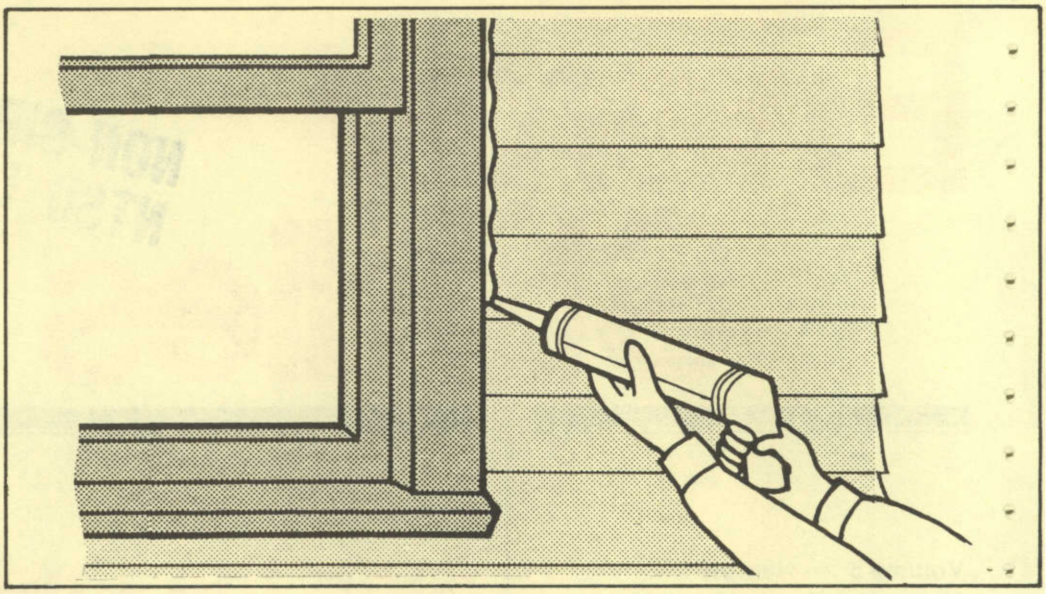

Figure 2

Weatherstripping is applied to windows to prevent passage of air in the channels of the jamb, on the bottom of the lower sash, and at the point where the two sashes meet (figure 2). Several types exist, including spring metal strips, foam and sponge rubber tape, vinyl bulb strips, and felt strips. Weatherstripping is sometimes self-adhering, or it can be nailed (if reinforced with metal), glued, or stapled in place. Weatherstripping of windows reduces drafts, moisture penetration, and even noise.

The proper maintenance of glazing is another way to prevent infiltration. With time, the compounds used to hold the glazing in place will degrade. Cracks and loosened glazing result and infiltration increases. Repairs should be made periodically to prevent this source of energy waste. The two types of glazing sealants are putty, which is fairly short-lived in usefulness, and glazing compound, which is more costly but longer lasting.

Each of these measures to plug air leaks will result in less air infiltration on the windward side of the building and less exfiltration on the leeward side.

