Affordable Housing Through Energy Conservation

A Guide to Designing and Constructing Energy Efficient Homes

U.S. Department of Energy
Assistant Secretary, Conservation and
Renewable Energy
Office of Buildings and Community Systems
Building Systems Division
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In cooperation with:
Applied Science Division
Lawrence Berkeley Laboratory
University of California
and
American Institute of Architects Foundation

June 1989

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Foreword

This guide is part of a set of publications and simplified energy analyses tools that is the result of research done in support of the Residential Building System Integration Research Program, and the Voluntary Energy Conservation Standards for New Buildings. The goal was to develop voluntary guidelines for constructing energy efficient site built housing, that were accurate and easy to use.

The guide consists of four parts:

• The design and construction guidebook that explains how to specify, install, and operate the several energy conservation options that can be analyzed by using an accompanying diskette;

• PEAR, an easy to use software program on a diskette that provides estimates of energy use reductions for selected combinations of options with potential fuel and cost savings;

• The microcomputer program users manual that contains instructions for using the microcomputer diskette; and

• The technical support document that describes the data base, operating assumptions, and algorithms used in the microcomputer program.

This guide, for homebuilders, financial institutions, and others, provides a simple, reliable way to determine the cost effectiveness of different energy conservation options without prescribing a specific level of investment for energy conservation. It allows the user to consider regional differences in climatic conditions, building materials and labor costs, and energy preferences and costs. The data base developed for the guidelines has also been utilized in the Federal Residential Standard for the design of federally owned buildings and in the development of proposed modifications to the residential portion of ANSI/ASHRAE/IES Standard 90A-1980.

The development effort utilized the skills and talents of many individuals and organizations. Their contributions are important to note in terms of any success the guidelines achieve.

Any comments, observations, or thoughts about this guide or related materials will be gratefully received by the authors or program manager.

Marvin Gorelick, Program Manager
Architectural & Engineering Systems Group
Building Systems Division

Acknowledgements

The collective knowledge and creative work of many people and institutions helped shape the content and form of these guidelines for homebuilders, and their efforts deserve recognition.

The program to develop guidelines was initiated by the American Institute of Architects/Foundation under the direction of Earle Kennett with the assistance of Peter Whitehead and Karen Smith.

The guidelines were conceived of and developed by Steven Winter Associates (SWA), Inc. Technical management was provided by Adrian Tuluca with assistance from Steven Bales. Deane Evans, Emanuel Levy, Philip Mitnick, and Cynthia Gardstein each provided overall management and coordination at various stages of the project. In addition, the following SWA staff provided valuable support and critique: Steven Winter, Alex Grinnell, Onaje Jackson, Donald Carr, Bronwen Eastwood, Richard Boshen and Patrice Duggan.

PEAR was developed by Lawrence Berkeley Laboratory (LBL) under the management of Ronald Ritschard and technical direction of Joe Huang. Steven Byrne was responsible for incorporating thermal mass considerations into the program.

Two panels were convened to periodically review and comment on drafts of the guidelines and supporting research. A home builders technical review panel included: Carroll Brock — M.J. Brock and Sons, Inc.; Marlin Grant — Marvin H. Anderson, Inc.; Lawrence Goldrich — The Larry More Organization; James W. Leach — Wonderland Hill Development Company; Leonard Miller — Pasadena Homes, Inc.; David Smith — David C. Smith and Sons; Robert Spies—Robert, Inc.; Richard Tracey — Ryan Homes; Richard Kuchnicki — Council of American Building Officials; Orville Lee — U.S. Department of Housing and Urban Development; Martin Mintz and Michael Bell — National Association of Home Builders.

A separate panel providing a detailed critique of the thermal mass research included: Tamami Kusuda — National Institute of Standards and Technology; George Courville — Oak Ridge National Laboratory; Bruce Wilcox — Berkeley Solar Group; George Barney — Portland Cement Association; Bob Beiner — International Masonry Institute; Arnold Caputo and Bion Howard — National Concrete Masonry Association; Doris Lackey — Masonry Research Foundation; Ed Perazone — Log Home Council and Steven Szoke — Brick Institute of America.

Special mention should be made of the following individuals who provided insight into myriad issues, identifying potential future barriers to adoption of the guidelines by the industry, and posing insightful solutions: Michael McGrath and Joe Van Den Berg with the Edison Electric Institute; Lowell Endahl with the National Rural Electric Cooperation Association; Mark Decker, Robert Lynch and Robert Parr with the National Oil Jobbers Council; Phil Mahla and Rick Kutina with the American Gas Association; Gregory Literis with Gas Research Institute; Walter Johnson with the National LP-Cooling Council; Naresh Koshla with Enviro-Management & Research; Earl Ferguson with Compliance Systems Publications; Alan Davies with the National Institute of Standards and Technology; Andrew Parker with Mueller Engineers; Sharon Rossi with Vitro Laboratories; and John Yellott with John Yellott Engineering Associates.

1 Introduction

Overview

You Can Sell Houses by Selling Energy Conservation

This Guide was created for one basic purpose: to assist the single-family homebuilder to sell more houses by offering options to potential homebuyers that save energy and reduce the cost of homeownership. Today there is a strong link between the overall quality and desirability of a new home and the extent to which it saves energy for its owners. That link has been forged by homebuyers themselves and by today's energy costs.

Many homebuyers are well aware of the big bite that expensive energy can take out of a monthly budget. When they go house shopping, the features they are looking for include more than dishwashers, handsome siding, and all the other quality components. They want thicker insulation in walls, ceilings, and floors; they want energy-efficient windows and appliances. In fact, the National Appliance Energy Conservation Act of 1987 set energy conservation standards for 11 types of household appliances, including space conditioning, kitchen and laundry appliances. Also, many homebuyers see that solar heating can make a lot of sense. What they *do not* want is high monthly energy costs that seem like an "energy mortgage," a burden on top of their home mortgage.

Conservation is the bargain energy source for the eighties and nineties. It economically replaces excessive energy use with efficiency, allowing heating and cooling systems and appliances to provide the same service with less energy. It also makes homes more comfortable and livable year-round. Well-insulated homes are literally warmer in winter. Properly shaded windows can prevent overheating in summer. But the use of these and other energy-saving features in new homes has not always kept up with the demand from the homebuying public.

One of the main barriers is information. The materials and technology are available right now, but information on how and when to properly use them has not been available in a form that homebuilders can readily use, until now. These Guidelines have been specially created to fill this information gap.

As a homebuilder, homeseller, or both, you can make energy conservation an effective marketing tool that can be used right along with a home's other selling points. This Guide helps you do that in a number of ways. The energy-use tools give you a way to make quick estimates of the energy savings created by adding specific conservation features. A wide variety of conservation options for space heating and cooling, domestic hot water heating, and appliances can be considered, and the ones that make the most energy-saving sense for your specific climate, site and application can be quickly identified.

With the economics tools these energy savings can be translated into real dollar savings. In the past energy analysis techniques have been too cumbersome and time-consuming. Some have also been limited by not allowing users to easily compare the benefits of different options. For example, is it better to increase insulation or put in a solar water heater? The answer for your situation can be found using this Guide. It has an easy-to-use microcomputer program called PEAR (Program for Energy Analysis of Residences) that mades quick work of what used to be complicated calculations.

You can use PEAR to examine the energy savings potential of energy conservation options, and then to estimate the economic benefit of implementing these options. Two worksheets included in the accompanying User's Manual allow you to investigate other economic calculations.

The bottom line, of course, is in the comparison of the homeowners' energy-dollar savings with the cost of a given option or package of options. The economic analysis method gives you clear, concise comparisons that you can present to potential customers. While it's true that many homebuyers are wide awake to the realities of high energy costs, there are those who are not aware of the extent to which energy conservation helps to hold the line on home-related expenses (including mortgage, taxes, insurance, and *energy*). The economic facts that are revealed by PEAR and the worksheets will demonstrate convincingly that conservation investments are too good to pass up; they can even be better than money in the bank.

The results you get from these economic analyses can also help homebuyers when they go to a lender for mortgage money. The homebuilding industry is all too aware of the way that increasing new home costs and high interest rates can make monthly mortgage costs rise sharply. Many homebuyers have been priced out of the market because lenders just cannot qualify them. Lenders also see that high energy costs can make matters even worse. If a potential borrower is already going to the limit with a $600 monthly payment for mortgage, taxes and insurance, how can that person manage an additional $200 a month in average energy costs? And how secure will a loan be if energy costs go up?

This is where this Guide can again help to provide some answers by presenting, in black and white, the dollar savings to be achieved through energy conservation. The various conservation options described in this Guide can indeed increase the retail price and therefore the monthly mortgage cost of a home. But the *dollar value* of the energy savings created by these options actually results in a *net reduction* of the monthly mortgage, tax, insurance, and energy payments (compared to the payments for a home without energy improvements). If a certain option will not result in dollar savings, PEAR will tell you.

When potential homebuyers become potential borrowers, this is the kind of information they can truly take to the bank. Many lenders are even offering better financing terms to homebuyers who can show that a new home will be an energy-conserving one. So this Guide really has a variety of uses: it can be used to create a "best" package of energy improvements; the results can then be used as selling points by demonstrating to homebuyers and, in turn, to lenders an increased ability to pay for a home with lower total monthly costs (a home, by the way, with higher resale value).

The Guide is a total system designed to provide the type of energy information useful in selling homes.

Using the Guide

This Guide provides information on energy savings for five basic house types:

Single-Story Ranch

Two-Story

Split-Level

Mid-Unit Townhouse

End-Unit Townhouse

and for three construction types:

Wood Frame

Masonry

Solid Wood

By making full use of the Guide you will be able to make estimates of the dollar savings created by various energy conservation improvements. You will be able to see and show how those savings compare with the price increases that each improvement adds to the retail price of the home. In most cases the savings will outstrip the increases—the basis of a pretty powerful marketing tool. The information can convince buyers that an energy-conserving home ultimately costs less to own and operate, and buyers can use the same information to convince lenders to improve their qualifying status and terms.

The information included in this Guide and the accompanying PEAR computer program provides everything needed to estimate the savings and costs for conservation options in over 1000 specific locations throughout the 50 states. These options for saving energy in new single family homes can be grouped into three categories: space conditioning (that is, space heating and cooling), domestic hot water heating, and appliances.

Space Conditioning

The space conditioning section is where the PEAR microcomputer program comes into play. If the words "computer program" conjure up visions of complicated mathematics, you can lay your fears to rest. This program is easy to use and specifically designed for estimating energy savings. There is little chance for confusion or error in its use and the results will be trustworthy.

PEAR can be used to estimate the energy savings associated with a large number of options that fall into the space heating and space cooling category. But the energy savings estimates will only be accurate if the options ultimately selected are carefully and properly constructed in the field. To that end, Chapter 2, presents suggested techniques and construction tips that will aid in selecting, specifying, and constructing the various space conditioning options that are discussed. This "nuts and bolts" information will help ensure that PEAR's predictions of energy savings are actually achieved.

The information in Chapter 2 is divided into ten areas:

- Ceiling insulation
- Wall insulation
- Floor/foundation insulation
- Air infiltration
- Windows
- Shading
- Movable insulation

- Passive solar heating
- Equipment
- Fans

These categories, and the options included in each, encompass major opportunities for building energy conservation into new homes. As such they are likely to be highly attractive to homebuyers in search of an energy-efficient home.

Domestic Hot Water Heating and Appliances
Chapter 3 covers the conservation options for domestic water heating and appliances. The procedure for estimating energy savings for options in both the Domestic Hot Water and Appliances categories makes use of the EnergyGuide labels attached to most major household appliances. The energy-use information from these labels is then plugged directly into PEAR. All in all, short work can be made of these energy savings estimates.

Putting it All Together
It is one thing to be able to examine the energy savings potential of options in three distinct categories, but it is much more useful to look at all the options as a total group, comparing individual costs and energy savings values, and ultimately assembling individual options into packages to be offered to the homebuyer. The "Economics Input" section of the User's Manual for PEAR does just that with a goal of helping to determine which individual and groups of options are the most cost effective and marketable when considering *only* their cost and energy-dollar savings.

The following list summarizes the steps this Guide takes toward helping pick the right conservation options for the homes you build.

- Construction details and tips for energy conservation options which reduce space heating and cooling loads are introduced and explained (Chapter 2).

- The advantages of installing energy conserving domestic hot water systems and energy efficient appliances are reviewed (Chapter 3).

- An easy-to-use computer program, PEAR, is provided to estimate the energy conservation potential of options in three categories: space conditioning, domestic water heating and appliances.

- Instructions for using PEAR are provided in the accompanying booklet, "PEAR 2.0 — Program for Energy Analysis of Residences, USER's MANUAL".

- An economic analysis included in PEAR and explained in the User's Manual gives you and prospective home buyers the most useful information needed to sell and finance both individual options and option packages.

(Since its use is closely linked to the remainder of this booklet, it is suggested that you briefly review PEAR User's Manual before continuing with this Guide.)

2 Space Conditioning

Introduction

Space Heating and Cooling: The Biggest Piece of the Conservation Pie

In most areas of the country space heating and cooling energy use can account for the greatest share of the total energy use in the home. So it naturally follows that the lion's share of conservation opportunities are found in this category. The basic goal in selecting space conditioning conservation options is to minimize the energy requirements which must be met by furnaces, boilers, space heaters, baseboard systems or heat pumps for heating, and air conditioners and heat pumps for cooling. Achieving that goal can be as simple and easy as adding more insulation or as comprehensive as a "redesign" of the entire home, from the ground up.

A home should be thought of as a total energy system whose main purpose is to provide comfort (heating and cooling) and convenience (hot water and appliances). This chapter divides the "comfort system" into ten parts, each part having its own set of energy conservation options. Each option contributes to making the home more efficient, providing the same comfort with lower energy requirements. These options fall into one of the following categories:

- Ceiling insulation
- Wall insulation
- Floor/foundation insulation
- Air infiltration
- Windows
- Shading
- Movable insulation
- Passive solar heating
- Heating and cooling equipment
- Fans

For each of the options presented in these areas, the essential selection, construction, installation, and specification information is provided. Exhaustive detail, however, is not within the scope of this Guide, and for a couple of reasons the discussions of these options have been kept deliberately general.

First, it goes without saying that there is usually more than one correct way to detail construction. What really matters is that the general intent of the information presented for a given option is followed to ensure the energy savings, predicted by PEAR, are achieved.

This brings up a second reason for the overview approach to these options. With further research and/or your own experience you may find proven techniques or products that are not covered in this Guide. If they are appropriate, proven and effective then there is every reason to use them. This Guide does not, by any means, cover all of the options for conserving energy, and the options which are covered should serve as springboards for continued innovation.

Finally, a note about heating and cooling equipment: In addition to energy conservation standards required by law for these products, energy and cost savings associated with various options can be determined using EnergyGuide labels. Energy efficiency rating labels were developed to allow comparisons among competing models of central air conditioners, including heat pumps, that are distributed in the United States. Central air conditioners and heat pumps are required by law to carry a label and manufacturers are required to have available directories or fact sheets providing further information on equipment efficiency and operating cost. Furnaces also are required to carry a label. These labels contain general energy conservation information and include availability of the manufacturer's fact sheet containing the efficiency of a particular model along with the efficiencies of the highest and lowest efficiency model within a range of similar capacities, and gives energy costs of the system for various heating loads and utility rates.

Ceiling Insulation

Increasing the amount of ceiling insulation is very effective for minimizing heat loss through the roof of a home. And, it provides more than just heating season benefits. In summer, having extra ceiling insulation also reduces unwanted heat gain through the ceiling into the home.

No matter what the actual material, insulation is typically described in terms of its *R-value*. This is a number that represents a resistance to heat flow, with a higher number indicating a greater resistance value and thus a slower rate of heat flow through the ceiling.

R-value is a standardized measurement that is used by insulation manufacturers on their product labels. Ceiling insulation is available in a wide range of R-values and also in a wide range of forms including short batts, long rolls, and loose fill varieties for pouring and blowing into ceilings. The materials that are most commonly used today include glass fiber (batts, rolls, loose fill), mineral wool (loose fill), cellulose fiber (loose fill) and a variety of plastic insulating products (loose fill and rigid and sprayed foams). It is important that insulation not be compressed when it is installed, as this reduces the actual R-value at the point of compression. For example, a piece of fiberglass insulation that is rated at R-19 at a six-inch thickness will only provide about R-10 insulation value if compressed to a three-inch thickness. One place where such compression is often unavoidable is at the eaves, although there are construction details that allow insulation to "loft" to its full thickness even at this location.

Construction Considerations

• Ceiling insulation should be installed to be as continuous a blanket as possible. Ceiling penetrations are of course unavoidable, but openings can be detailed for fans, flues and other vents so that the insulation tightly surrounds them (see Figure 2.1). Any voids or openings between these penetrations and the insulation will provide passages for increased heat flow. In some cases the heat loss caused by these voids can negate the energy-saving value of several square feet of insulation! Some penetrations such as flues from stoves, furnaces or boilers, however, will not allow close packing of the insulation for reasons of fire safety. For these cases you should check manufacturer's installation instructions and local codes for specific detailing requirements.

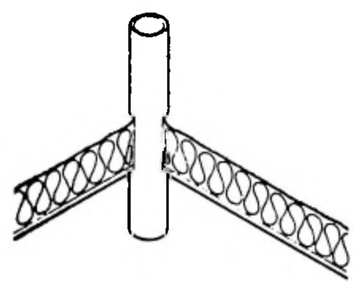

Figure 2.1

igure 2.1 Reducing heat flow t ceiling penetrations. The ceiling insulation should be tightly wrapped around ceiling penetrations (such as pipes) for added thermal protection in the ceiling.

Some types of recessed light fixtures must also be left uncovered and untouched by insulation because of the heat they trap from light bulbs (see Figure 2.2). Yet again, this hole in the insulation blanket can be a source of significant heat loss in cold weather and heat gain in warm

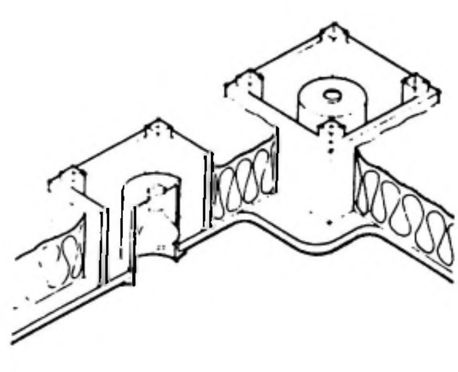

Figure 2.2

igure 2.2 nstallation of recessed light fixtures. minimum of 3" must e provided between on-labeled fixtures and e surrounding material. Insulation must not e placed above such tures.

weather. The problem can be avoided completely by specifying nonrecessed fixtures or recessed fixtures that allow insulation to be placed right up to them. Most electrical equipment suppliers can provide guidance on the availability of these types of recessed housing. If specified, the manufacturer's installation instructions should be carefully followed.

• Moisture control is very important for maintaining the maximum R-value of a given type of insulation. Water vapor is generated in the living space by people and such activities as cooking. Much of this vapor rises through the ceiling and can condense in the insulation and reduce its effective R-value. One of the most effective ways to remove this moisture is through the use of *continuous soffit* and *ridge vents.* A soffit and ridge vent system is useful when insulation is installed either in standard or cathedral ceilings. In either location a minimum 1-inch air gap between the insulation and the underside of the roof must be provided so as not to block the movement of the ventilating air that carries away the moisture. To ensure air movement between the soffit and the ridge, special baffles can be used that are placed between the roof truss chords (see Figure 2.3). If these manufactured baffles are not available in your area, other options such as chicken wire or other mesh stapled to the rafters can be employed. The goal here is simply to ensure that the insulation near the eaves is compressed just enough to allow air flow. If gable end vents are specified, it is important that insulation not be allowed to block these vents. In all cases a free flow of air must be maintained (see Figure 2.4).

Cathedral ceilings should be as well insulated as all other ceiling sections, and there are a number of ways to achieve this with the use of batts and/or rigid foam insulation (see Figure 2.5). One advantage of using rigid foam insulation between rafters and roof sheathing is that the foam cuts off a potential "thermal bridge" for heat loss through the rafter itself. Heat travels faster through solid wood than through insulation, and if you can interrupt that flow with a layer of foam, you will be increasing the overall R-value of the entire roof construction.

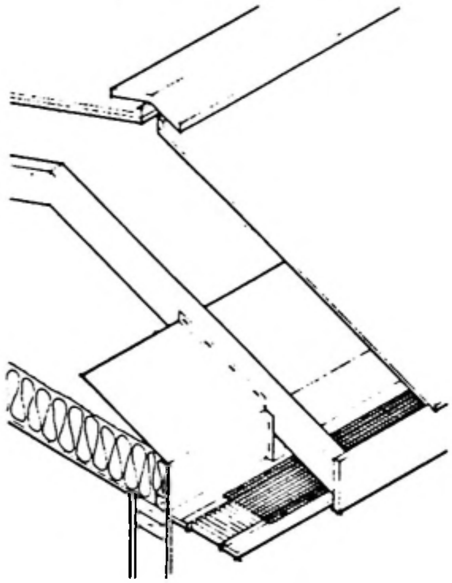

Figure 2.3

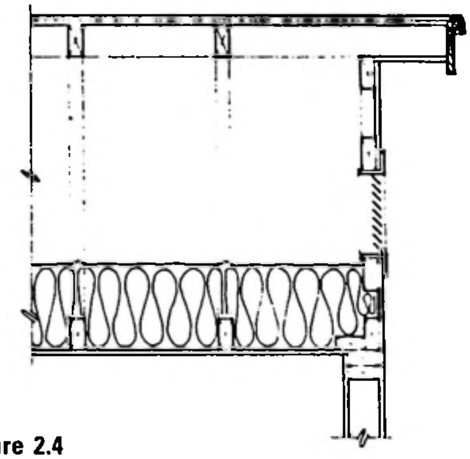

Figure 2.4

Figure 2.3
Compressing the insulation for adequate venting. In soffit and ridge vent systems baffles can be installed to provide a continuous air space above the insulation.

Figure 2.4
Insulation at gable end vents. To prevent blockage of the gable end vents by the insulation gable end vents should be installed above the top of insulation or the insulation should be compressed below the vent.

Figure 2.5
Insulation at cathedral ceilings. Four basic techniques are shown for the effective installation of insulation at cathedral ceilings.
- a: Standard batt insulation. A 1" airspace is provided for ventilation.
- b: Batt insulation has been installed above tongue and groove ceiling panels. A 1" airspace is provided for ventilation.
- c: Rigid insulation installed above tongue and groove paneling. Roofing is installed on furring strips above insulation.
- d: Rigid insulation installed above paneling in log construction.

Figure 2.6
Batt insulation at truss chords. Batt insulation should be installed so that bottom chords of roof trusses are covered reducing heat flow through the ceiling.

Figure 2.7
Blown-in insulation. An even layer of blown-in ceiling insulation results in complete coverage of roof truss chords.

Figure 2.8
Insulating attic access door. Insulation is placed over access door with tight edge fit.

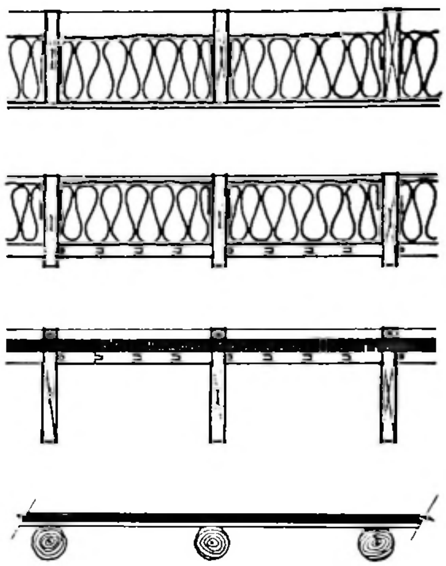

Figure 2.5

• To further reduce heat flow through the ceiling, it is important that the insulation be installed so that it completely covers the bottom chords of all the roof trusses. If batt or roll type insulation is used, it will be important to specify the proper width to ensure this total coverage and to minimize installation labor costs (see Figure 2.6).

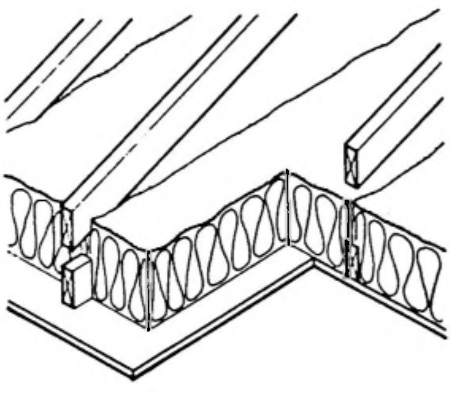

Figure 2.6

• If blown-in or loose-fill insulation is specified be sure that coverage is of a uniform thickness across the entire ceiling surface (see Figure 2.7). Of course, the manufacturer's recommendations should be followed regarding minimum thickness and minimum weight per square foot in order to achieve the desired R-value.

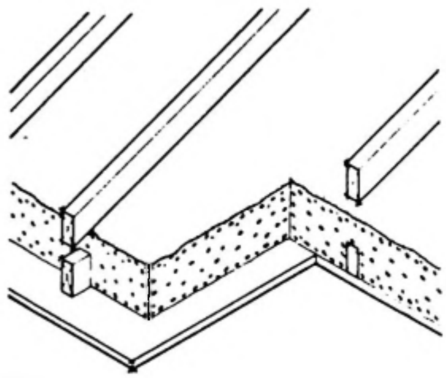

Figure 2.7

• If the home has an attic access door, it is just as important to have it insulated as it is for any other part of the ceiling. Layers of rigid foam insulation can be used to create an R-value that is equal to that of the rest of the ceiling insulation. A cut piece of batt or roll type insulation can also be used. Whatever insulation is used, it should be brought right to the edge of the hatch to minimize the air gap between it and the surrounding framing (see Figure 2.8).

• In some locations it will be cost-effective to use relatively high levels of insulation in ceilings. Yet with standard construction details, deep insulation (providing R-values of over R-30) will usually be compressed where the roof

Figure 2.8

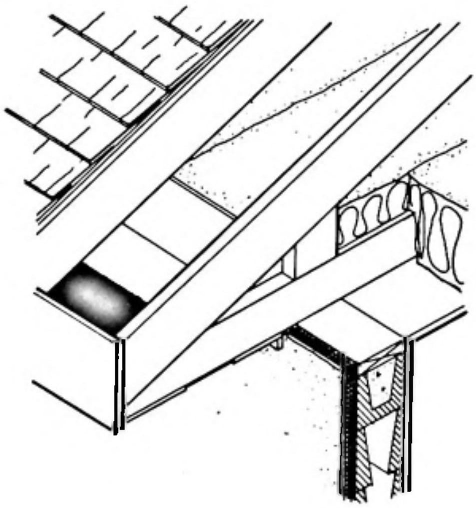

Figure 2.9a

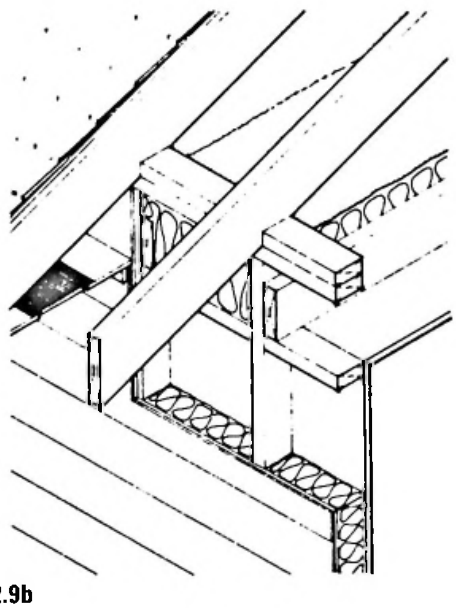

Figure 2.9b

rafters pitch down to the vertical walls. As has been mentioned, this compression both reduces actual R-value and cuts off the necessary flow of ventilation air (when soffit and ridge vents are used). The solution in truss construction is to increase the heel height of the truss (see Figure 2.9a). In sitebuilt construction the rafters can be

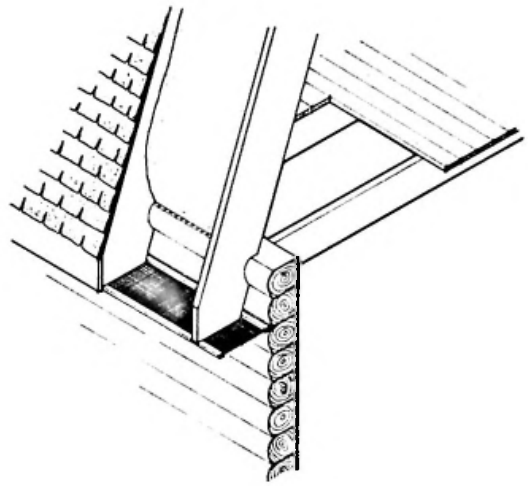

Figure 2.10

raised up through the use of a knee wall or longer wall studs (see Figure 2.9b). In gambrel-type roofs, insulation is placed directly in the rafter cavity (see Figure 2.10).

Figure 2.9a
Providing additional height for insulation at eaves. Trusses can be specified with highe heel height to accommodate thicker batts without compression a the eaves.

Figure 2.9b
Providing additional height for insulatio Using longer studs for wall framing while maintaining a standar ceiling height provide a deeper eave dimension avoiding insulati compression in site-built roof construction.

Figure 2.10
Gambrel roofs. Oft encountered in log struction gambrel r place insulation in rafter cavity.

The R-values you input into PEAR must correspond to R-values that are listed by the manufacturer for the insulating material *only*. You should *not* include or add any insulation value for other building materials such as shingles or drywall.

The following table presents examples of R-values associated with specific construction suggestions. However, PEAR will accept any insulation R-values between 0 and 60. These suggestions are made in addition to any that may have been recommended by the manufacturer and to the construction considerations previously discussed.

Insulation R-Value	Construction
R-11, R-19, R-22	Standard roof construction details can be used for insulation levels in this range.
R-30, R-33, R-38, R-49, R-60	Construction details at the eaves must be designed to minimize compression of the insulation. Higher heel heights can be specified for truss construction, or raised rafters can be developed for site-built construction using knee walls or longer wall studs.

Wall Insulation

In frame construction, walls are most commonly insulated with batts or sections cut from roll tye insulation. When a highter R-value is desired, batts and roll sections are used in combination with rigid insulating boards. The batts fill the stud cavities in frame walls, and the rigid insulation is nailed onto the outside or inside of the wall studs. Some builders have been successful with the use of sprayed foam insulation in the stud cavities, with rigid insulation fastened to the studs. An innovative technique such as this should, of course, be researched and verified before being incorporated into the home.

In masonry construction, rigid insulation can be applied directly to the exterior wall surface or inside the cavity in double wythe or veneer construction. Likewise, rigid or bat insulation can be applied on the inside wall surface covered by some form of interior finish. The cores of the masonry units can also be insulated with rigid inserts, fills, or foam. The insulating value of solid wood walls can also be augmented by the addition of insulation.

Wall insulation materials are available in a wide variety of thicknesses providing a wide range of R-values. In order to get the most energy-saving value from the insulation, proper construction detailing and installation are a must. This cannot be overemphasized. As with ceiling insulation, for example, compression of the insulation must be avoided or there may be significant reductions in the actual R-value of a given wall section. Along with proper construction detailing, this is a case where on-site supervision of the actual installation may be the best way to ensure that desired R-values are achieved.

Installers should also take special care to ensure that the insulation is fit tightly around any wall penetrations for such items as vents or outlets. These penetrations provide a path for some heat flow, but those effects can be minimized with careful attention to detail. Any penetrations that do occur should be well sealed, as well as thoroughly surrounded with insulation.

Wall construction is generally divided into two groups: standard frame walls of light construction and heavy weight walls that are built with either masonry or solid wood materials. These heavy weight walls present a special case. The mass in these walls can result in heating and cooling energy savings which will vary depending upon building design and climate. Using just the R-value of such walls has been shown to often over estimate the extent of these savings. The benefit is usually greatest with mass walls that are insulated on the outside or, as in the case of solid wood walls, where a single material provides both insulation and mass benefits. Location of insulation on the inside surface of mass walls significantly reduces the potential benefit of these walls in most climates.

As mentioned above, the amount of benefit derived from mass walls is also strongly influenced by climate. Generally, buildings in climates with large daily temperature swings, where the outside temperature fluctuates above and below the thermostat setpoint, will benefit most from the mass. Particularly advantageous are areas experiencing hot days and cold nights for extended periods of time.

Construction Considerations for Frame Walls

- In standard frame construction where batt or roll insulation is placed between the studs, the studs act as a "thermal bridge," an effect mentioned previously in the discussion of roof rafters in cathedral ceilings. For example, a 2 × 4 stud wall cavity can be insulated with R-13 batt insulation, but the stud itself has an R-value of only about 4.4. Heat can thus pass much more easily through the studs and significantly decrease the overall R-value of the wall. The thermal bridge, however, can be eliminated by adding rigid board insulating sheathing over the inside or outside of the studs.

• Additional framing lumber, such as would be used to support cabinetry or partition intersections, also acts as a thermal ridge. Components such as entry chimes and medicine cabinets should, for the same reason, be kept off of exterior insulated walls and placed on interior partitions.

• If metal studs are specified, insulation can be placed in the opening of the metal studs as well as in the cavities between the studs to provide as continuous a blanket of insulation as possible (see Figure 2.11). This will partially off-set the energy losses due to thermal bridging which is increased because metal conducts heat quite rapidly.

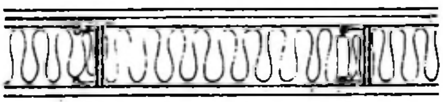

Figure 2.11

• Wall penetrations that are made by such elements as vents or piping should be detailed so that they are completely surrounded by insulation (see Figure 2.12). Rather than compressing the insulation which will decrease in R-value around the compressed area, the insulation should be carefully cut to fit around the penetration. When an exhaust flue from such sources as stoves, furnaces or boilers passes through the wall, it may not be advisable to use this detailing due to potential fire safety problems. The manufacturer's installation instructions and local codes should be consulted for specific requirements in these cases.

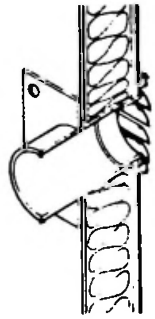

Figure 2.12

• Problems are even more likely to be encountered with compression of the insulation by water pipes and air ducts. First try to minimize their placement in the exterior insulated walls. But in cases where this is unavoidable, the insulation should be continuous around pipes and ducts where not restricted by the local codes or standards. However, continuous insulation around these components will likely result in compression and decreased R-value. You may be able to limit this compression by cutting the insulation (not the paper or foil vapor barrier) so that it literally envelopes the water pipe, or by surrounding a run of ductwork with a rigid foam insulation that has a higher R-value per unit of thickness than does the batt insulation.

• Wall insulation can also be compressed by electrical outlets. When an outlet must be placed in an exterior wall, be sure that the insulation is continuous around each electrical box (see Figure 2.13).

• Along with electrical outlets, the wiring runs themselves can cause compression of the insulation. Again, it may be possible to minimize or even eliminate the need for wiring in exterior insulated walls. But when such wiring runs are unavoidable, the batt can be cut so that it envelopes the wiring. Care should be taken so as not to cut the paper or foil vapor barier, and

igure 2.11
nsulating at metal tuds. For maximum overage the insulation s placed within the tud.

igure 2.12
educing heat flow t wall penetrations. sulation is installed so s to tightly surround enetrations reducing at flow through the all.

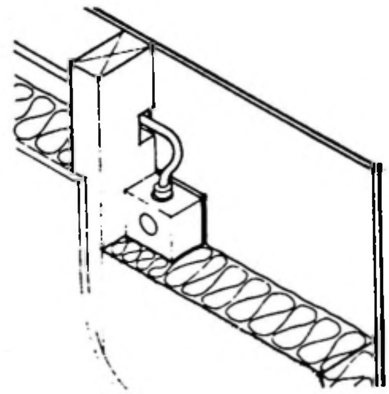

Figure 2.13

to tape it up if it is cut. Another option is to run the conduit along the surface of the wall through precut notches on the inside faces of the studs, close to the floor level (see Figure 2.14). These surface notches should then be covered with a metal plate to prevent penetration of the wire by a drywall or other nail. Wiring can also be run through precut notches in the bottom of the wall studs (see Figure 2.15). In the same way, a groove could be cut into the top face of the bottom plate (see Figure 2.16). A fourth method involves running wires through the floor joists below the stud wall (see Figure 2.17).

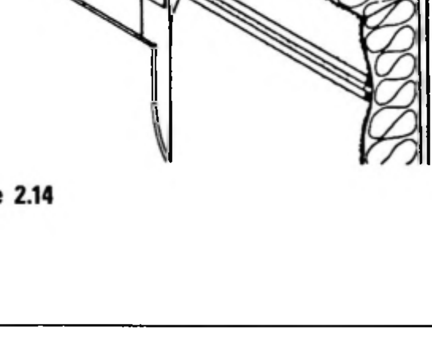

Figure 2.14

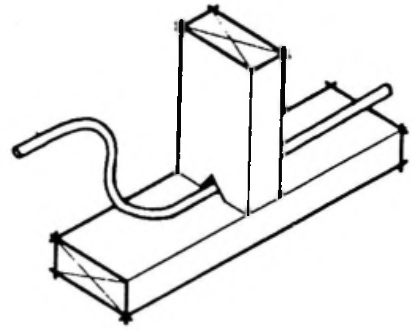

Figure 2.15

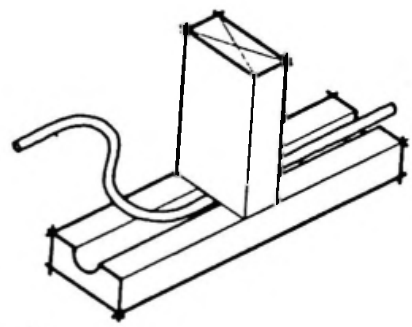

Figure 2.16

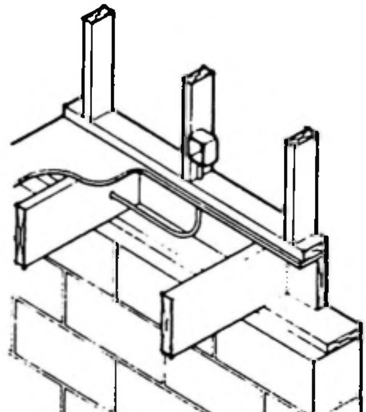

Figure 2.17

Figure 2.13
Compression of in-sulation at electric outlets. If location o electrical outlets is u avoidable on the exte rior wall, insulation c be placed behind the outlets providing son thermal protection.

Figure 2.14
Wiring in exterior walls. Wiring can b placed on the interio side of the studs rec ing the extent of ins tion compression. M plates will have to placed over the not in the studs to prot the wiring.

Figure 2.15
Notching at stud Wiring can be run notch at base of stud to minimize tion compression

Figure 2.16
Providing a gr bottom plate. can be run in a in the bottom p minimize insula compression.

Figure 2.17
Wiring belo Another meth ning wiring w compressing tion is to run duit through joists.

Figure 2.18
Installation of insulation in exterior walls. Three basic techniques are shown for installing exterior wall insulation to reduce buckling and settling.
a: Kraft paper tabs of faced insulation stapled to side of studs.
b: Kraft paper tabs of faced insulation glued to stud edge.
c: Unfaced insulation batts are wedged or 'friction fit.'

Figure 2.19
Exterior corners and wall intersections. Two methods are shown for constructing both corners and intersecting walls.
a: Three-stud corner with some insulation compression.
b: Two-stud corner allows for full insulation. Special clips must be provided for installing drywall (preferred detail).
c: Wall intersection using 2 × 4 stud and 1 × 6 backer.
d: Two-stud intersection allows for more insulation coverage. Drywall clips are required.

Figure 2.20
Insulating headers. A rigid board insulation is provided between headers to reduce heat flow.

• When installing batt or roll type insulation, make sure that it fits tightly, but without excessive compression between the studs. Proper stapling or other fastening is of great importance to prevent buckling or settling which over time will degrade performance (that is, lower the effective R-value) because of gaps in the insulation (see Figure 2.18).

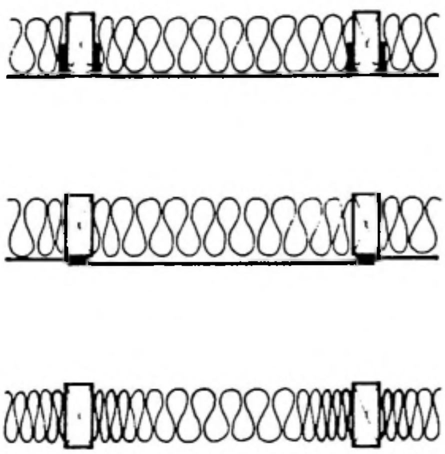

Figure 2.18

• Exterior corners and the intersections of interior and exterior walls can be designed to minimize the interruption of the insulation by framing lumber. Both corners and wall intersections can be built with either two or three studs (see Figure 2.19). When two studs are used in these details, special clips are required for securing drywall at the inside corners. (Note that the construction is slightly more energy efficient when the two stud methods are used.)