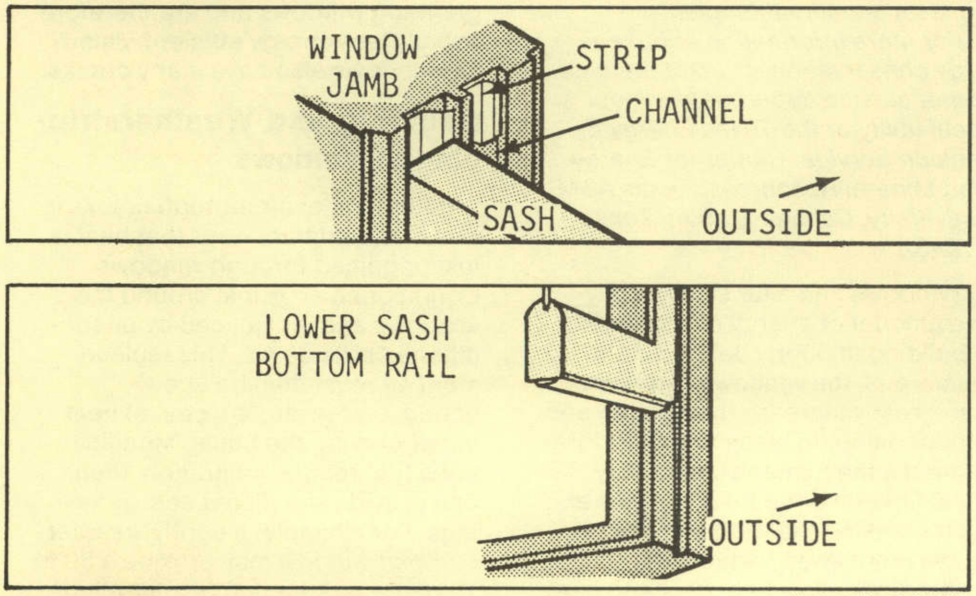

Figure 1

Illustrated by Emily Little

Shading

While all parts of a building are affected by the amount of shading available, windows are the most important, since they transmit directly into the living space most of the solar radiation that hits them. The goal in shading windows, then, should be to allow appropriate winter solar heat gain and to eliminate, as much as possible, summer solar heat gain.

A primary consideration in window shading is that of interior-versus-exterior shades. Exterior shading is approximately twice as effective as interior shading for the same window. This rule is not always accurate, however, since results depend upon the design modifications used and/or products used, but it does provide a rough guideline. Several options will be discussed here.

One of the more beneficial shading devices is the roof overhang, particularly on a southern exposure. Properly designed and constructed, the roof overhang can provide shading during the summer and still allow solar radiation to enter the building as the sun's altitude angle decreases with the approach of winter. Adding an overhang is easy during the design and construction phase, but it is difficult, sometimes impossible, for existing buildings. On east or west exposures, patio covers may also be used to great advantage if summer solar heat gain is a problem.

Another very useful conservation tool is trees or shrubs planted at strategic locations about the homesite. Deciduous trees, which shed their leaves in winter, are most beneficial since they provide shade in the summer and admit sunlight during the winter on the south, east, and west (figure 3).

Evergreens can be used to shade successfully and can be effective wind barriers if planted on the north side of the house. However, if used on other exposures, evergreens may reduce the amount of incoming solar radiation that could be utilized during the winter.

Various exterior shading devices exist: louvered screens, roll blinds, shutters, and awnings. Interior shading products are also available: venetian blinds, drapes, roll shades, and shutters. Each of these options should be carefully evaluated as to its cost, appearance, and ease of installation and use. Product literature is useful in comparing these options, but claims of increased energy efficiency are occasionally exaggerated. In general, the exterior shading devices are superior in performance to the interior devices, although some insulated interior shading products that fit tightly against the interior trim can also decrease heat loss or gain. Table 1 lists shading coefficients for various devices.

Specialized Glazing and Applied Films

Various types of glass and applied films that reduce the transmission of solar radiation are available. Special glazing materials are made by adding metallic or metallic oxide chemicals to regular glass during manufacturing, causing the treated glass to react differently to certain wavelengths of solar radiation. The glass may be tinted, reflective, or heat absorbing, depending upon the bands of wavelengths that are transmitted, reflected, or absorbed.

The cost of specialized glass and applied films is relatively high compared to their effectiveness. The

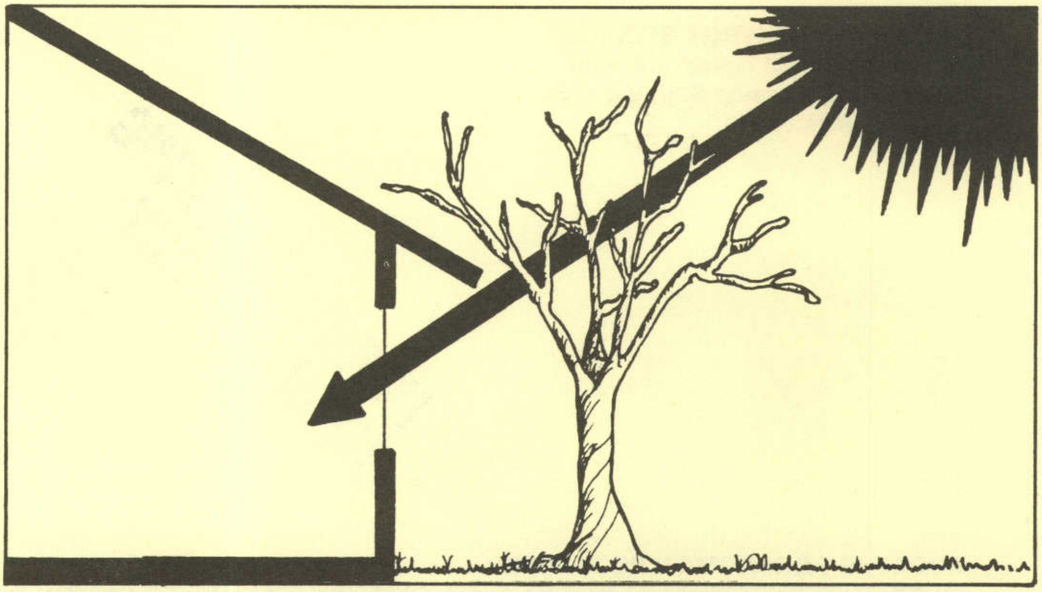

Figure 3

shading options normally are more cost effective than special glass or films in residential applications.

Multiple Glazing

Installation of windows containing two or more sheets of glass separated by a sealed dead air space is another way to save energy. The function of this multiple glazing is to increase the resistance of the window to heat transfer. Since air is a poor conductor of heat, the air layer between the two sheets of glazing acts as an insulator. And since the air layer is motionless, convection currents that transfer heat between the two glass surfaces are reduced. Radiation is also reduced by having two or more layers of glass in the window, although this factor is of much less significance, particularly if the window is unshaded.

The width of the still air space is of prime importance to the effectiveness of the multiple-glazed window. An air space narrower than 3/16-inch has a low overall resistance because conduction heat transfer increases significantly below that width. The wider the air space between 3/16-inch and 5/8-inch, the greater the resistance of the window to heat exchange. Increasing the air space beyond 5/8-inch does not substantially increase the resistance to conduction, and increasing convection becomes a major factor if spacing is greater than about 4 inches.

Storm Windows

Made-to-fit window coverings of glass or rigid plastic are referred to as storm windows. They are framed and applied to the prime window by screws or other fasteners. Care should be taken to use fasteners of the same metal as the frame to prevent rapid corrosion. Storm windows are retrofit items that are very popular in the severe winter climates.

Where winter conditions are extremely cold and windy, storm windows can enhance comfort and substantially reduce the cost of heating. However, because their impact is primarily in heating, storm windows may not be cost effective in the more temperate climates of the southern and southwestern United States. Storm windows are of little benefit if the chief problem encountered in a home is summer solar heat gain, since multiple glazing has only a limited effect upon solar transmission.

Vinyl or rigid plastic storm windows are available in kits or can be made by hand. They can be applied easily to windows in winter and removed during summer. These storm windows are effective and much less costly to install than permanent ones. For maximum effectiveness the inner air pocket between the prime window and the storm window should be between 5/8-inch and 4 inches. Plastic storm windows made to attach on the inside of the window rather than the outside will generally last longer. The useful life of plastic storm windows is limited to about three years, and storage space may also be a problem with any removable type.

(Continued on page 6)

CES Update

Office of Director

The General Electric Foundation has awarded $15,000 to the Center for Energy Studies for policy-related research activities.