• In certain conditions rigid board insulation used as an exterior sheathing in cooler climates could act as a vapor barrier on the cold side of the wall and cause water vapor to condense in the stud wall cavity. The presence of condensed water in batt or roll type insulation can significantly reduce its effective R-value and lead to

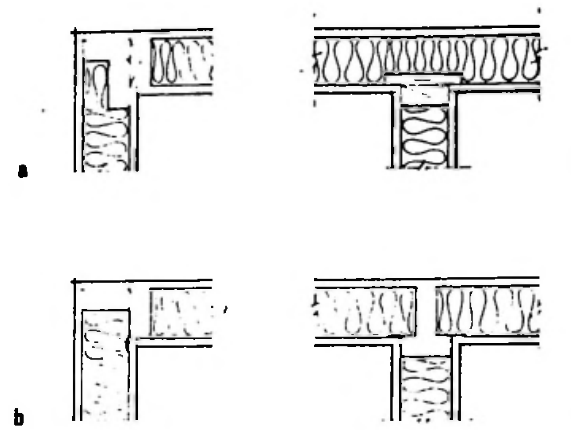

Figure 2.19

rotting of framing members over time. This problem may exist even if there is a vapor barrier installed in the proper place on the warm side of the wall. The insulation manufacturer is likely to have developed appropriate installation methods to reduce the chance of condensation occuring within the cavity. In addition, consult any permeability requirements that are specified in local building codes.

• A significant but often ignored source of building heat loss occurs through headers above

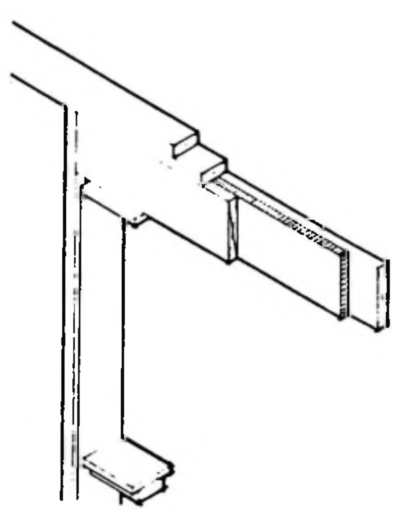

Figure 2.20

window, door and other openings. You can limit this loss by using a piece of rigid insulation at the header between blockings (see Figure 2.20).

Construction Considerations for Masonry Walls

• Where rigid insulation is installed behind or between masonry exterior walls, a 1" minimum airspace should be provided between the insulation and the exterior wythe of masonry. This will ensure that any moisture trapped by the masonry will not degrade the insulation, but rather it will accumulate at the bottom of the air space and will run out through weep holes (see Figure 2.21). The bottom of the air space must be properly flased.

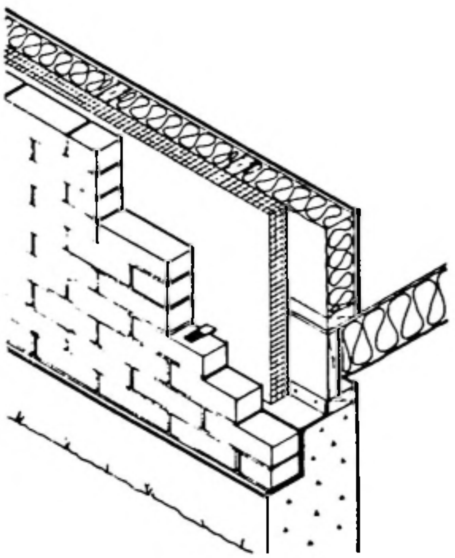

Figure 2.21

Loose fill or foamed-in-place insulation can also be used in cavity wall construction. Local codes and manufacturer's recommendations should be consulted for further information on these products.

For this type of construction flashing and weep holes should also be provided for the removal of moisture. An air space is not required, but weep holes should be wicked to ensure that moisture is not trapped if weep holes become clogged.

• Insulation is often placed in the interior of masonry construction. This can be accomplished using batt insulation (see Figure 2.22a) or rigid

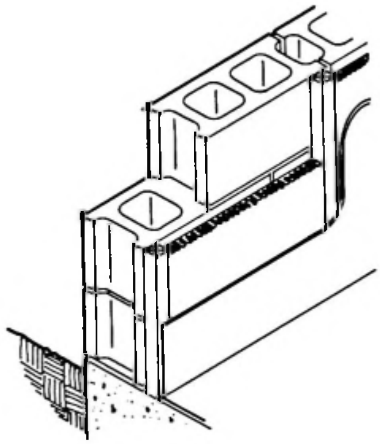

Figure 2.22a

boards (see Figure 2.22b). Reflective backed wall finish materials with an air space behind can also be effective.

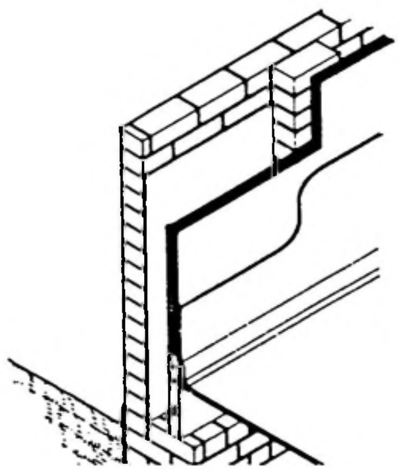

Figure 2.22b

Figure 2.21
Providing ventilation in masonry walls. Collected moisture will escape through weep holes typically placed 24" on center.

Figure 2.22a
Typical interior insulation placement. Solid masonry wall is insulated with batts or boards secured to furring strips and covered with interior finish material.

Figure 2.22b
Rigid board interior insulation. Insulating boards span between and are secured to masonry piers. Interior finish is installed over the insulation.

As was previously mentioned the use of exterior insulation with masonry construction can be even more effective in reducing the total energy use of a home. When exterior rigid insulation is used on a masonry wall, it is usually adhered directly to the masonry with a special adhesive or fasteners made for the purpose. Special care should be taken during the installation of the rigid boards to avoid crushing them which would reduce the R-value (see Figure 2.22c).

Whether applied to the exterior or interior face of the wall, an uninterrupted layer of insulation has the advantage of minimizing the thermal bridging that can occur in masonry walls across the webs of individual masonry units.

- When a masonry cavity wall is used, the insulation is applied to the exterior surface of the interior wythe of masonry. As mentioned, you should be sure to provide flashing and weep holes in the exterior masonry wythe (see Figure 2.22d).

Masonry walls can also be insulated by placing

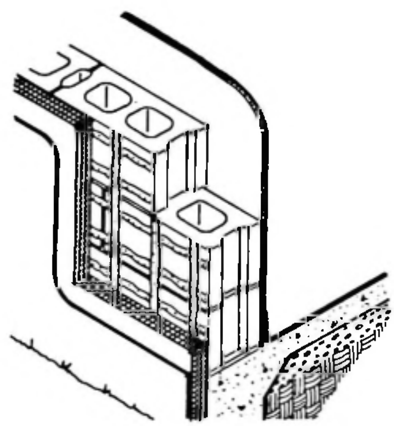

Figure 2.22c

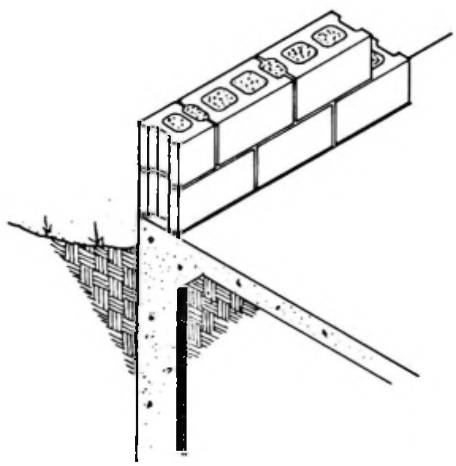

Figure 2.23a

Figure 2.22c Exterior masonry wall insulation. Rigid insulation is installed with adhesive to masonry and covered with stucco or other suitable finish material. Rigid insulation must be protected from exposure to sunlight.

Figure 2.22d Insulating a masonry cavity wall. Air space, flashing and weep holes are provided to ensure drainage of trapped moisture.

Figure 2.23 Insulating the cores of masonry units.
a: Loose fill or foamed-in-place insulation can be placed in the cores.
b & c: Rigid insulation inserts can be installed in the cores of masonry units.

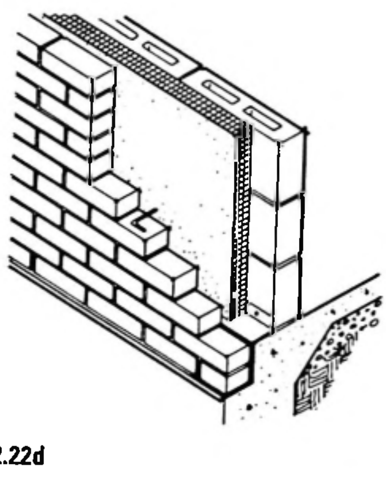

Figure 2.22d

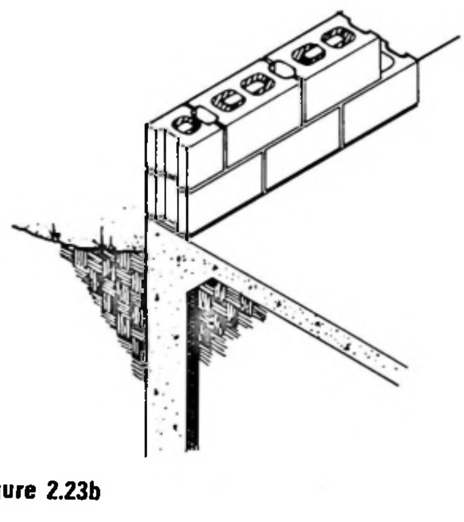

Figure 2.23b

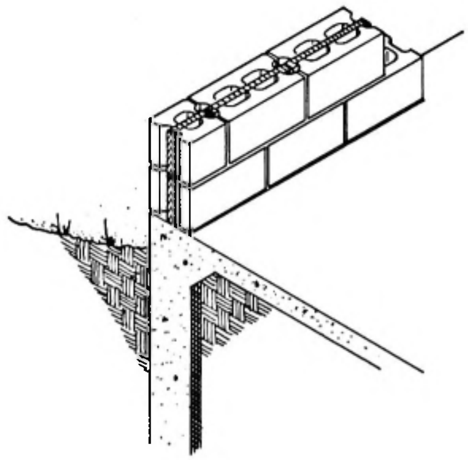

Figure 2.23c

loose fill insulation, foamed-in-place insulation or premolded rigid foam insulation inserts in the cores of the masonry units themselves. (See Figure 2.23) The overall effectiveness of core insulation may be reduced in those situations where fully grouted cores are required for structural reasons. Consult local codes for such requirements.

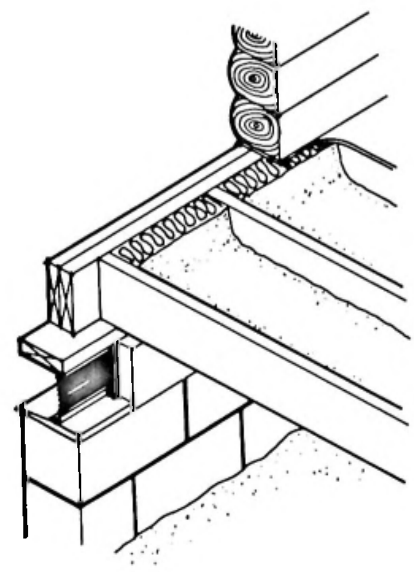

Figure 2.24

Solid wood walls may require no insulation beyond that provided by the wood. (See Figure 2.24) When additional insulation is required, solid wood walls can be insulated in several ways. When insulation is placed on the inside, batt insulation can be used with furring strips, or rigid insulation can be applied directly to the solid wood wall (see Figure 2.25a). When a solid wood cavity wall is used insulation can be applied to either the interior or exterior wood

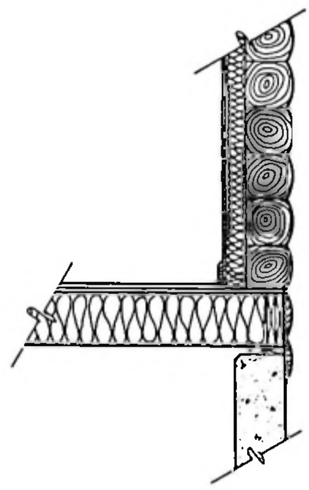

Figure 2.25a

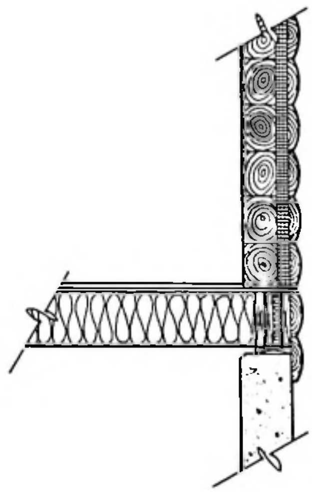

Figure 2.25b

Figure 2.24
Uninsulated Solid Wood Walls

Figure 2.25
Insulating solid wood walls.
a: Interior insulation
b: Cavity insulation

course. Cavity walls built of properly dried wood usually will not need airspaces, weep holes or flashing, but manufacturer's literature and local codes should be consulted for specific applications. (See Figure 2.25b)

With either wood or masonry cavity walls, the energy benefits of mass will be enhanced if the majority of the mass is inside the insulation.

In masonry construction the cores can also be insulated with rigid board insulation.

The R-values input into PEAR must correspond to R-values that are listed by the manufacturer for the insulating material *only*. You should *not* include or add any insulation value for other building materials such as siding or drywall. Where R-values vary due to different construction of opaque walls, an average R-value should be used.

The following table presents examples of R-values associated with specific construction suggestions. However, PEAR will accept any insulation R-value between 0 and 27. These suggestions are made in addition to any that may have been recommended by the manufacturer and to the construction considerations previously discussed.

Insulation R-Value	Construction
R-11, R-13	Standard construction and installation procedures for insulated 2 × 4 stud walls, insulated load-bearing masonry walls, and solid wood walls are satisfactory for achieving insulation levels in this range.
R-19	In standard wood frame construction this level of insulation can be achieved in two ways: by combining 2 × 4 stud wall cavity insulation (batts, rolls) with an insulating sheathing, or by using 2 × 6 stud wall construction with cavity insulation only. Rigid insulation can be placed on either the interior or the exterior of the wall studs, but local building codes may list fireproofing requirements for applications using interior insulation and should be consulted. Interior or exterior insulation can also be added to masonry or solid wood walls. In masonry construction, an increased space may be required behind veneer or between wythes to accommodate increased insulation thickness. The cores of masonry units can also be insulated.
R-24, R-27	In standard wood frame construction these levels of insulation can be achieved with 2 × 6 stud wall construction that combines cavity insulation with an insulating sheathing applied to the interior or exterior of the wall. Again, consult local building codes for special fireproofing requirements for interior insulation applications. These insulation levels may also be achieved in masonry and solid wood construction by specifying combinations of differing types of insulation.

Mass Walls

An explanation of how mass walls are used in PEAR can be found in Table 2 "Conservation Measure Input" in the User's Manual and should be used for walls using either masonry or solid wood construction. This input option is necessary because of the combined effects of mass and insulation in heavy weight walls.

Floor/Foundation Insulation

There are several appropriate types of materials and methods for insulating floors and/or foundations. Selection will depend on whether the home is to be built on a slab on grade, or with a joist floor over a crawl space or a basement that is either heated or unheated. Of course, some homes, such as split levels, are built with more than one foundation type, in which case a combination of materials and techniques will be used.

Construction Considerations

Slab-on-Grade Foundations

• Concrete slabs cast on grade are usually insulated with a rigid foam insulation which is impervious to moisture such as extruded polystyrene. It can be placed on the exterior of the slab along the foundation wall to a depth that is below the frost line. Or, it can be placed inside the foundation wall under the slab in a perimeter band that is two to four feet wide. Since the edge of the slab can act as a thermal bridge for heat loss through the foundation, the exterior application is actually more effective than the under-slab method. The exterior insulation results in more complete coverage of the foundation, providing continuous thermal protection

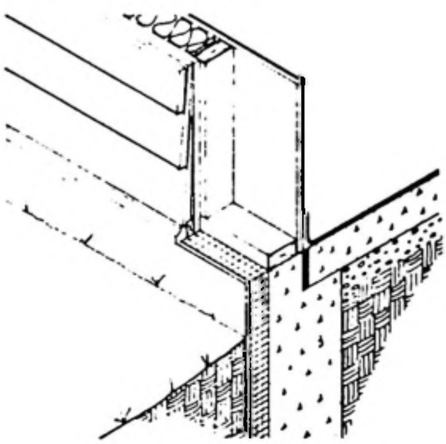

Figure 2.26a

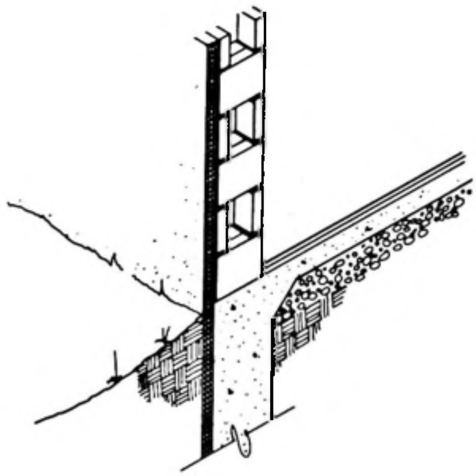

Figure 2.26b

(see Figure 2.26a and b). The actual depth to which the exterior insulation should be put will vary with local climate conditions, but the typical range is from two to four feet deep.

• When you install the insulation, care should be taken to avoid crushing or puncturing it, particularly during backfilling. It is also very important to cover the foam as soon as possible with a finish coating to prevent it from being degraded by sunlight. This type of exposure will, over time, reduce the R-value of the insulation.

Floors Built over Unheated Crawl Spaces

• When this type of construction is specified, it will be important to place a minimum of four foundation vents around the foundation wall. Local codes may vary, and a check of the specific local requirements will be necessary. The purpose of these vents is to provide an outlet for moisture, which could otherwise collect in the insulation (typically batt or roll type) and reduce its "effective" R-value (see Figure 2.27).

• Sometimes the spacing between two floor joists will be less than the standard widths of batt or roll insulation. When you insulate these spaces, it is important to cut the batt to fit

Figure 2.26a Insulating a slab-on-grade foundation. Insulation is shown on the exterior of the foundation of a frame wall (preferable to under slab insulation). Above grade rigid insulation must be protected.

Figure 2.26b Example of foundation and masonry wall insulation. Above grade rigid insulation must be protected.

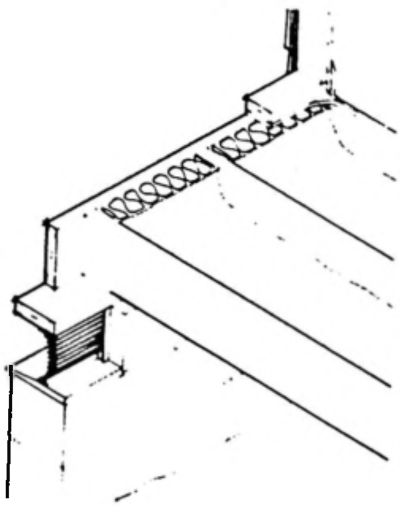

Figure 2.27

ˈigure 2.27
ˈentilated crawl ;paces. Vents are pro-ided to promote air ıovement for the re-ıoval of moisture.

tightly but without compressing the insulation. As has been mentioned, compressing the insulation will result in a reduction in "effective" R-value (see Figure 2.28).

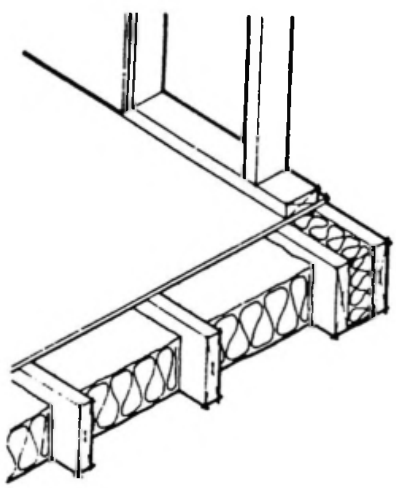

Figure 2.28

igure 2.28
ısulating irregular paced joists. Batts ıould be cut to fit ghtly between irreg-larly spaced joists for ısulation coverage.

• As with the walls and ceiling of the home, any penetrations of the floor by such items as pipes, ducts and wires should be completely surrounded by insulation, though again, insulation compression should be avoided. In certain cases, such as when the flue from a stove, furnace or boiler penetrates the floor, this particular detailing may not be advisable because of fire safety considerations. Detailing should conform to manufacturer's installation instructions and to local codes.