Dr. Herbert H. Woodson, director of the Center for Energy Studies, chaired a panel at the National Energy Forum Seven November 7–9 in Houston, Texas. "Energy Economics" was the title of the panel. The conference was sponsored by the US National Committee of the World Energy Conference.

Electric Power

If power plant productivity levels can be improved 5 percent, the annual savings to Texas consumers will reach into the millions of dollars, according to the preliminary findings of a joint study by the Center for Energy Studies and the Texas Energy and Natural Resources Advisory Council (TENRAC).

CES researchers have compared the performance of a representative group of Texas electric utilities with the national average, said Dr. David R. Brown, assistant professor of electrical engineering. He and Dr. Martin L. Baughman, CES Electric Power Division director, are the principal investigators of the center's project.

Over the period 1965–75, gas-fired electric generating units of the Texas utilities being studied had:

—a higher availability factor (the time a unit is available for service whether or not actually in service) than the national average,

—a lower capacity rate (the ratio of a unit's average power output to its estimated maximum output),

—a lower forced outage rate (the time a unit is out of service because of equipment failure or accidents).

Five utilities are cooperating in the study—Texas Electric Service Company, Texas Power and Light, Dallas Power and Light, Central Power and Light, and Houston Lighting and Power. Based on performance data supplied by the companies, a forecast is being developed of the short- and long-term savings that can be achieved through improved productivity, Dr. Brown said.

A principal scenario that is being examined allows a decrease of 5 percent in the forced outage rates over the eight-year period 1980–87 in the utilities' baseload units. The resultant increase in productivity would have several benefits: it would decrease consumption of more costly fuel in peaking units, delay the need to build new plants, and reduce capital investment and the cost of electricity to consumers.

The results of a preliminary forecast indicate that savings of more than $1 million can be achieved in one year by a utility. The researchers are using two production simulation models, one from Philadelphia Electric Company, the other from Texas Electric Service Company. Simulations done with each of these models found concurring results: if one sample utility improved its productivity rate by ⅝ percent in one year, the utility's total fuel bill would drop about ¼ percent, representing more than $1 million in saved fuel costs.

The Baughman-Joskow Regionalized Electricity Model (REM) is being used to study the economic effects created if this type of increased productivity were to be maintained to the year 2000 in the utilities in the Electric Reliability Council of Texas region.

One way to encourage utilities to strive for increased productivity might be to allow a slightly higher rate of return on investment to those utilities that improve their productivity rates significantly. This measure and other incentives are being studied by TENRAC, said Dr. Brown. The study will conclude in early 1980, and a report is planned at that time.

Five research assistants participating in the project are Larry Günter, Sarut Panjavan, Saifuddin Mogri, Larry Vanston, and Arastou Oskui.

Energy Computer Game Workshops Offered by CES

Groups interested in learning about the world's energy situation can participate in a Citizen's Workshop on Energy and the Environment.

The nationwide program is designed to bring together interested citizens and a knowledgeable scientist or engineer to explore energy and environmental policy by means of a computer game complete with blinking lights, countdowns, and warning buzzers. The Citizen's Workshop program in the Austin area is sponsored by the Center for Energy Studies.

To find out more about scheduling a free Citizen's Workshop on Energy and the Environment in the Austin area, contact the coordinator of the program, Dr. Dale Klein, Department of Mechanical Engineering, TAY 167, The University of Texas at Austin, Austin, Texas 78712 (512/471-5136).

Elsewhere in the United States contact the Northwest College and University Association for Science, 100 Sprout Road, Richland, Washington 99352 (509/375-3090).

Energy Conservation

Two Center for Energy Studies researchers are participating in the coordination of the **Second Annual Conference on Industrial Energy Conservation Technology,** to be held April 13–16 at the Hyatt-Regency Hotel in Houston.

US Secretary of Energy Charles W. Duncan, Jr., has made a tentative commitment to deliver the conference keynote address, said Mr. Milton A. Williams, center research engineer-scientist and the technical program chairman of the conference.