• Providing insulation at the rim joists is very important for achieving the full energy-saving benefit of floor insulation. The insulation coverage should be to the full height of the floor cavity. This is typically done by simply fastening a separate piece of insulation to the rim joist and draping it down to the top of the foundation wall (see Figure 2.29). As an alternative, the

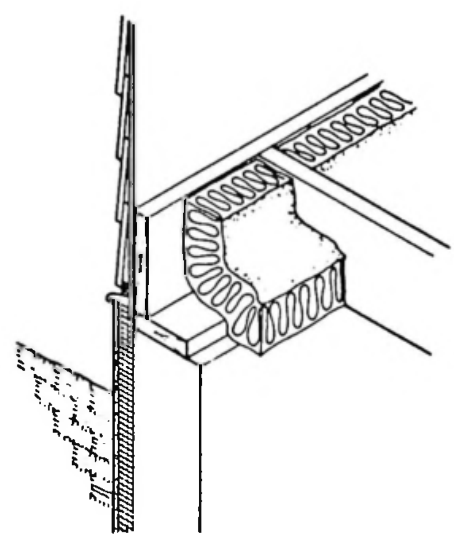

Figure 2.29

igure 2.29
ısulating the rim ist. A special piece of sulation should be cut ıd applied to the rim st.

insulation batt can be turned up when it reaches the rim joists (see Figure 2.30)

Homes Built over Basements
When specifying floor insulation for a home built over a basement, it is important to consider the true function of the basement, not only for the present, but also in the future. If the base-

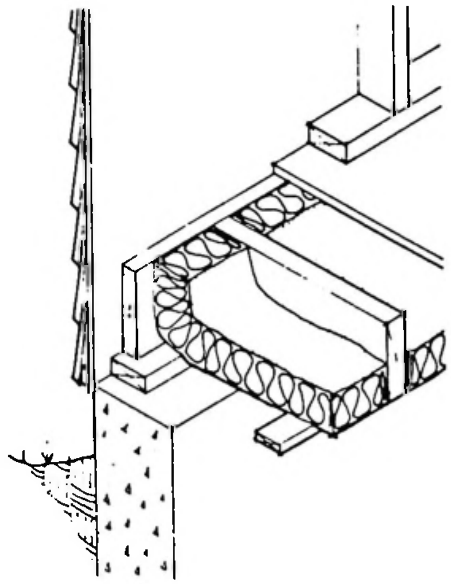

Figure 2.30

ment will not be used as a living space, it can be considered an unheated space. But what if the home heating system is a furnace or boiler installed in the basement? While not directly heated, the basement is being indirectly warmed by the heating unit. Also, it often happens that a basement is converted from its original "non-living space" status into a heated living space as the owner seeks to improve the property. All of these contingencies have implications for just how a basement ceiling and foundation should be insulated.

If a basement is to be unheated, meaning that the heating equipment is to be located elsewhere in the home, the insulation should be placed in the floor above the basement. In this case, the proper insulation techniques will be similar to those for unheated crawl spaces, discussed above. In heated basements, whether they are directly or indirectly heated, the basement wall should be insulated. Construction considerations will vary depending upon whether the walls are made of wood or masonry.

Basement walls are typically built below grade, or subgrade, which implies certain insulation requirements. But when the wall is substantially above grade, it should be insulated to the same degree as other exterior walls of the home using either exterior or interior insulating techniques discussed previously (see Wall Insulation).

• With walls made of masonry, the insulation can be placed on either the interior or exterior side. Rigid boards of extruded polystyrene are typically used for exterior application (see Figure 2.31). Again, whenever rigid insulation is used

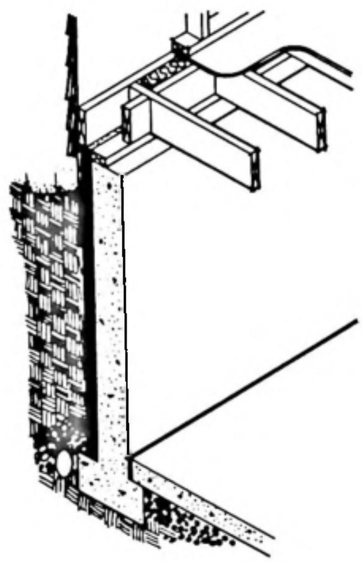

Figure 2.31

on the exterior, care should be taken to avoid damaging the insulation. For insulating the interior, rigid boards can be used or batts or rolls can be either draped or installed between furring or studs (see Figure 2.32). When using rigid foam insulation for interior installation, the local building codes must be consulted for specific fire protection requirements. When foam plastic insulation is exposed to flame, it can emit highly toxic gasses.

Figure 2.30
Insulation at rim.
floor insulation bat
be turned up when
reaches the rim jo
provide proper the
protection.

Figure 2.31
Exterior basem
wall insulation
system has been
tilevered to acco
date rigid insula
the outside of f
tion wall below
rim joist insulat

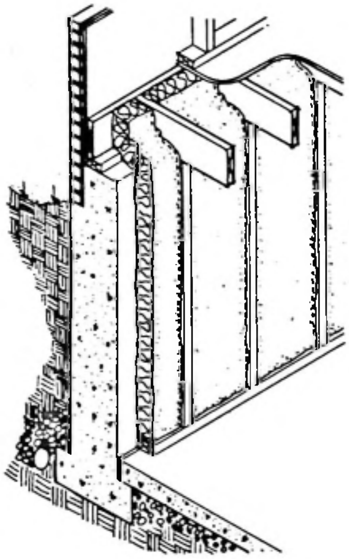

Figure 2.32

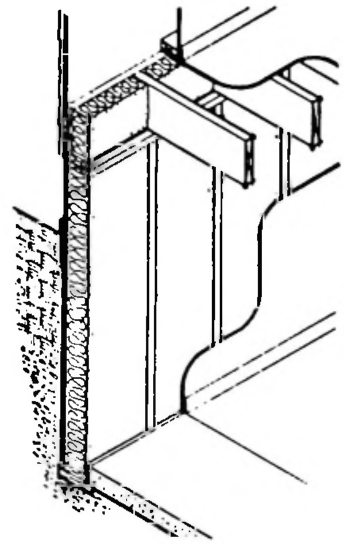

Figure 2.33

• Wood foundation walls are often referred to as "All Weather Wood Foundations" (AWWF). They are typically constructed of treated 2 × 6 lumber and insulated just as if they were standard above-grade stud walls, with batt or roll insulation between the 2 × 6's (see Figure 2.33). It is of course important that both the framing members and the wall sheathing be pressure treated with wood preservatives to prevent degradation over time of both the wood and the insulation. Manufacturer's recommendations and local codes should be consulted when All Weather Wood Foundations are being considered.

• Moisture protection is an important consideration for all insulated basement walls, including AWWF and furred-out masonry foundations. The insulation in the cavity could become wet due to water vapor condensation or because of moisture migration from the ground. In order to prevent this, a continuous vapor barrier should be installed. The bottom plate of the wall should also be covered with a moisture barrier.

Figure 2.32 Interior basement wall insulation. Batt or blanket type insulation is draped over the inside of the wall. If a finish is applied insulation should be installed between furring strips.

Figure 2.33 Interior basement wall insulation. Wood foundations are insulated in the same manner as standard above-grade home walls.

Upper Floors

• In multi-level homes, all rim joists should be insulated to the same level as the walls (see Figure 2.34).

• Where overhanging floors are incorporated into the design of the home, the insulation should both extend past the wall below, and be turned up to protect the rim joist (see Figure 2.35).

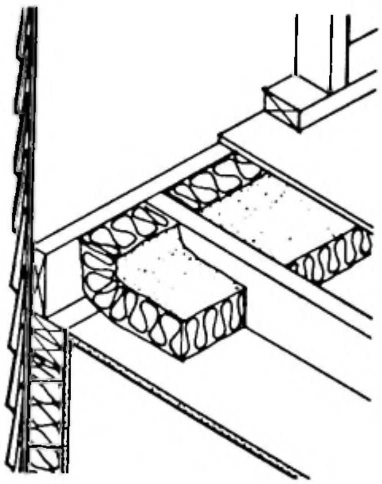

Figure 2.34

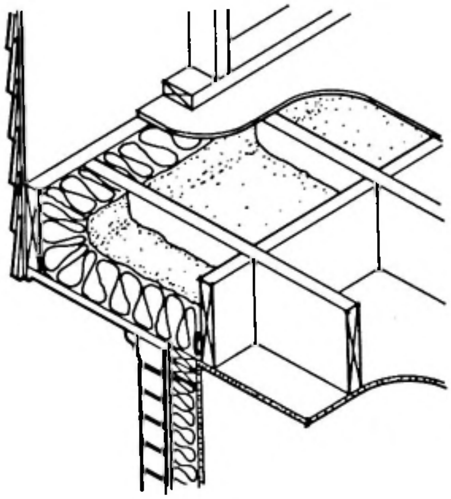

Figure 2.35

Figure 2.34
Rim joists at upper floors. All rim joists such as those at an upper floor should be insulated. Batts can be used to provide full coverage.

Figure 2.35
Insulating overhangs. Batts turned up at the rim and extending past the top plate of the wall below provide complete coverage at upper floor overhangs.

When using PEAR, you will find that separate keywords are provided for each of the floor and foundation types discussed in this section: slabs on grade; crawl spaces; and basements.

The R-values you input into PEAR must correspond to R-values that are listed by the manufacturer for the insulating material *only*. You should *not* include any insulation value for other building materials such as sheathing, studs, or masonry.

The following table presents examples of R-values associated with specific construction suggestions. These suggestions are made in addition to any that may have been recommended by the manufacturer and to the construction considerations previously discussed.

Foundation Insulation R-Value Slab-on-Grade Foundations	**PEAR Keyword**	**Construction**
R-0	None	No insulation is provided in this case.
R-5 (2 ft. deep)	R 5-2	This denotes the standard installation of 1-inch thick boards of extruded polystyrene placed either on the outside of the foundation to a depth of two feet.
R-5 (4 ft. deep)	R 5-4	This denotes the standard installation of 1-inch thick (R-5) boards of extruded polystyrene placed on the outside of the foundation to a depth of four feet.
R-10 (4 ft. deep)	R 10-4	This denotes the standard installation of 2-inch thick (R-10) boards of extruded polystyrene placed on the outside of the foundation to a depth of four feet.

Floor Insulation R-Value Floors Built Over a Crawl Space*	PEAR Keyword	Construction
R-7, R-11, R-19, R-22	R7 thru R22	To obtain insulation levels in this range, standard 2 × 8 floor joist construction can be used.

*These values are also used for floors over unheated basements. In that case, this is taken to mean basements that do not contain heating equipment and are not expected to be used as living space. PEAR will accept any insulation R-value between 0 and 22.

Foundation Insulation R-Value Heated Basements*	PEAR Keyword	Construction
R-0	None	No insulation is provided in this case.
R-5 (4 ft. deep)	R 5-4	This denotes the standard installation of 1-inch thick boards of extruded polystyrene on the inside (on furring) or on the outside of the foundation to a depth of four feet.
R-5 (8 ft. deep)	R 5-8	This denotes standard exterior or interior (on furring) installation of 1-inch extruded polystyrene to a depth of eight feet.
R-10 (8 ft. deep)	R10-8	This denotes the exterior or interior (on furring) installation of 2-inch extruded polystyrene to a depth of eight feet.

*Where batt or roll insulation is used, standard installation procedures should be employed.

Infiltration

Energy-efficient homes save money for a number of reasons, but one overriding reason is that they give the occupants better control over indoor comfort conditions. The living spaces can be heated or cooled on demand, and when a home is energy-efficient it is less subject to outdoor weather conditions. Air infiltration is a perfect example of a loss of control over interior conditions. It is essentially the *uncontrolled* leakage of air through the building envelope, and it can have a significant effect on a home's energy consumption for both heating and cooling. While new homes are typically built to be more resistant to infiltration than older, existing homes, there is usually a lot of room for improvement. The problem can be particularly severe in homes exposed to constant winds, that are unprotected by buffers such as surrounding trees, plants and other buildings. But infiltration problems are by no means limited to those situations.

Of course, some rate of continual exchange of inside air with outside air is necessary for ventilating stale air and excess humidity. Energy problems arise, however, when this rate of exchange becomes excessive. This is because any air that gets into the home through cracks, gaps, and other openings is bringing outside air temperatures with it. Incoming winter air has to be heated up, while hot summer air that gets in has to be cooled down in order to maintain comfort levels, and this is where infiltration leads to higher energy costs. Imagine a home with a high infiltration rate as being like a sieve unable to hold onto any of the hot or cold water poured into it.

While the homeowner will influence the amount of outside air coming into the home (for example, by opening and closing windows and doors), you will find that there are many construction features that affect a home's infiltration rate. One factor is the type of heating system that is used and its location in the home. For example, a fuel-burning (non-electric) furnace or boiler that pulls combustion air from inside the home will increase the overall air infiltration rate.

Combustion air taken from within the home must ultimately be replaced by outside air pulled in through the walls, ceiling, and floor. There are, however, solutions to the need for combustion air. A furnace or boiler can be specified that is a *sealed combustion* ("direct vent") unit. These units get their combustion air directly from the outside through a venting system which is equipped with both air intake and flue gas discharge tubes (see Figure 2.36). The same kind of system can be selected for fireplaces. Using a sealed combustion fireplace with fresh air supply will also reduce air infiltration. Fireplaces are notorious for the extent to which they send heated house air up the chimney and out.

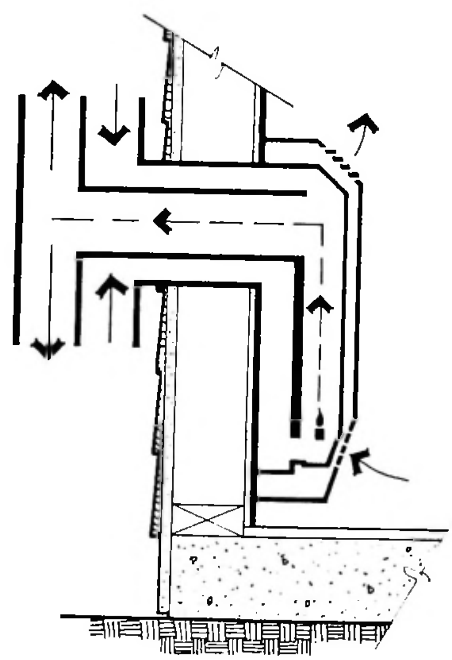

Figure 2.36

Figure 2.36 Sealed combustion furnace. Combustion air is provided directly from outside reducing the home's air infiltration rate.

A further improvement with a sealed combustion fireplace is the addition of special glass doors across the front. These doors reduce the air flow from the home when the fireplace is being used.

From a construction point of view, the main way that air infiltration is reduced is in the building of a "tighter" envelope. This requires fairly careful detailing and construction practice to ensure that cracks, holes, penetrations, and other infiltration sources are sealed. Yet even with the attention to detail that is required, "anti-infiltration" techniques are easily incorporated into standard procedures for constructing new homes. The energy savings they create make their inclusion well worth it. Another important point to remember is that it is much easier to build a tighter house from the start than it is to go back and make a leaky house tighter.

Experience has shown that it is actually possible to tighten the envelope to the point where the rate of air infiltration is no longer sufficient to provide adequate ventilation. This, of course, gives the homeowner maximum control over infiltration-related energy use. When the weather is mild, for example, simply opening a door or window will produce a sufficient amount of ventilation. In cold weather, however, opening doors and windows is not a very practical solution. If you do build a "very tight" home, you should consider providing forced ventilation with a heat reclaiming device such as an air-to-air heat exchanger. These devices work by simultaneously exhausting stale house air and bringing in fresh outside air. They save energy compared to opening and closing doors and windows because the incoming air is preheated with heat that is held by the exhausted air. Thus, adequate ventilation is achieved without sacrificing the energy-efficiency inherent in very tight construction.

Cracks around windows and doors are often perceived to be the primary sources of air infiltration, but in fact there is a rather wide variety of ways that air can leak into a home. The following list identifies the major infiltration areas. Outside air can leak in:

- around doors and door jambs
- around windows and window frames
- through walls
- through the foundation and the floor
- at ceiling-to-wall connections
- at wall-to-floor connections
- at wall-to-foundation connections
- at vents, flues, light fixtures, electrical outlets, switches, and any other penetrations of the ceiling, walls, floor, and foundation.

Sealing up these and other infiltration sources can be considered among the most cost-effective ways of reducing energy use. The following construction considerations cover all the areas in the above list.

Construction Considerations

Doors

- The space between the door jamb and the rough opening should be filled with insulation prior to installing siding or trim. Tightly stuffed fiberglass insulation can be used, as can spray-in foam caulking, subject to the requirements of local codes.
- The seam between the exterior door trim and the rough opening should be carefully caulked. In most cases a caulk can be selected that is close to the color of the siding or trim, or clear caulk can be used (see Figure 2.37).

Figure 2.37 Caulking door rough opening. Caulk should be provided between door rough opening and exterior trim. Insulation should also be provided between rough opening and door frame.

Figure 2.38 Integrated weatherstripping at doors. Weatherstripping may be integrated into the design of metal door frames. Two types are illustrated.
a: Rolled vinyl tubes secured by metal flange.
b: Foam secured by metal flange.

Figure 2.39 Applied weatherstripping at doors. Weather-stripping may be applied to the door or frame. Two typical details are ilustrated.
a: Foam applied to the frame or doorstop.
b: Rolled vinyl tube applied to the door frame.

Figure 2.40 Weatherstripping at door threshold. Weatherstripping may be applied to the door or special thresholds may be provided. Four weatherstripping details are illustrated.
a: Sweeps attached to the door.
b: Door shoe attached to the door.
c: Interlocking metal threshold requiring special hardware on both threshold and door.
d: Vinyl gasket threshold.

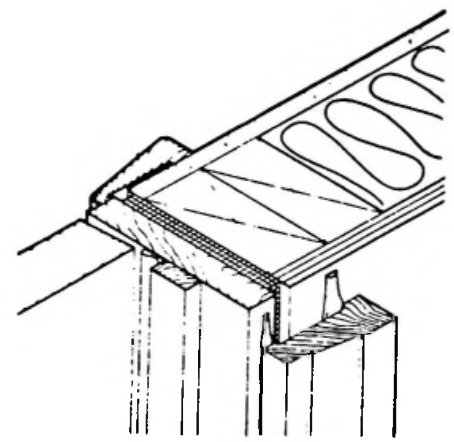

Figure 2.37

• The door itself should be carefully weatherstripped so that it forms a tight seal when closed against the jamb stops. For the sides and top of the door, choose from among several types of weatherstripping that can be effective when they are properly installed: felt, foam strips, rolled vinyl, rolled vinyl with magnetic core (for metal doors), foam or vinyl stiffened with wood, spring metal, and interlocking metal channels (see Figures 2.38 and 2.39). For sealing the bottom of a door, a number of materials are available in the form of sweeps, door shoes, threshold gaskets, and metal or interlocking metal thresholds (see Figure 2.40). Many prehung exterior doors come with built-in weatherstripping. When specifying one of these units, make allowances for dimensional changes in the door due to swelling, shrinkage or warping. When selecting weatherstripping, materials will vary in cost and quality. It will usually be best to select the most durable materials, since weatherstripping is always exposed to the extremes of the outdoor weather conditions.

• Storm doors provide the dual service of resisting infiltration and adding some insulation value.

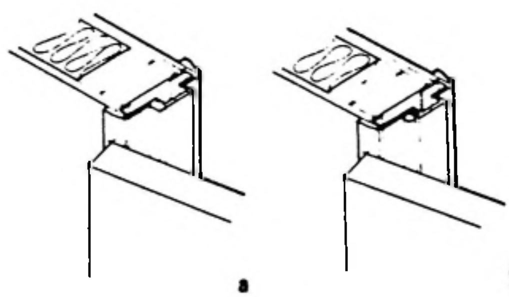

Figure 2.38

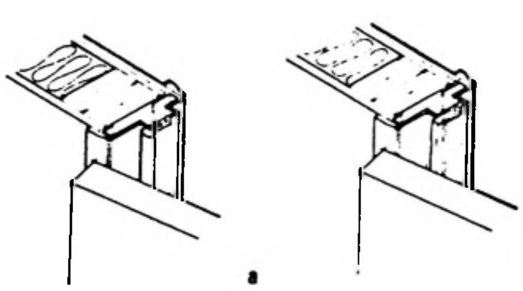

Figure 2.39

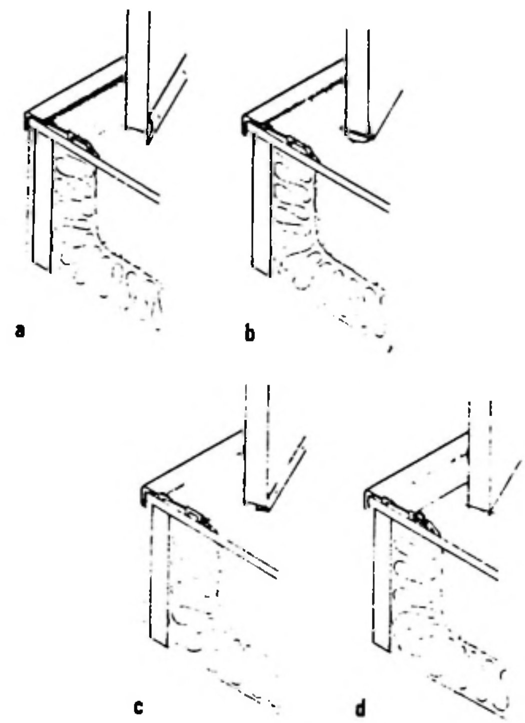

Figure 2.40

• An airlock entry can substantially reduce the air infiltrating as a result of the traffic of people in and out of the home. Airlocks are essentially buffer zones between the inside and outside, and will be especially effective in homes that are subject to a great deal of in-and-out traffic (see Figure 2.41).

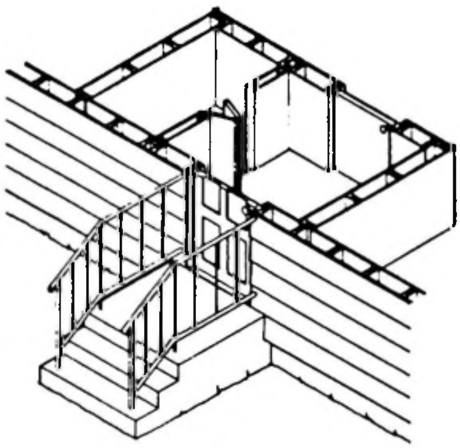

Figure 2.41

Windows

• A window's ability to resist air infiltration will depend upon its quality and type. The basic types of windows that are currently being manufactured can be ranked according to their general effectiveness at resisting air leaks (from worst to best): jalousie, horizontal sliders, vertical sliders (single- and double-hung), casement (side- or top-hinged) and fixed or non-operable windows. When comparing windows of the same type for qualitative differences special attention should be paid to the quality and durability of the seals and weatherstripping at all the moving parts of the sash. Even though there are now minimum infiltration performance standards for new windows, this does not guarantee long-term durability.

• Nowadays local building codes often require that the window sash be weatherstripped, but nevertheless there will be wide variations in the quality of weatherstripping materials. For tightening up metal windows two types of weatherstripping are commonly used; vinyl or rubber lip seals, and wool felt or pile. Lip seals are the most effective infiltration barriers when they are compressed as in casement and awning windows. Wool pile, although not as effective as lip seals, is effective if used on sliding sashes such as on double-hung windows. Wood windows can be weatherstripped with a wider variety of materials than metal windows including metal and plastic tension weatherstripping (see Figures 2.42 a and b), and closed-cell foam compression gaskets.

• From the standpoint of infiltration the most effective method for providing double- or triple-glazed windows is through the use of a single- or double-glazed prime window in combination with separate storm window. Because the storm and the prime window frame provide essentially a double seal, with the storm acting like a fixed

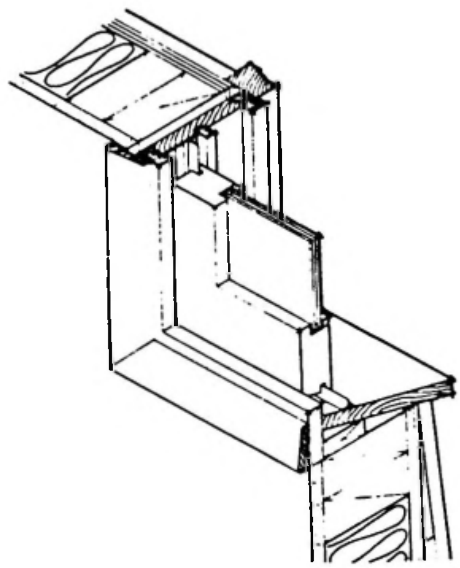

Figure 2.42a

Figure 2.41
Airlock entry. A small airlock entry space can be used to reduce air infiltration.

Figure 2.42a
a: Weatherstripping at windows. Metal tension strips are an effective and durable means for providing weatherstripping at window frame and sash.

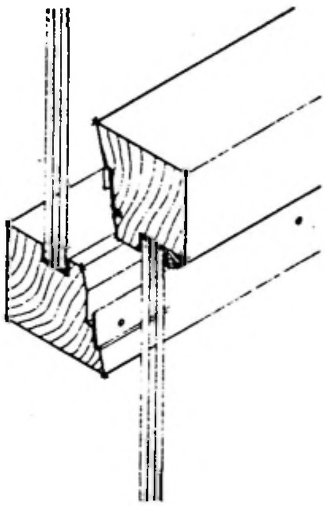

Figure 2.42b

window, infiltration will be lower than it would be with one prime window that is double- or triple-glazed.

• As is recommended with door jambs, the entire gap between the rough opening and the window frame should be caulked or stuffed with insulation (see Figure 2.43). The window manufacturer will often supply instructions for energy-efficient installation procedures. Some windows, for example come with nailing flanges for attachment to the outside of this rough framing. The inside of the flange should be continuously caulked to ensure a tight seal.

Floors

• When a floor is built above an unheated space, the seams between the floor sheathing or subfloor, should be well sealed. If a continuous vapor barrier is provided between the subfloor and the floor joists, it will also serve as an effective infiltration barrier.

Walls

• Since the exterior wall area of a home is often the largest single exposed surface area, anti-infiltration measures are especially important here. Barriers specifically designed to reduce air infiltration can be installed on the outside of the exterior wall. Such an infiltration barrier should be a fairly water permeable material so that it will not impede the passage of moisture through the wall. In a typical installation the barrier material wraps around the whole house. Cuts for window, door, and other openings are carefully made so that the barrier can

Figure 2.42b
b: Weatherstripping at operable sash. Metal tension strips are also an effective means of weatherstripping vertical sliding windows.

Figure 2.43
Insulating at window. All spaces between rough opening and window frame should be protected either with insulation (shown) or caulk to reduce infiltration.

Figure 2.44
Exterior air infiltration barrier. Joints in exterior air infiltration barrier should be taped and sealed.

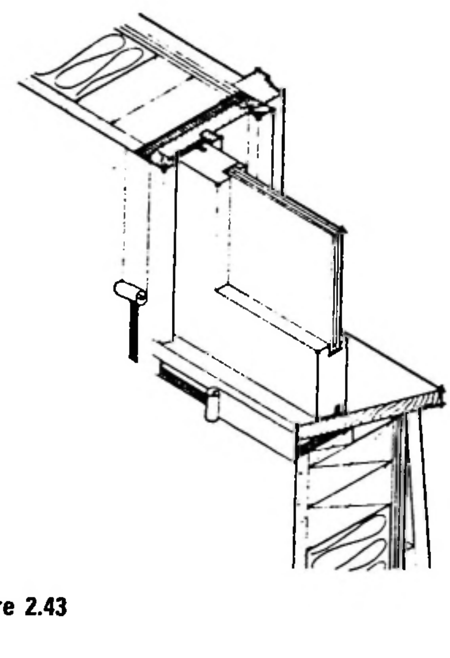

Figure 2.43

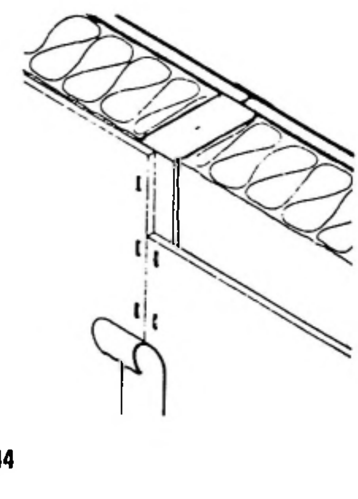

Figure 2.44

literally be wrapped around the edges of the rough openings. Any seams in the barrier material are thoroughly taped or otherwise sealed (see Figure 2.44).

• When the siding goes on, it is important to seal any seams where siding materials meet. This includes seams between individual siding boards, inside and outside corners, all seams between trim and siding, and the seam between the siding and the foundation (see Figure 2.45).

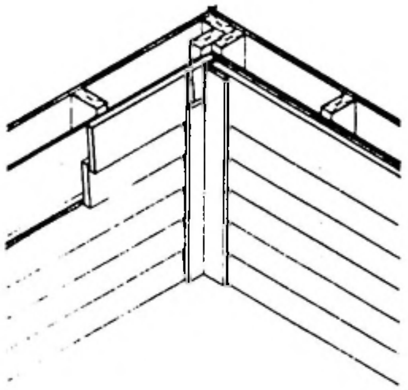

Figure 2.45

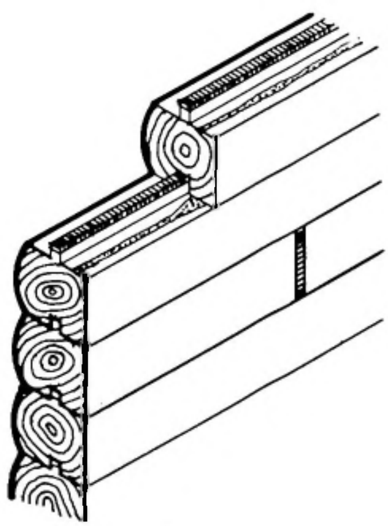

Figure 2.46

In solid wood homes infiltration protection must be provided at all joints between logs. Caulking, compressible gaskets and the log profile itself all contribute to reducing air infiltration (see Figure 2.46). Special attention should also be paid to butt joints between logs.

Ceiling to Wall Connection

• If trim is to be applied at the corner formed by the ceiling and the walls, a continuous bead of caulk should first be applied along the ceiling-wall seam. If no trim is to be used here, drywall tape and joint compound should be used carefully to seal this seam, especially if the ceiling is to receive a texturing treatment that only visually hides this seam.

• On the outside, the exterior sheathing material should extend all the way to the underside of the rafter when the roof is site-built. With prefabricated truss construction the sheathing should reach to the underside of the truss top chord (see Figure 2.47).

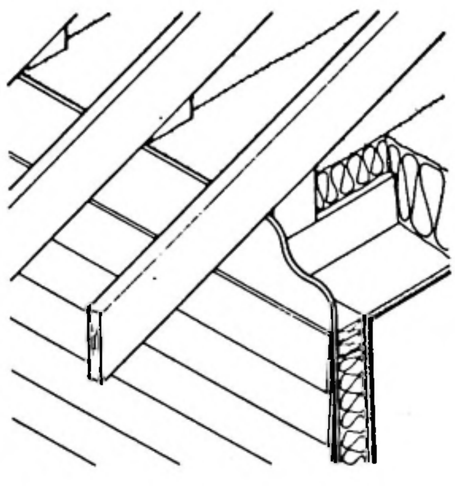

Figure 2.47

• Any seams where ceiling or roof sheathing materials come together should be sealed carefully.

Figure 2.45
Sealing seams in siding. A generous amount of caulking material should be provided at any point where exterior siding or sheathing meet, such as at corners.

Figure 2.46
Infiltration control in solid wood walls. Caulking and/or compressible gaskets should be used at all vertical and horizontal joints.

Figure 2.47
Air infiltration reduction at top plate. The exterior sheathing should extend above the top plate to the underside of top chord of roof truss to prevent air leakage into home at top plate/roof truss connection.

ure 2.48
iltration reduction
bottom plate. ulking (or similar ma- al) should be used to vent air leakage at connection between s and floor.

re 2.49
king at floor to dation. Caulking is ied along the bot- late, and at the ist and sole plate ctions. Any breaks rim joist, should ll sealed with

2.50
ing air infiltra- electrical out- listed foam protect against ge at electrical nstalled in exte- s.

Wall to Floor Connection

• A significant but often unsuspected source of air infiltration is the seam between the sole plate of a stud wall and the subfloor. Standard caulking materials, sill sealers, and foam gaskets can be used to reduce infiltration at this location (see Figure 2.48).

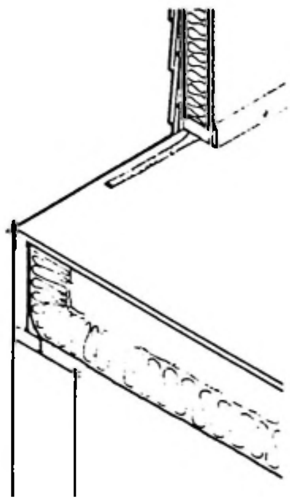

Figure 2.48

Floor to Foundation Connection

• In homes with heated basements, including those that have heating equipment in the basement, a continuous seal should be made between the rim joist, the sill plate, and the foundation wall. The same types of sealers that were recommended for use between the sole plate and subfloor can be used here (see Figure 2.49).

• Caulking should also be provided at any splices in the rim joist or the sill plate. There may also be other seams and gaps that are unique to individual home designs. The home should be carefully inspected for such potential sources of air leaks and the appropriate sealing materials applied.

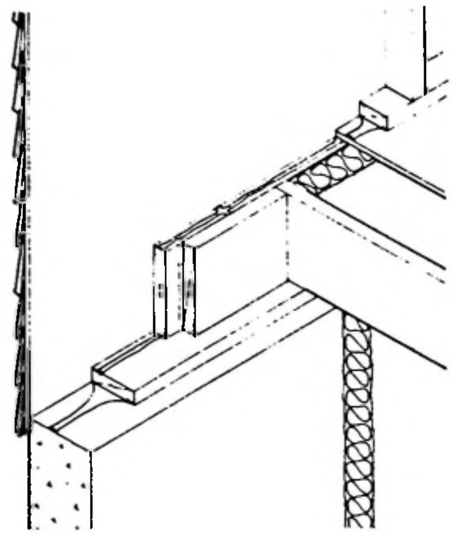

Figure 2.49

Envelope Penetrations

• Studies have shown that there can be a great deal of air infiltrating through a single, unprotected electrical outlet or switch box mounted in an exterior wall. If a continuous vapor barrier is installed, you can carefully slit the barrier at the electrical box and then tape the vapor barrier material all around the box. Specially made foam gaskets placed behind the cover plates can also be used as seals. Due to fire safety considerations, selected gaskets should be listed by the

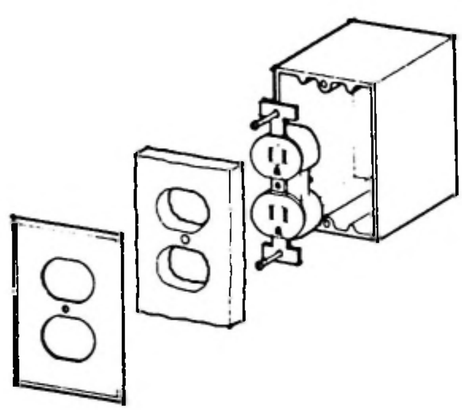

Figure 2.50

Underwriters Laboratories, Inc. (see Figure 2.50).

• Openings around such roof penetrations as vents, flues, chimneys, piping, ductwork, attic access doors, and whole-house fans should be tightly sealed (see Figure 2.51). The same treatment should be given to all openings around wall (see Figure 2.52) and floor penetrations. When seals are required around flues from heated sources such as stoves, furnaces and boilers, sealants should be specified with a higher service temperature.

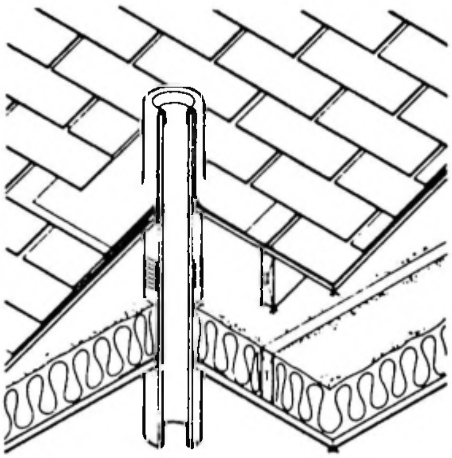

Figure 2.51

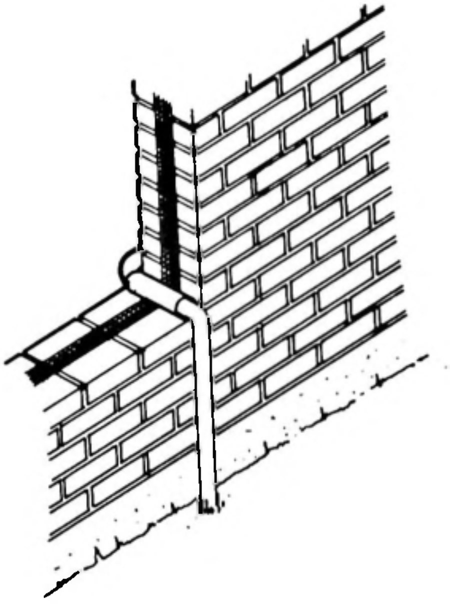

Figure 2.52b

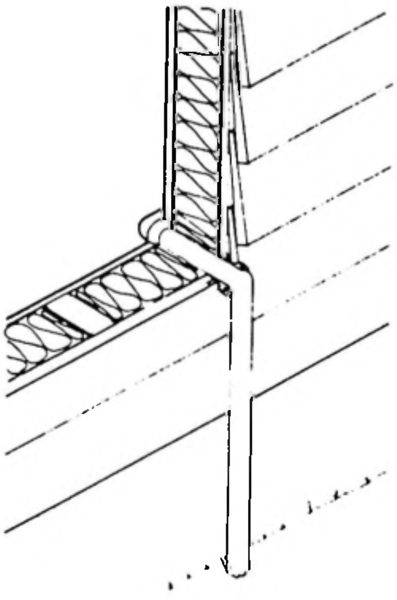

Figure 2.52a

Figure 2.51
Reducing air infiltration at ceiling penetrations. All penetrations through the ceiling (such as vents) should be carefully caulked
sealed to reduce infiltration.

Figure 2.52a and 2.52b
Reducing air infiltration at wall penetrations. All penetrations through the exterior walls should be carefully caulked and sealed.

PEAR allows you to select any infiltration rate between 0.4 and 1.0 Air Changes per Hour (ACH). 1 ACH means that all the air in the house is replaced during one hour by outside air.

The table below has been provided to aid in calculating the infiltration level for your home. Each construction characteristic listed in the table has been assigned points determined by that characteristic's effectiveness in reducing air infiltration. You should go through the table and select the features which you are incorporating into the design and construction of the home. Then, add up the total points accumulated.

For 21 points or less, enter 1.0 ACH (note that at a minimum all features labeled "Required" must be implemented to correspond to the 1.0 ACH home). For 22–30 points, enter 0.7 ACH and for 31 points or more, enter 0.4 ACH. Although only 3 infiltration rates are mentiond here, PEAR will accept any air change rate between 0.4 and 1.0.

It is important to remember that the ultimate decision as to whether or not to incorporate a feature will depend upon many factors including cost of materials and labor, and marketability, as well as energy reduction. These factors can only be determined on a case-by-case basis and should always be considered in your selection process.

Points	Construction
Required	All doors and windows caulked and weather-stripped.
Required	Cover caulk, seal, or weatherstrip all envelope joints around windows, between wall panels and between floor/wall and wall/ceiling surfaces.
Required	Cover, caulk, seal, or weatherstrip all envelope penetrations for plumbing, space conditioning ducts, electricity, telephone, and utility services.
Required	Cover, caulk, seal, or weatherstrip all attic or basement openings for access panels, flues, or party wall penetrations.
Required	Provide back draft or automaic dampers on all exhaust systems.

Points	Construction
13	Continuous air infiltration barrier with all joints in the barrier and all penetrations through the barrier sealed; barrier must cover all joints in the building envelope, from sill to top plate, and must act as a gasket or be sealed to all window and door frames.
6	Specification of sealed combustion furnace (gas or oil), or non-combustion heating equipment (electric baseboard, furnace, or heatpump).
5	Specification of medium-to-long life caulking materials (greater than 5 year expected life), highest quality weatherstripping, and gaskets on all exterior wall electric outlets.
4	Airlock entry provided.
4	Continuous vapor retarder installed on heated-in-winter side of exterior walls with all penetrations sealed.
3	Interior partitions framed after installation of continuous vapor barrier (polyethylene sheeting), or drywall on ceiling.
3	Glass doors provided on all fireplaces with outside air source and specification of tight fitting dampers.
3	Windows and doors certified to be equal to infiltration rates of 0.25 cfm per foot of crack (windows) or per square foot (doors).

2	Storm doors and windows provided.
2	Duct drops and cabinet soffits framed after installation of continuous vapor barrier (polyethylene sheeting) or drywall in ceiling, or no soffits or drops.
2	Sealed ductwork specified for all supply and return air.
2	No recessed lighting fixtures installed in ceilings between conditioned or unconditioned spaces, or specification of "IC" (Insulated Ceiling) recessed light fixtures.
2	Windows and doors certified to be equal to infiltration rates of 0.34 cfm per foot of crack (windows) or per square foot (doors).

1	Windows and exterior doors certified to be equal to recognized infiltration requirements of 0.5 cfm per foot of crack (windows) or per square foot (doors).