The topic of the conference is state-of-the-art methods of industrial energy conservation, including fluid systems, electrical systems, heat recovery, instrumentation and measurement, economic analysis, combustion processes, alternative energy sources, government programs, industrial buildings, and many other topics. About 160 technical papers will be presented. An exhibition of industrial energy conservation products and services will run concurrent with the conference.

Dr. Philip S. Schmidt, associate professor of mechanical engineering and associate dean of graduate studies, is the technical proceedings chairman.

Cosponsors of the conference are the Texas Industrial Commission, the Texas Energy and Natural Resources Advisory Council, and the US Department of Energy.

For information about submitting papers, contact Dr. Schmidt at the Department of Mechanical Engineering, TAY 167, The University of Texas at Austin, Austin, Texas 78712. Deadline for submitting an abstract of a proposed paper is December 15.

Environmental Studies

A tool that could allow **cities to project their future air pollution levels** is being developed by researchers from the Center for Energy Studies and the National Center for Atmospheric Research (NCAR).

CES participants are graduate student Rachel Laird and Dr. Richard W. Miksad, associate professor of environmental health engineering. Dr. Paulette Middleton of the National Center for Atmospheric Research is coordinating the project.

Ms. Laird and Dr. Miksad said that the urban air quality model may be the first of its kind to project levels of all major pollutants in a simplified, integrated way.

The principal application of the model, once developed, will be to evaluate the effect on air quality of different energy use options and pollution control strategies in a city.

The researchers are attempting to model the two major elements of urban air pollution: dispersion from the sources and photochemical reactions in the air. All the major regulated pollutants will be included in the model—carbon monoxide, nitrogen oxides, sulfur dioxide, hydrocarbons, oxidants, and particulates (sulfates and nitrates).

Air quality data from Denver and Houston are being used in development of the model. The Denver data were obtained by NCAR from local air quality control agencies; the Houston data are from the Texas Air Control Board and the Houston Area Oxidant Study, sponsored by the Houston Chamber of Commerce.

Houston and Denver have quite different air pollution problems, Ms. Laird said. At sea level, Houston experiences hot, humid weather, and peak demand for electric power occurs in the summer. Mile-high Denver is colder and drier, experiencing its peak electric demand in the winter. The Houston area is industrialized, while, for the most part, the Denver area is not. In both cities, automobile exhaust is a large-scale polluter. All these factors affect the two cities' air pollution, Ms. Laird said.

NCAR researchers are developing the dispersion segment of the model; Ms. Laird is developing the chemical reaction segment, and she and Dr. Miksad will integrate the two parts. What the researchers are aiming for is a relatively simple, validated model that can be used by decision makers concerned with the overall impact of urban planning options.

The time frame for the model's projections will be monthly or seasonal and will initially be in five-year periods.

A project to predict more realistically **how water is deposited from the plumes of power plants** is under way in the UT Environmental Health Engineering Group, with support from the CES Environmental Studies Division and Argonne National Laboratory.

Cooling tower plumes, which contain water in the forms of vapor and small drops, are a common feature of power plants, and can have an environmental impact, said Dr. Richard W. Miksad, the project's supervisor.

Often the water drops in a plume contain toxic additives, which can damage plant life in the dispersal area. Also, in winter the water in the plume can create hazardous icing on nearby power lines and highway surfaces. Thus in designing a power plant, the area in which the deposit of this water will occur must be accurately predicted so that the environmental effects can be assessed

With two graduate students, M. A. Ratcliff and Michael Hunt, Dr. Miksad is developing a computer model of cooling tower drift deposition that will predict both the amount of water deposited over the ground path of a plume and the size distribution of the water droplets being deposited at different distances.

A report, *Development and Verification of a Natural Draft Cooling Tower Drift Deposition Model,* by M. A. Ratcliff and Richard W. Miksad, is available from the UT Atmospheric Science Group of the College of Engineering of The University of Texas at Austin, Austin, Texas 78712. A second report is forthcoming.