Windows

The types of windows selected and where they are installed around a home can greatly affect the home's energy consumption. Relative to other parts of the home, windows are generally considered to be energy losers. After all, even a double-glazed window with an additional storm window has a combined R-value of only about 3. Adjacent wall sections, on the other hand, can provide resistance values of R-19, R-27 and higher, and ceilings can be R-40 and higher. Thus, in general practice most window-related energy conservation measures are aimed at reducing the amount of energy lost through a window. However, an important fact that is sometimes neglected is that with careful selection, sizing and placement, windows actually can become net energy *gainers*. South facing windows can provide significant amounts of space heat to help offset heat losses in winter.

There are some basic factors that have the most effect on the total energy use of a given window. These include:

- the number of *layers* of glazing in each window
- the *sash material*
- the *total window area* in the home
- the *orientation* of the windows
- the *glazing material* used in windows
- the *type of sash* that is used (such as casement or double-hung)
- the *width of the air gap* between glazing layers in multiple glazed units

All these factors, except for sash type, are directly addressed by the PEAR computer program and described in the User's Manual. Sash type is discussed in the Infiltration section of the Guide.

Glazing Layers

Glazing layers are like insulation. The more layers there are on a window, the higher the insulation value. There are of course practical limits to this that have to do with window size, weight and cost, and the diminishing energy savings that go with each additional glazing layer. For example, going from single-to double-glazing increases the window R-value from about R-1 to R-2, which actually represents a 50 percent decrease in heat loss. Going from two to three layers, however, provides just an additional 33 percent reduction in heat loss, and going from three to four layers reduces heat loss by only 25 percent. Thus, quadruple-glazing is rarely used, and then only in very cold climates, while single-, double-, and triple-glazed windows are most commonly specified.

Construction Considerations

- Options for double-glazing the window are either to use prime windows that are double-glazed — two sheets of glazing material built into one sash (see Figure 2.53) — or to combine a single-

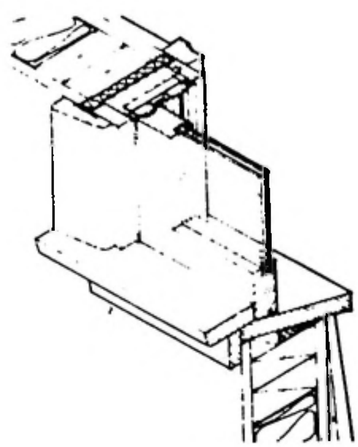

Figure 2.53

Figure 2.53 Double-glazed windows. Two layers of glass for incorporated into a single frame, providing an insulating air space between the layers.

glazed prime window with a storm window (see Figure 2.54). The latter method, by providing two separate frames, can be more energy-efficient because it creates a large insulating space between the layers (see Air Space) and because this combination can be more resistant to air infiltration (see Infiltration).

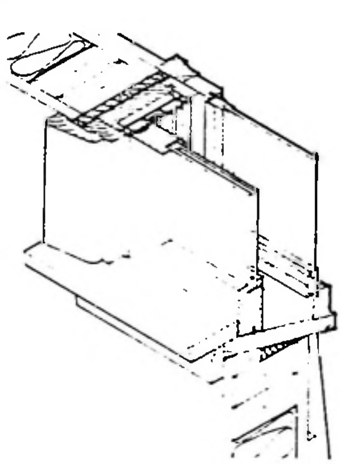

Figure 2.54

• Triple-glazing can be created by using standard triple glazed prime windows (see Figure 2.55) or be combining a double-glazed prime unit with a separate storm window (see Figure 2.56).

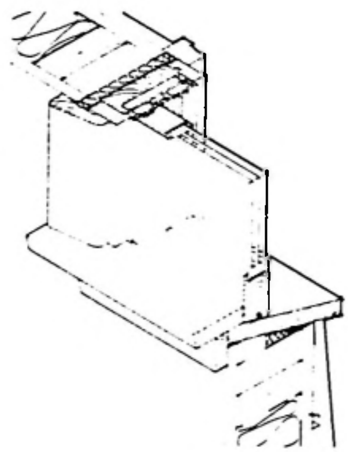

Figure 2.55

gure 2.54
ngle-glazed windows th storm. Double-zing layers can be cified as a standard le-glazed window a storm.

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le-glazed win-s. Three layers of are incorporated in-single frame, pro- two insulating air s between the .

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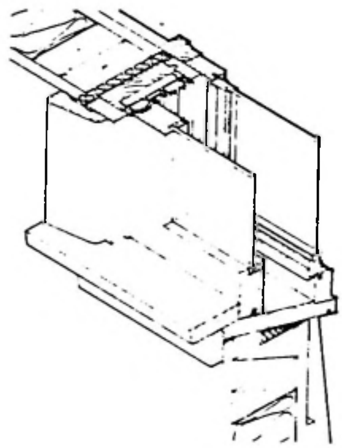

Figure 2.56

For the reasons discussed above, the latter method can result in higher energy savings than those that would be created by the first method.

• If you use a separate storm sash to create double- or triple-glazing, it is important that the prime window be well sealed (weatherstripped) to prevent possible moisture condensation problems between the window and the storm.

Sash Material

In this discussion the term sash includes both the traditional window sash (that is, the component that holds the window glass) and the frame (that is, the component that holds the sash). Also, all references to sash material refer only to the prime window, not to the storm window. New storm window sashes are usually of a simple metal construction that has very little impact on energy use beyond its ability to resist air infiltration.

Construction Considerations

• Both the window sash and frame can be made of materials that vary widely in their own intrinsic R-value, which means the choice of these materials can have a significant effect on energy use.

• The least efficient material is metal (usually aluminum) that does not include any thermal breaks. Solid metal sashes and frames may be inexpensive, but they are excellent conductors of heat and therefore create undesirable thermal bridges. Aluminum and steel both provide an easy path for heat to flow out of the home in winter and into the home in summer (see Figure 2.57). However, metal sashes and frames can be fabricated to incorporate *thermal breaks,* which consist of a rubber or plastic layer that literally separates the interior of the window from its exterior sash and frame (see Figure 2.58). The inclusion of thermal breaks makes for a substantial increase in the R-value of the sash and frame members without having any negative effect on the window's structural integrity.

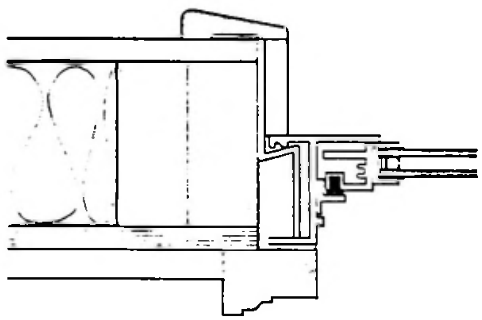

Figure 2.57

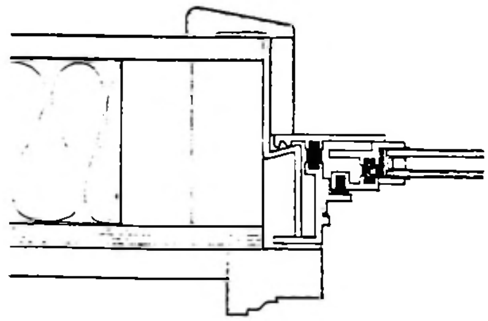

Figure 2.58

• Wood is naturally a better insulator than metal, and windows that have wood sashes and frames will generally be more energy-efficient than metal windows without thermal breaks. They will have the same or greater energy efficiency than metal windows with thermal breaks (see Figure 2.59). Outside coverings or coatings that are applied over wood sashes and frames, such as vinyl, will have little impact on energy use. Some new prime windows are made with all-plastic (usually vinyl) sashes and frames. The energy-efficiency of these units will be between that of wood and metal units.

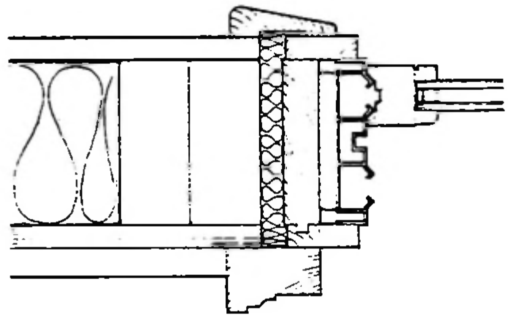

Figure 2.59

Glazing Area

Because windows have a lower overall R-value than the walls, ceiling, and floors of a home, the total glazing area in a given home has a large impact on the home's energy use. In addition, glazing area also has an impact on the other window characteristics that might be specified. For example, consider two homes, one with 150 square feet of glazing and one with 250 square feet. Changing from single- to double-glazing in the first home will create less of a net energy savings than would making the second home double-glazed. The location of windows in a home also affects net energy savings. For example, a home with 250 square feet of glazing might have half that area, 125 square feet, located on the south wall where a lot of solar heat can be collected.

Figure 2.57
Metal sash windows. The frame and sash of metal windows without thermal breaks are sources of high heat flow reducing the thermal effectiveness of the window.

Figure 2.58
Metal windows with thermal breaks. Plastic or rubber gaskets which separate metal portions of the frame and sash act to reduce heat flow increasing the overall thermal performance of the window.

Figure 2.59
Wood windows. The use of wood for sash and frame material results in high thermal performance of the window due to the higher thermal resistance (R-value) of wood.

Another home with 250 square feet of glazing might have only 50 square feet located on the south side. It stands to reason that in predominantly heating areas the first home benefits much more from the way its window area is distributed.

Thus, if a home is designed and sited to take advantage of the daily and seasonal position of the sun, the windows will have a truly positive impact on overall energy use. South windows can provide energy from the sun and be net energy winners, not losers. Care should be taken, however, in the overall plan for window placement to ensure that fixed and operable windows are effectively shaded from unwanted heat gain during warm weather (see Shading). In fact, in regions where most of the energy used for space conditioning goes to cooling, the importance of proper shading and site planning increases directly with increases in window area. Mistakes can lead to dramatic increases in cooling energy use.

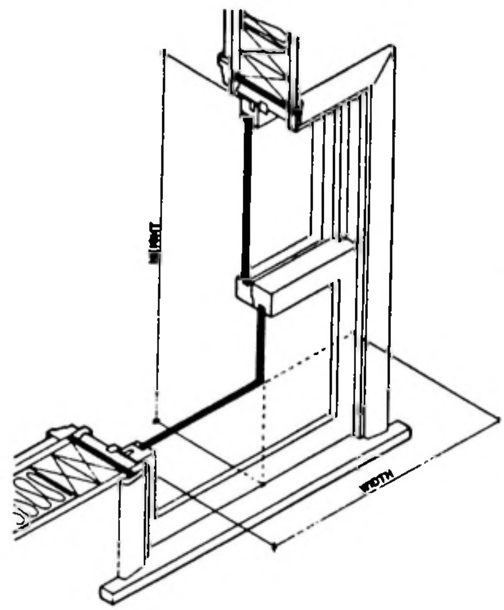

Figure 2.60

Construction Considerations

• When calculating the window area percentage for use with the PEAR calculations, the gross window area including sash, frame and mullions should be used (see Figure 2.60). Of course, all the glazing in the home should be included in the estimate. For example, along with all the standard windows, bay windows and sliding glass patio doors should also be included in the total. Refer to Table 1 of the PEAR User's Manual for an explanation of the restrictions for window area input.

Figure 2.60
Computing glass area.
The area, as a percentage of the floor area, used in the calculation procedures includes sash, frame and mullions.

As was mentioned previously, the input values for windows in PEAR are for the following characteristics: sash material, the number of glazing layers, and the total glazing area. The following table lists the specific materials and components on which the PEAR values are based.

Sash Material	Construction
Aluminum (ALUM)	This includes any aluminum window that is not provided with thermal breaks.
Aluminum with thermal breaks (ALUMTB)	This denotes an aluminum window in which the frame and/or sash incorporate a thermal break material that completely separates the indoor side from the outdoor side of the frame or sash, thereby increasing its insulating value.
Wood (WOOD)	This denotes a window in which the frame and the sash are made of solid wood with any variety of finish coating or sheathing over the wood.

*Note that when storm windows are used, the material selected is that of the sash and frame material of the prime window only. The value for the frame of a storm window is not to be used.

Glazing Layers	Construction
Single (1)	This denotes any single-glazed windows.
Double (2)	This value denotes either a single-glazed prime window plus a separate storm window, or a primary window with double glazing.
Triple (3)	This value denotes either a double-glazed primary window used with a separate storm window, or a triple-glazed primary window.

*If limited use is made of various numbers of layers (for example, most of a home's windows are single-glazed, but there is a double-glazed patio door) select the number of layers constituting the greater window area (which in the example with be "Single").

Window Orientation

One strategy for using windows to reduce energy use is orientation. Specifically, orientation includes considering how much of the window area is placed on each side of the home, or the overall orientation of the windows with respect to the daily and seasonal paths of the sun.

The distribution of windows around the north, east, west, and south sides of a home can greatly affect energy use in both the heating and the cooling seasons. So can the positioning of the home itself on the site, again with respect to the path of the sun. Both of these aspects of home design are covered by the term "orientation."

As has been mentioned before, orientation is considered primarily in relation to the movement of the sun. In winter the sun is at a low-angle relative to the horizon, while in summer it takes a high-angle path (see Figure 2.61). The closer you are to the Equator, the higher the angle of the sun, no matter what the season. As you travel toward the North Pole, the sun's angle of elevation gets lower and lower, again no matter what the season. The movement of the sun and the severity of the winter and summer heating and cooling requirements, will indicate the best combination of window orientation and shading requirements.

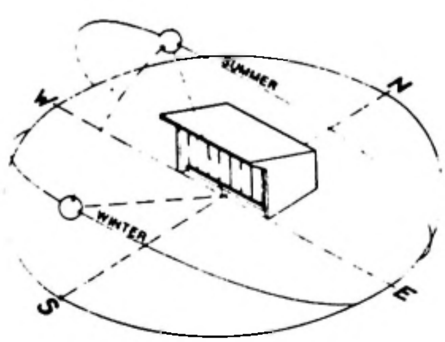

Figure 2.61

Figure 2.61
Seasonal sun path. In winter the sun travels across the sky at a low angle whereas in summer the sun is high in the sky.

Figure 2.62
Orienting the home for suntempering. Siting the home with major glass areas facing south will result in the home taking most advantage of the sun to reduce overall energy cost.

Design Considerations

• When positioning the home on the site try to orient the windows so that the largest areas face south. Generally the largest wall areas will face south and north, while the two smallest walls will face east and west (see Figure 2.62).

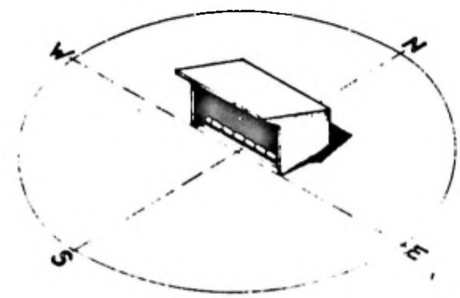

Figure 2.62

Increasing the south window area to allow more sun in to provide supplementary heating is often referred to as Suntempering. While increasing south window area is, in general, beneficial in locations with high heating requirements, large window areas can often lead to problems of overheating. When large south window areas are desired in order to substantially reduce the home's heating requirements, the problem of overheating can be dealt with by designing the home as a passive solar home (see Passive Solar).

Climates with minimal heating benefit even more from windows positioned on the north side of the building. In such climates where cooling is the overriding concern, north windows reduce the amount of solar gain.

• In summer the south wall receives some energy from the higher-angle sun, but this can be reduced with certain shading techniques such as the use of overhangs (see "Shading" below). The result will be lower summer cooling energy needs and also lower winter heating requirements. In the winter the sun will be at lower angle, streaming through the south windows, providing supplementary heat to the living spaces of the home. If you were to site the home with the short side running north-south, and most windows on the east and west, total energy use would increase since there would be minimal solar gain on the south face (in winter) and maximum solar gain on the east and west faces (in summer).

• The house should be placed on the site to take advantage of any available site features that could help reduce energy consumption. The first and foremost consideration in this regard in areas with heating requirements is to locate the house so that it receives most of all of the available sunshine at the site during winter. Since the winter sun has a low-angle elevation, any solid objects in the path of its rays will cast longer shadows than they would in summer when the sun is more overhead. Thus the house should be located away from trees, (except for deciduous trees which lose their leaves in winter), other buildings and any other obstruction. On the other hand, obstruction to the east and west are encouraged, as they will help to block the intense afternoon rays of the summer sun. The location of any obstructions to the north will have little effect on winter or summer solar gain. However, such obstructions may serve as blocks to winter winds.

• Although the ideal orientation for the south facing windows is toward true south (which can differ a few degrees from compass or magnetic south), variations of as much as 20° east or west of true south are possible with no significant decrease in winter solar gain or increase in summer solar gain. Since many building sites are very often less than perfectly suited to south orientation, there is a fair amount of siting and orientation flexibility to be able to deal properly with other siting factors such as view, local ordinances, obstructions to the sun and site improvements.

• In order to maximize winter solar heat gain in colder climates, most of the house window area should be located on the south, southwest and/or southeast sides. Avoiding excessive, unwanted summer heat gain requires minimizing window area on the east and west sides. And to avoid excessive heat *loss* in winter, window area on the north side should also be minimized. This general scheme of window placement can be a truly effective way of improving the energy performance of a home.

Glazing Material

There is a variety of different glazing materials that can be used in windows for single family homes. Depending upon the material selected, the amount of sunlight (and therefore heat) passing into the living space will vary, influencing the amount of energy used in the home. Glazing can be grouped into categories of materials reflecting the amount of light they allow to penetrate the window. The most popular are: clear glass, reflective glass and films, and heat absorbing glass and films.

Clear glass is, of course, the industry standard, being the most widely used and commonly accepted by homebuyers. Of the three types listed above, clear glass has the highest *transmittance,* which means it allows the highest percentage of the available sunlight to pass through it to the inside. This makes clear glass the most effective choice for windows that are located to receive the most sunlight during the heating season (south facing windows).

In warmer climates where maximum solar gain is not always desirable, the other glazing options help to reduce the transmission of light into the living space, meaning that they collect less solar heat. Thus reflective glass and films, and heat absorbing glass and films represent useful options for reducing cooling energy costs. This is true for both warm and cold climates, because in colder climates that still experience hot summers windows that are on the east and west sides of the home can be treated with one of these transmission-reducing options to reduce unwanted heat gain.

As its name implies, heat absorbing glass reduces solar heat gain by absorbing much of the solar energy (which becomes heat) that strikes it, rather than letting the heat, in the form of light, penetrate into the living space. Windows equipped with heat absorbing glass are rarely single-glazed, because the best results are obtained by having the heat absorbing glass pane be the exterior layer of a multiple glazed unit. In this way the heat contained by the heat absorbing glass is isolated from the living space. This is an essential design requirement when working with heat absorbing glass.

Instead of actually absorbing heat, reflective glass reflects sunlight back to the outside before it can enter the home (see Figure 2.63). Like a mirror, it reflects sunlight right at the glass surface and, like heat absorbing glass, reflective glazing is generally more effective when it's used as the outer glazing in a multiple glazing arrangement.

The effectiveness of both heat absorbing and reflective glazing materials is measured by a shading coefficient listed by the manufacturer in product literature. In general, the lower the shading coefficient, the more effective is the glass in limiting solar heat gains and increasing cooling savings.

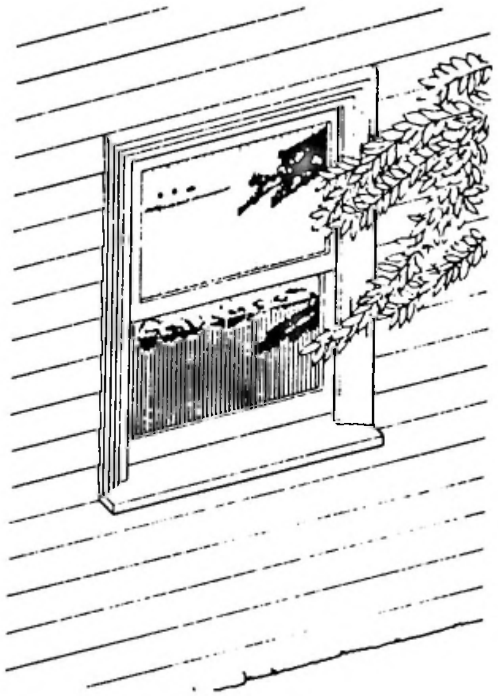

Figure 2.63

Figure 2.63
Reflective glazing. The amount of sunlight entering into the home thereby increasing the cooling load may be reduced through the use of reflective glazing or reflective films applied to clear glass.

There are a number of glazing films that can be applied directly to clear glass windows for increased sunlight control. These films are usually less expensive than special types of glass discussed above, and they can give about the same reductions in light and heat transmission. But since they are made of plastic, film materials may be more difficult to maintain than hard glass. Films can be more easily scratched, such as during cleaning, and they may need to be replaced from time to time, certainly sooner than replacement would be needed for the glass options.

Because of the fact that all these transmission-reducing glazings reduce solar gain, they may not be desirable for use on south facing windows where solar heat gain is needed during the heating season (except in predominantly cooling areas). They are useful, however, in reducing unwanted heat gain through south windows during the cooling season. So a possible strategy here is to have these glazings be removable for heat gain and replacable for heat gain reduction.

PEAR allows you to specify the type of glazing material used. For a more detailed discussion, refer to Table 3 in the User's Manual.

The following table give information on the assumed properties of the glazing options regardless of whether glass or film is selected. For an explanation of glazing characteristics used by PEAR, refer to Table 3 of the User's Manual.

Glazing Material Value	Construction
Clear glass (REG)	The values in PEAR assume the use of standard clear float glass.
Reflective glass or film (REFL)	This denotes a reflective glass or film material. Depending upon the number of layers of glass, PEAR will specify the transmissive and reflective properties of the window. For single pane the shading coefficient is 0.36; for double pane 0.28; and for triple pane 0.25. For more information refer to Table 3 of the User's Manual.
Heat absorbing glass or film (HA)	This denotes a heat absorbing glass or film material. Depending upon the number of layers of glass, PEAR will specify the transmissive and reflective properties of the window. For single pane the shading coefficient is 0.7; for double pane 0.59; for triple pane 0.52. For more information refer to Table 3 of the User's Manual.

Sash Type

The type of sash selected can greatly influence energy performance. Although difficult to quantify precisely, variation in energy performance attributable to sash (or window) type, is primarily a result of the window's ability to reduce air infiltration.

Among the most common sash types, *jalousie windows* are probably the least effective at resisting air infiltration. The reasons are pretty clear. This "slatted" window design has so many exposed seams that it would be very difficult to successfully weatherstrip them to be as tight as other sash designs (see Figure 2.64).

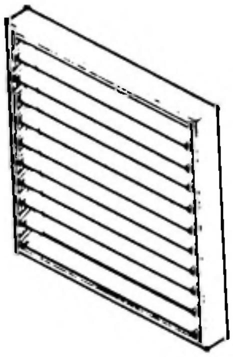

Figure 2.64

Horizontal sliders also have weatherstripping problems, but for a different reason. Weatherstripping in these units tends to degrade over time because it is worn down by friction and because water and dirt tend to accumulate in the lower channels, causing still more wear to the weatherstripping (see Figure 2.65). Compared to vertical sliders or double hung units (see Figure 2.66) they are simply not as effective at resisting air infiltration.

Casement windows are usually recognized as being the most effective against air infiltration because of the way that the sash can be secured tight to the frame, which usually is fully weatherstripped with effective compression type weatherstripping (see Figure 2.67) Awning and hopper type windows share the same beneficial design characteristic (see Figure 2.68).

Fixed windows of course have no moving parts and when they are properly made and installed they are the least prone to air infiltration problems. They are, therefore, good performers with regard to infiltration if well installed. They do, of course, have the disadvantage of not being openable to provide ventilation.

Proper installation is an extremely important consideration for gauging window performance.

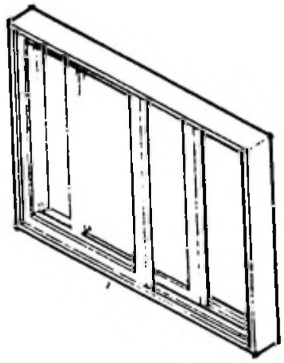

Figure 2.65

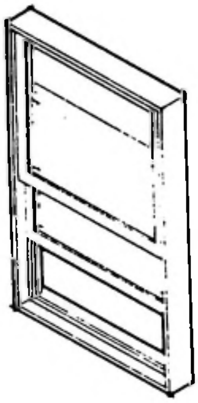

Figure 2.66

Figure 2.64
Jalousie windows. Due to the large number of glazing blades, jalousie windows are the most difficult to weatherstrip and least effective in terms of thermal performance.

Figure 2.65
Horizontal sliding windows. Horizontal sliding windows may not be as thermally effective as most other window types due to the degradation of the weatherstripping in the bottom track.

Figure 2.66
Vertical sliding windows. Both single and double hung windows can be easily and effectively weather stripped ensuring relatively good thermal performance.

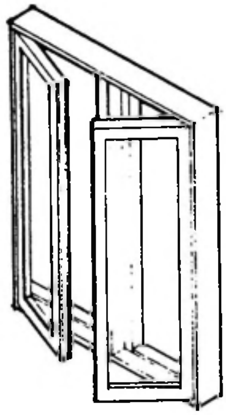

Figure 2.67

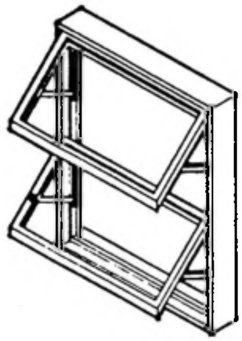

Figure 2.68

Figure 2.67
Casement windows. The very tight seal resulting from the closure mechanism used in casement windows improves their ability to limit air leakage.

Figure 2.68
Awning windows. The closure mechanism used on awning windows, similar to that used in casement windows, provides a tight seal against air infiltration.

Figure 2.69
Air space between glazing layers. Specifying factory double-glazed windows in which the sealed air space has been increased to ½" will result in a window with a higher R-value.

Care should be taken to keep the window frame square before it is installed. Any locking hardware used with an operable window should be adjusted to close tightly or the sash can be pushed *away* from the frame and somewhat reduce the effectiveness of the weatherstripping.

Air Gap Between Glazing Layers

As discussed above, the R-value of the window glazing itself can be increased with the use of more than one glazing layer (see Glazing Layers). This is due to the insulating properties of the sealed or "dead" air space between the layers in double- or triple-glazed units. However, the actual insulating value of this dead air space varies with the width of the gap between glazing layers.

The general rule of thumb is that the wider this gap, the higher the R-value. However, at about a gap of 1 inch the R-value does not increase and, in fact, when the spacing exceeds 4 inches, there is actually a decrease in R-value. Thus, air gaps of ⅝ or ¾ inch are generally considered to be the most effective.

Unfortunately, in most prefabricated double- or triple-glazed windows the air gaps between glazing layers are either 1/4 or 3/16 inch (see Figure 2.69). Wider gaps, however, can normally be specified. If the gap were increased to 1/2 inch, there would be an increase in the glazing R-value and thereby a decrease in annual energy use. Another type of sealed double glazing has been shown to have a relatively high R-value, even though it has an air gap of 3/16 inch or less. This glazing has what is called a "welded" glass edge in which the two layers are bonded at the edges by glass, not sealants. The air gap in these units

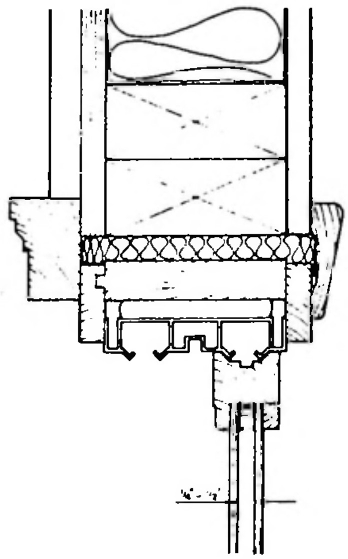

Figure 2.69

is filled with a special gas, which gives them their higher R-value.

The R-value of a single-glazed prime window used with a storm window could be higher than that of a standard double-glazed prime unit with a small air gap that is not filled with gas. This is because of the wider air gap (1 to 3 inches) between the two glazing layers (see Figure 2.70). It was also noted in the infiltration discussion above that the presence of two window frames (prime and storm) can provide better resistance to air infiltration than a double-glazed prime window.

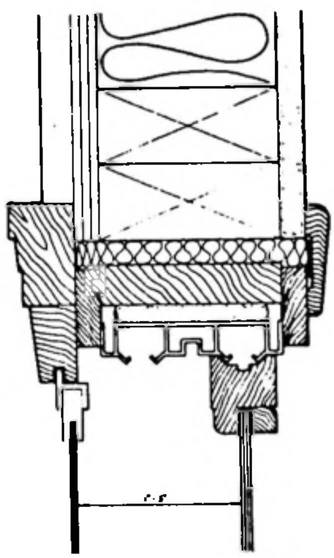

Figure 2.70

With their double air gaps, triple layer glazings can provide even more insulating value than double layer glazings.

The guidelines for the width of the air gaps in triple-glazed units are the same as those for double glazing. One common arrangement with triple-glazed windows is a double-glazed primary unit with a storm. This arrangement can result in a higher overall R-value for the glazing, again because of the wider air gap between the storm glazing and the double-glazing of the prime unit (see Figure 2.71).

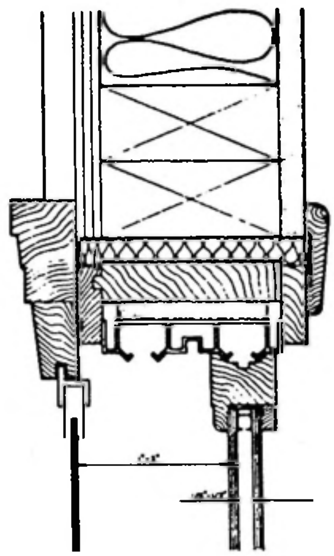

Figure 2.71

Figure 2.70
Air space between primary and storm windows. The width of the air space between the primary and storm window will vary depending upon the detailing of the windows. Air spaces from 1" to 3" will provide effective resistance to heat flow.

Figure 2.71
Air space between glazing layers. Windows used in combination to achieve multiple glazing layers will provide air spaces of varying widths. Here a combination of prefabricated double-glazed primary window and a storm window results in high R-value triple glazing.

Shading

Shading is one of the most effective strategies in reducing a home's energy use for cooling. Factors such as the local climate, and the orientation and size of the windows to be shaded can greatly affect the energy-saving value and thus the cost-effectiveness of a given shading strategy.

The south side of the home is usally the easiest to shade from the summer sun. Since the sun is high in the sky a small overhang that can shade not only the window but the entire wall as well is usually sufficient (see Window Orientation above). Because of the morning and afternoon positions of the summer sun, east and west facing windows are considerably more difficult to shade. At these times the sun is low in the sky and while a horizontal overhang would not be very effective for shading, a vertical shading device can substantially reduce the amount of direct sun on the windows. North windows usually need shading only in the southernmost parts of the country where the summer sun rises to the north of east and sets to the north of west. In these instances the use of "wing walls," which are narrow vertical wall sections that are placed perpendicular to the north wall are particularly effective. Wing walls are located right next to the window they are to shade. The further they extend out from the north wall, the more of the wall that will be shaded.

Any shading strategy or device is most effective when it is placed *outside* the home. Shading placed on the inside results in the sun penetrating the glazing, adding solar heat to the interior despite the presence of the shading device. An effective and visually appealing exterior shading device is a tree or other vegetation that shades a window and/or a large part of a wall. In selecting a site for the home it's always a good idea to try to take advantage of such on-site features. In addition to what Nature can provide there is also a variety of devices that can be bought or built to provide exterior shading.

Interior shading devices can reduce unwanted heat gain, relative to having no shading device at all, but as mentioned above they are not as effective as the exterior devices. Standard roller shades and venetian blinds that are light colored work better than dark colored units as they reflect more sunlight back out through the window. Common drapes can also be effective at blocking sunlight, and if they are properly sealed at the edges, they can also provide some insulating value during the heating season (see Movable Insulation). In fact, there are many window insulation devices that can also be used to provide some shading thus increasing their overall energy-saving value. Some of the more popular shading devices, which are discussed here, include overhangs, shutters, sunscreens, and awnings.

Overhangs

A basic roof overhang is perhaps the simplest and most maintenance free of all exterior shading ideas. They are permanent, require little or no maintenance, and when properly sized allow winter solar heat gain through south windows. Overhangs are most effective on south walls, although they can be used on southeast and southwest facades as well. An effective overhang for a west or east facing wall would need to be very deep as would be the case with a porch or carport roof (see Figure 2.72).

Figure 2.72

Figure 2.72
Overhangs. Wide overhangs, such as porches or carports will provide effective shading on the east and west sides, whereas smaller overhangs of up to 2 feet, will generally suffice on the south side.

Shutters
Exterior shutters, roll-down shades, and blinds provide effective shading on all facades as they can literally block the sun from any angle. However, they are perhaps most appropriate on east and west windows, which are very difficult to shade with standard overhangs or awnings.

Shutters do, of course, require some operation, although products now available have motorized controls and can be operated manually from the inside of the home (see Figure 2.73). The main drawback of shutters is that they may reduce the amount of daylight too much. This is why a combination of shutters and overhangs is a good idea for achieving the desired shading while maintaining some natural daylighting for the home. Another factor to consider with these solid shading devices is the extent which they might inhibit egress in the case of fire.

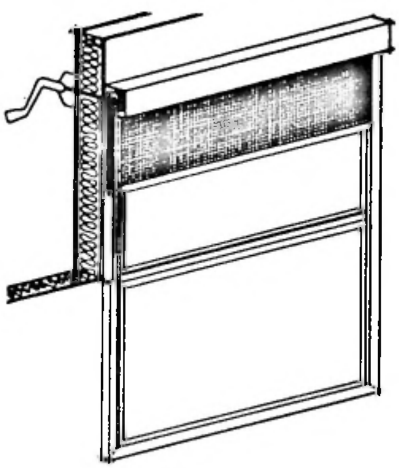

Figure 2.73

Sunscreens
Sunscreens are used in the same way and places that insect screens are used. In fact they perform the double duty of insect screen and shading device. They are a specially designed, close-weave plastic mesh that has somewhat more solidity than does an insect screen, hence their shading capability. Unlike shutters, sunscreens allow view to the outside and more daylight. They are most effective in blocking higher angle sunlight (south windows) although they do provide shading benefits on east and west windows.

Awnings
Awnings are a popular and quite effective way of reducing solar heat gain, especially when they are used over south facing windows. Awnings are usually adjustable, which allows for some seasonal adjustment of their projection from the home (see Figure 2.74).

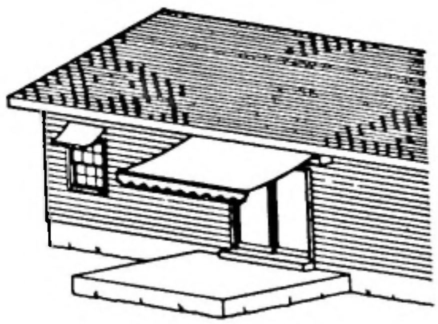

Figure 2.74

Awnings can also be effective over east and west windows if they are designed to come "out and down" to provide adequate coverage against the low-angle summer morning and late afternoon sun. Of course, south windows will also be exposed to some morning and afternoon sunlight. Side panels on the awning can be effective in blocking some of the sunlight at these times. Some awnings are fixed, particularly those constructed of metal, and do not allow for adjustment. As with fixed overhangs, fixed awnings limit the flexibility of adjusting the projection seasonally. Basically the same design parameters that are followed for stan-

Figure 2.73
Roll-down screens for shading. Exterior roll-down screens are effective for shading individual windows, particularly on the east and west sides where long overhangs may not be practical.

Figure 2.74
Awnings used for shading. Adjustable canvas awnings are excellent shading devices and can be adjusted on an "as needed" basis.

dard roof overhangs should be followed for fixed window awnings.

Awnings that are solid metal or plastic or unvented canvas can also create a problem of heat build-up under the awning enclosure. Open-slat awnings allieviate this problem by allowing for a free flow of air around the awning, exhausting any heat build-up beneath it.

Design Considerations

• In warmer climates with large cooling loads it is always a good idea to incorporate appropriate shading devices into every home design. Decisions on which strategy to choose will be based on the nature and layout of the site and the positioning and orientation of the home.

• Whenever possible, take advantage of any existing site elements that can provide shading. Trees for shading the south, east, and west sides of the home are effective. However, if solar heat is desirable, only trees that drop their leaves in the winter (deciduous) should be used for shading.

Movable Insulation

As insulation levels in the ceiling, walls, and floor continue to increase, windows account for an ever increasing proportion of the home's total energy use. In other words, in homes that are tightly constructed, weatherstripped, and well insulated, even double- and triple-glazed windows can still be energy "culprits." Increasing the window R-value by adding movable insulation may prove to be a good investment in these circumstances, especially in colder climates.

Unfortunately, window insulation products have only become widely available in recent years. With a limited market thus far the products have tended to be expensive and not particularly well-suited to mass production. There has however, been a surge of product developments linking window insulation with interior decoration in the form of insulating drapery and shading products. This new form of double duty, decoration plus energy conservation, may be the link that most contributes to getting prices lower for more broadly based product lines. While becoming more readily available, less expensive, and less exotic, movable window insulation is slowly becoming a popular measure for saving energy.

True to its name, this form of insulation is moved into place by the homeowner. Typically, this is a task for evenings during the heating season, when there is no sunlight coming through the windows, just heat going out.

Of course, homeowners who buy window insulation as an option or as part of a total energy conservation package have to be made well aware that, to be effective, the insulation must be conscientiously pulled into place in the evening. Therefore the task of handling the insulation shouldn't be an inconvenience. Since many window insulation products double as shades or curtains, they would be used at night for privacy anyway.

With the range of products that are now available, movable insulation can be installed on either the interior or exterior of the window. On occasion condensation may occur on windows covered with interior insulation, but with proper design, installation and use this should not be a significant problem. Condensation will not be a problem with exterior insulation, although such movable insulation will be subject to the effects of weathering. In addition, exterior insulation may be difficult to operate.

Window insulation can actually deliver more than just the benefit of reduced heat loss. Because window insulation products usually make a tight seal with the entire window frame, they can also play a role in reducing air infiltration. Also, during the cooling season window insulation can be used as a shading device. Exterior window insulation would be more effective for this application, but this is secondary to its task of reducing heat loss. If interior insulation is used for shading, the side facing out should be light colored to reflect as much sunlight as possible back outside. Otherwise, with dark colored insulation, there can be a significant build-up of heat between the insulation and the glass, and this heat will get into the home.

Construction Considerations

- For the best energy performance, proper installation of movable insulation is a must. Some designs will require the same level of accuracy as do window and door installation. Most have some unique installation instructions, so it will be important to follow carefully the manufacturer's directions and recommendations. Proper operation is just as important, although certainly most of these products have been designed for ease of use as well as energy-savings. In any event, the homeowner should be made fully aware of how the movable insulation is to be operated.

Interior Drapes

Insulating drapes are commonly made with materials such as quilted fabrics with thin fillings of insulating material, reflective liners and/or multiple layers of fabric or plastic film — all aimed at reducing heat flow. With the wide variety of materials and detailing from product to product, R-values will vary somewhat, with most drape-style products having R-values between R-1 and R-4. While drapes that are specifically labeled as movable insulation can be expected to save energy, some energy savings can be realized from standard drapes if the edges and bottom are well sealed. Actually, a well sealed drape provides an R-value of about R-1 and, when placed over a double-glazed window, can reduce that rate of heat loss through the window by about 30 percent.

Construction Considerations

- As with all types of movable insulation, having a good seal between the insulation and the window is important. In the case of flexible drapes the seal along the side is often achieved by providing edge sealing strips of Velcro or magnetic tape. The bottom hem of the drape can be fitted with weights sewn into it, maintaining a good seal at the floor or sill (see Figures 2.75 and 2.76). The top of the drape usually has some sort of hood or covered valence to restrict room air from entering the often wide gap between drape and window. In general, the particular construction of the seal will need to be matched to the drape.

Interior Shades

Insulating shades can be made of the same materials as insulating drapes, and are often thicker with the use of more fiber fill insulation or more layers of air spaces. The primary difference is in the range of available R-values, usually between R-3 and R-12. Again, always consult manufacturers for precise specifications.