Nuclear Studies

Two projects, sponsored by the Texas Atomic Energy Research Foundation, are under way in the Nuclear Studies Division:

Fission-Fusion Hybrid Waste Generation: A Parametric Analysis—Fission-fusion hybrids are being studied today as a promising power generation technology of the future.

In a fission-fusion hybrid, the intense fusion reaction would throw off heat and neutrons. The stream of neutrons would pass through a surrounding blanket of fissile material, causing some of it to fission (split) and give off heat. Electric power could be generated with the heat given off by both the fusion and the fission reactions.

The neutrons could be used in another way also, to pass through a blanket of fertile material, causing part of it to change to fissile material. This second step would be a process for breeding new nuclear fuel.

The current project is a computer modeling study of the varying radioactive wastes created by such systems and the factors that affect them, such as the energy level of the neutron stream, the composition of the blankets, and use of moderating zones to slow down the neutrons.

The major goal in the research is to pinpoint the theoretical scheme that results in the least potential radioactive hazard. Full analysis will be performed for two fuel cycles: thorium-232 → uranium-233 and uranium-238 → plutonium-239.

Mechanical engineering graduate student R. Daniel Smith is performing the analysis under supervision of Dr. Dale Klein, director of the Nuclear Studies Division.

Study of Waste Toxicity in Six Nuclear Fuel Cycles—Existing and proposed nuclear fuel cycles vary in

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the toxicity of the discharged, or leftover, fuel materials. The purpose of this study, now nearing completion, is to quantify and compare the toxicity levels of discharged fuels.

By means of two computer codes, five different fuel cycles were examined that involved the recovery, enrichment, and recycling of uranium, plutonium, and thorium fuels. A once-through cycle in which no reprocessing takes place was also examined.

One significant finding in the study is that the thorium-uranium cycle does not result in great reduction in the toxicity of its discharged fuel.

The project is being carried out by mechanical engineering graduate student Yukitaka Kunimoto under the supervision of Dr. Nolan Hertel, assistant professor of mechanical engineering.

(Continued from page 3)

TABLE 1. Shading Coefficients (SC)

	With single glazing, clear glass	With double glazing, 3/16–½" air space, clear glass
Venetian blinds		
Med. color	0.64	0.57
Light color	0.55	0.51
Interior roller shade		
Opaque, dark	0.59	0.60
Opaque, white	0.25	0.25
Translucent, light	0.39	0.37
	With clear ¼" glass (SC = 0.95)	With clear double glazing, ½" air space, ¼" glass
Drapes (approximate values)		
Dark, open weave	0.77	0.64
Light, open weave	0.67	0.57
Dark, closed weave	0.62	0.54
Light, closed weave	0.47	0.42
Exterior louvered sunscreens (23 louvers/inch)		
Black, profile (shadow) angle 10°	0.35	0.27
20°	0.17	0.11
30°	0.15	0.10
40°	0.15	0.10
Light, profile (shadow) angle 10°	0.33	0.25
20°	0.23	0.16
30°	0.21	0.15
40°	0.20	0.15

Sources: *ASHRAE Handbook of Fundamentals*, 1977, pp. 26.30–26.31 and *ASHRAE Cooling and Heating Load Manual*, 1979, p. 3.33.

Window Design Strategies

Little purpose is served in investing money from home improvements if the effect is simply to shift energy costs from the summer season to the winter season, or vice versa. For example, a plan to use shading to reduce the summer cooling load could increase the winter heating load by blocking beneficial winter sunshine (see section on shading).

In the southern and southwestern states a substantial portion of a home's energy costs is for cooling; thus strategies to prevent heat gain in the summer should be given highest priority. Conversely, in northern states, heating is a predominant cost, and strategies for maximizing solar heat gain in the winter should be emphasized in these regions.

The more costly measures described here must be evaluated carefully to determine if the initial investment can be recovered in a reasonable period of time through reduced utility bills.

All the measures are effective ways of reducing a home's energy consumption while creating a draft-free, more comfortable living environment.