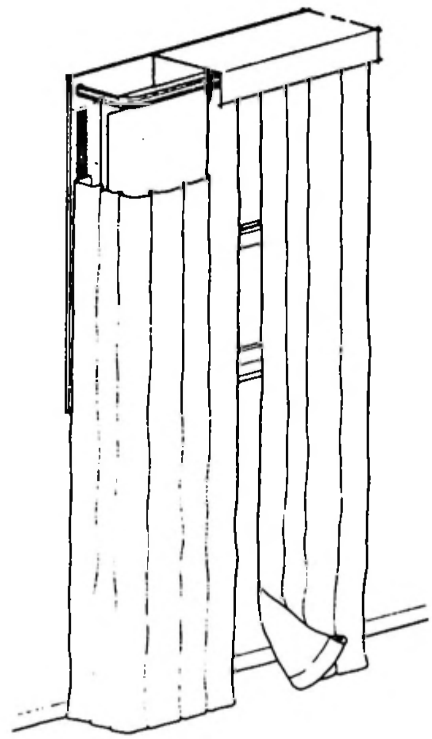

Figure 2.75

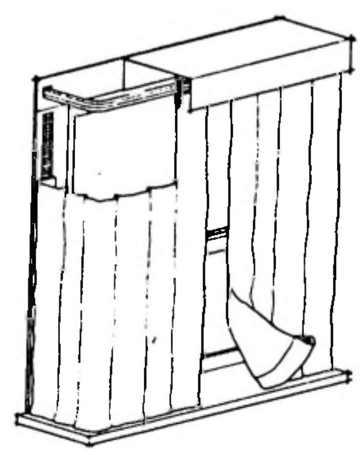

Figure 2.76

Figure 2.75
Floor length drapes.
Nighttime insulation may be provided by quilted or standard drapes which are sealed around the sides and the floor. Velcro strips can be provided at the sides along with weights in the hem.

Figure 2.76
Sill length curtains.
Velcro strips, at the sides, and weights, in the hem, transform standard fabric curtains into effective movable insulation for windows.

Construction Considerations

• There are a few styles available in insulating shades, such as the Roman fold-up or the roll-up styles (see Figure 2.77), and some are used with

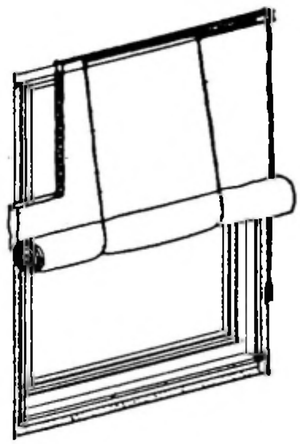

Figure 2.77

valences (see Figures 2.78 and 2.79), some not. Seals, like those used with drapes, can be specified or the shade can be sealed with special side tracks or side clamping bars. Bottom seals are achieved by simple contact between shade and windowsill or by some form of clamp-

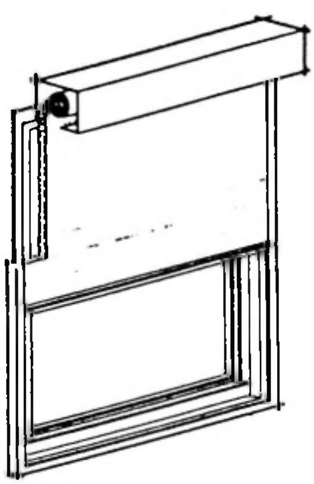

Figure 2.78

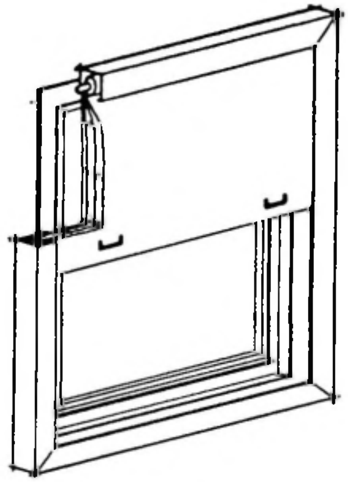

Figure 2.79

ing device. Like their standard drape counterparts shades of standard design can also provide some insulation value if the sides and bottom are sealed to the wall or window frame.

Interior Shutters

Insulating shutters are rigid window coverings that are usually fabricated from such materials as polystyrene or polyisocyanurate foam boards of varying thicknesses. Typically the foam is sandwiched between two layers of some finish material such as thin wood or patterned wallboard. The R-value of these units essentially varies with the R-value of the insulating foam, which can range from R-3 to R-8 per inch of thickness. The finish coverings only add fractionally to that R-value, unless a thick wood or composite material is used. For example, two ½-inch coverings could raise an R-4 shutter to R-5, an increase that can reduce the rate of heat loss by 20 percent.

Construction Considerations

• Being rigid panels, shutters are typically hinged at the sides and sometimes at the top. Side-hinged units can also be multifolding so

Figure 2.77
Roman shades. Roman type shades made out of quilted fabric and designed with velcro seals at sides and bottom are effective nighttime insulation.

Figure 2.78
Roll-up shades. Side and bottom tracks ensure that the movable insulation remains well sealed while in place.

Figure 2.79
Roll-up shades. Some types of nighttime insulation provide resistance to heat flow by expanding when opened, forming air spaces. Such shades may require larger valences and side tracks than standard insulating materials.

that a wide shutter will not take up a lot of wall space when open (see Figure 2.80). Shutters

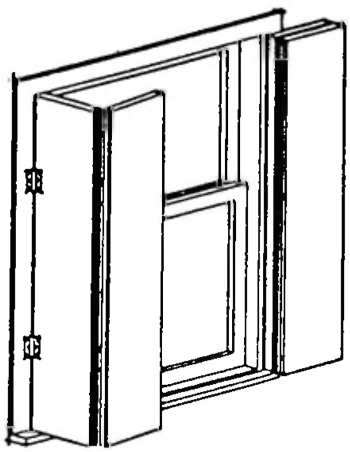

Figure 2.80

usually achieve a tight seal with some sort of compression-type weatherstripping such as might be used for a casement window. These rigid panels are somewhat less forgiving than drapes or shades when it comes to installation errors. The problem is sometimes compounded when the window is out of square. But with proper installation they are indeed effective, and, perhaps, the most effective type of movable insulation with regard to reducing air infiltration.

gure 2.80
erior shutters.
nstructed out of rigid ulating panels, interior utters can provide move insulation with relaely high R-values.

gure 2.81
movable panels.
id insulating panels y be designed to be red when not in use l attached to the dows at night or on udy days.

ure 2.82
erior shutters.
ndwich panel' shuts may be installed on exterior but must be igned to withstand effects of weather- such as warping. tters can also be for shading during

Interior Panels

Insulating panels are relatively simple in design. They are basically removable panels that are pressed and held into a window opening or over it by some simple fastening or holding device such as magnetic or Velcro strips (see Figure 2.81). Because they are frequently handled, they are designed to be lightweight, often consisting of a rigid foam board or other insulating material with a thin, light covering. They do require some storage when not in place, though as space permits they can be hung on the wall next

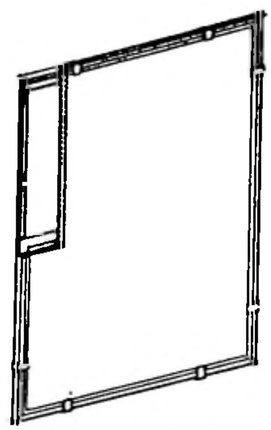

Figure 2.81

to the window and covered with a decorative fabric for good appearance.

Exterior Shutter and Panels

Insulating shutters and panels made for exterior use are similar in construction to interior units with the main difference being in their weather resistance. They seal tight to the exterior window or frame either by operation from the inside or the outside (see Figure 2.82). Because of the

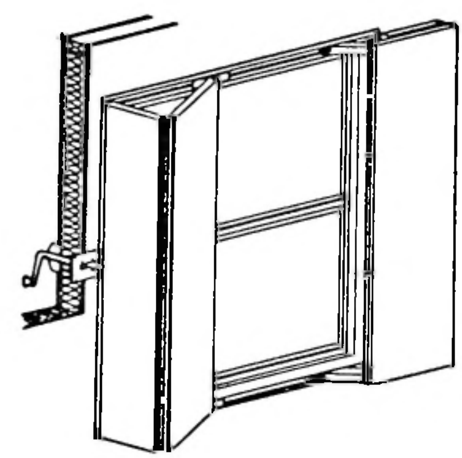

Figure 2.82

often severe weather conditions, creating and maintaining a good edge seal becomes all the more important. Insulating value for these units is again mostly a function of the heat resistance of the insulation core, which is often some type of rigid foam board. The R-value ranges from R-3 to R-8 per inch. While interior shutters and panels are usually limited in thickness to 1 inch for appearance and practicality, most exterior products are fabricated in thicker widths.

Exterior Roll-Down Shutters

These shutters are typically made from interlocking slats of wood, aluminum or PVC plastic that are rolled up and down with either interior or exterior controls. They are guided and edge-sealed by side tracks with a compression seal being made along the rigid bottom edge (see Figure 2.83). R-values can vary somewhat depending on the insulating value of the slats. Sometimes hollow PVC and aluminum slats are filled with insulation to improve the R-value. Devices like these can also be very effective for window shading during the cooling season. In a warmer climate, for example, it might make more sense to specify exterior shutters to take better advantage of their shading value.

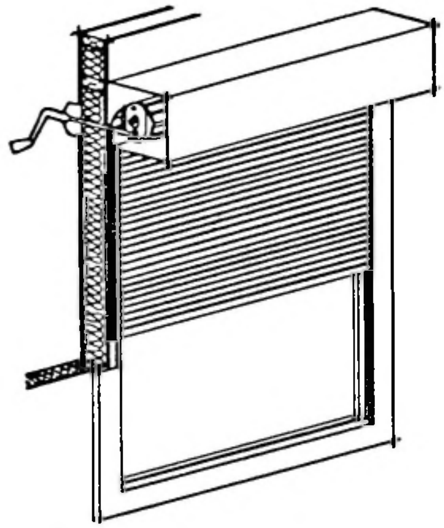

Figure 2.83

Figure 2.83
Exterior roll- **shutters.** Mo sulation is pr slatted shad in tracks on rior. In addit providing in such device provide sha the summer

All types of movable insulation, interior and exterior, can be bought off-the-shelf or shop- or site-fabricated to provide a wide range of R-values. The following table gives basic information on the assumed characteristics for each of the movable insulation R-values listed in PEAR. For more information refer to Table 3 in the User's manual.

Movable insulation R-value	Construction
None	No movable insulation is used.
R-1	This R-value is assumed for conventional drapes and shades that are installed with good perimeter seals
R-3, R-5	These R-values have been specified for both interior and exterior products that have been made specifically to be used as movable insulation. The advertised R-values for these products should be used only if the products are well sealed and installed according to the manufacturer's instructions.

Passive Solar

Thus far most of the materials and techniques covered in this Guide have been designed to help reduce the amount of energy used by a home for heating and cooling. This of course is the essence of energy conservation: to reduce fuel energy consumption. Yet there is another side to energy conservation: passive solar space heating. It consists of designs, techniques and materials that also help to reduce heating (and sometimes cooling) energy consumption, but in this case with the *input* of solar energy.

Passive solar heating systems that have been included in new homes have been shown to be effective energy savers, some of which also add aesthetic, market, and resale value to a home. In fact some passive solar homes have been designed to completely eliminate the need for purchased energy, employing a combination of energy-efficient and passive solar design and construction techniques.

The central features of passive solar designs are the large areas of south facing or nearly south facing glazing and thermal mass (discussed below). As was mentioned in the "Windows" section, increasing the area of properly oriented glazing can create significant increases in solar heat gain. In addition to window size and orientation, passive solar design techniques consider a number of other energy-related features of a home — all helping to create an effective, comfortable, "Nature-driven" heating system.

The "passive" part of passive solar design refers to the way in which heat from solar energy is collected, distributed, and stored in the home without the use of other energy sources. An "active" system, on the other hand, would use a pump to circulate water or other fluid through an array of roof-mounted collector panels. In large active space heating systems, the energy consumption for pumps and controls can be significant, which, in the final analysis, subtracts from the energy savings of the solar contribution.

Passive systems are also different from their active counterparts by being easily integrated into the overall design of the home rather than treated as a separate mechanical system. In really passive homes, the passive components themselves become the major design features.

It should be stressed here that this discussion is only a general introduction to a subject that is very well documented in a large body of literature that ranges from technical to popular. This literature should be consulted before deciding on the type of system and its construction.

One thing that is always emphasized about passive solar heating systems is that they are only effective in reducing energy use if they are combined with a full complement of energy conservation features. This is essentially because, on a cost-effectiveness scale, passive solar options generally follow those for conservation. Passive systems have proven themselves to be cost-effective but primarily as an extension of the line of energy improvements begun by the conservation options. It makes little sense, for example, to create special systems for collecting solar energy for a home that is not well-insulated and tightly constructed. So in terms of priorities, it's conservation first, passive solar next.

As was mentioned, one of the primary elements of passive solar design is in the use of large expanses of glazing for collecting solar heat. The glazing is typically covered at night with movable insulation to reduce heat losses, which can be substantial. In fact, in some areas of the country, passive solar is only effective if movable insulation is used. The other fundamental passive solar design element, previously discussed in the wall construction section, is known as thermal mass. All materials in the home (framing, wall materials, furniture) have some mass, and therefore some ability to store heat, but denser, heavier materials such as masonry and water (in containers) can store much more heat per unit of volume. These are the materials that are commonly used as thermal mass in passive systems.

Why is thermal mass needed? The answer has to do with the fact that passive systems usually include large glazed areas to maximize the collection of solar heat. During the day that can lead to overheating problems if there is no thermal mass to absorb and store surplus heat (beyond what the home needs by day to maintain comfort). An often used analogy is that of the car sitting out under the sun with all of its windows rolled up. In a short time it overheats due to a lack of thermal mass to store all the excess solar heat. So in homes designed to be heated passively, the "glass and mass" combination is fundamental to proper performance (see Figure 2.84).

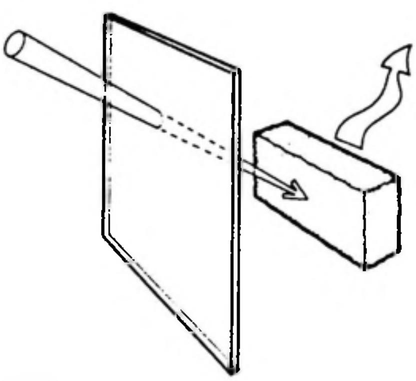

Figure 2.84

Figure 2.84
Glass and mass. In passive solar systems, sunlight passes through south facing glass, is converted to heat, and is stored in thermal mass.

Passive systems are essentially quite simple in their basic operation. Solar radiation enters through the south glazing, and when it strikes objects, it becomes heat. Typically most of the thermal mass intended for use with the system is located so as to intercept most of the incoming sunlight. This way it can absorb and store the heat directly, reducing the need to move the heat to a remote storage area. When evening comes and the house begins to lose more heat than is being collected from the sun, the thermal mass continues to supply its stored heat back into the living space in order to maintain comfort levels. Basically thermal mass aswers the question, "What do you do about solar heating when the sun goes down?" With sufficient glazing and mass area, the thermal mass can also be used as a carry-over heat source when sunny days are followed by cloudy days.

In houses with frame wall construction extra mass will usually need to be added to the house if passive solar design is used. Houses with masonry or solid wood walls, if insulated on the outside, already have some or all of the mass needed to absorb the heat collected by large areas of south facing glass.

The following discussions cover the four basic passive system types. It should be noted that in some designs the thermal mass can also serve as the structure of the home.

A *Direct Gain* system is one in which sunlight directly enters the living space through south windows, it heats the objects and the air in the space, thereby maintaining comfort levels during cold days. In a system like this the home itself is the collector. Thermal mass often takes the form of a concrete slab floor and/or a masonry wall at the back or side of the room, located to intercept direct sunlight (see Figure 2.85). Masonry or solid wood houses with the mass exposed on the inside already incorporate thermal

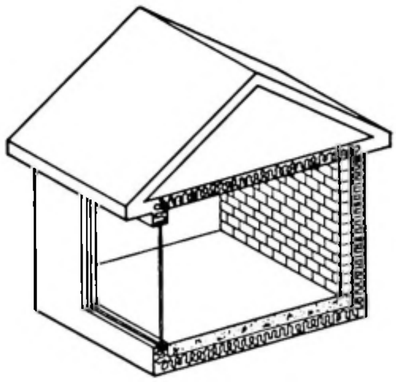

Figure 2.85

storage capacity in the basic construction of the home.

An *Attached Sunspace* or *Solar Greenhouse* is typically an enclosed space that is kept separate from the home's living space (see Figure 2.86). It employs large areas of glazing and is usually allowed to have much wider temperature variations than normally occur in a living space. During a sunny day, heat collected in the sunspace is transferred to the home through doors, windows or vents. Surplus heat that builds up in the sunspace is absorbed by thermal mass that is placed in the floor or wall that separates sunspace from the living space.

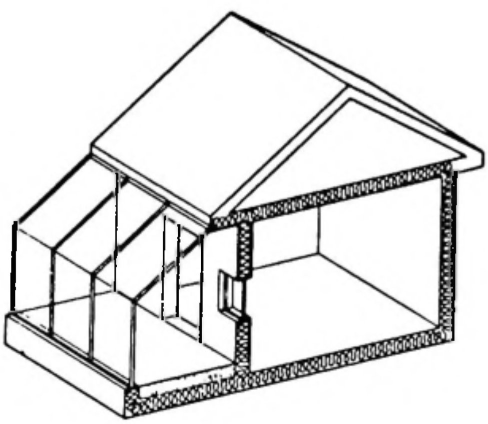

Figure 2.86

Houses with masonry or solid wood walls already provide some of this thermal mass in the basic design. Even with their wider temperature variations, sunspaces are commonly used as living spaces throughout the year.

A *Thermal Storage Wall* system is in some way like a direct gain system in that the glazing is part of the building envelope. But in this kind of system a thermal mass wall (typically masonry or water or phase change materials in suitable containers) is located between the glazing and the living space (see Figure 2.87). In operation,

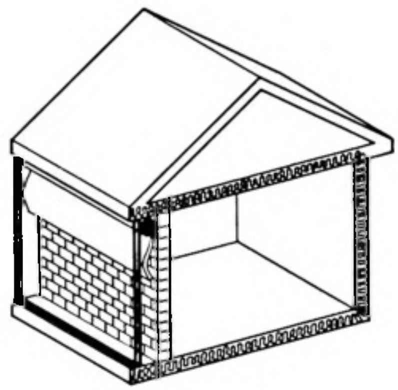

Figure 2.87

the wall absorbs and stores much of the incoming solar heat, releasing it to the living space through the day and night. The mass of the Thermal Storage Wall delays the transmission of heat to the living space. This delay allows the Thermal Storage Wall to store heat while the sun is shining and to release this stored energy later on, when heating needs are usually greater. Because the thermal mass is placed fairly close to the glazing there may also be somewhat more heat loss at night from the mass through the glass to the outside. Again, houses of masonry or solid wood wall construction already provide mass and are generally

Figure 2.85
Direct Gain systems. South facing windows collect solar heat which is stored in thermal mass placed directly in the living spaces.

Figure 2.86
Attached Sunspace systems. A Sunspace is a space, separated from the home, which collects and stores heat to heat itself and provide some additional heat to the other living spaces in the home.

Figure 2.87
Thermal Storage Wa systems. Mass is located directly behind the collector glazing, storing and slowly releasing heat into the adjacent living spaces

easier to adapt to a thermal storage wall configuration.

A *Convective Loop* system generally consists of collector panels used to heat air. The panels themselves are simple glazed boxes, placed on the south face of the home, that contain a blackened metal heat-absorbing plate with an insulation backing. When sunlight passes through the glazing, the metal absorber heats up. Heat is transferred into the living space by way of operable vents. Cooler air from the living space flows back into the collector to replace the exiting heated air to complete the "loop" (see Figure 2.88). With the operable vents the collector panels can be closed off from the living space at night to limit room heat loss. With large-area collector arrays there can be surplus heat (beyond the daytime heating needs of the home), which can necessitate the use of a remote thermal mass storage component to which heated air is delivered, usually via a duct system. Houses with masonry or solid wood walls exposed to the living spaces already provide storage mass and will be less likely to require remote heat storage systems.

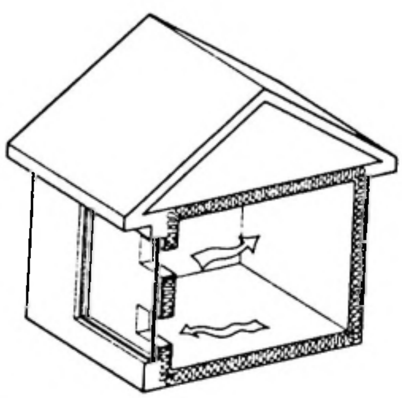

Figure 2.88

Figure 2.88 Convective Loop systems. In this system, glazed panels collect heat which is vented directly into the living space (without storage) or distributed to remote storage located elsewhere in the home.

Figure 2.89 Thermal Mass. Heat stored during the day is released slowly throughout the day and night by the thermal mass in the home.

These four passive solar heating systems represent options that are often used in residences, but of this group by far the most popular are Direct Gain and Attached Sunspaces. Design considerations and the advantages and disadvantages of these two system types are discussed in more detail below.

Direct Gain Systems
In any Direct Gain system, sunlight directly enters living spaces of the home through expanses of south facing glass. This solar radiation is in turn absorbed by elements in the space, such as floor, walls, ceiling, and furnishings, and converted to heat. This heat either warms the air in the space or is stored in interior objects for later use (see Figure 2.89).

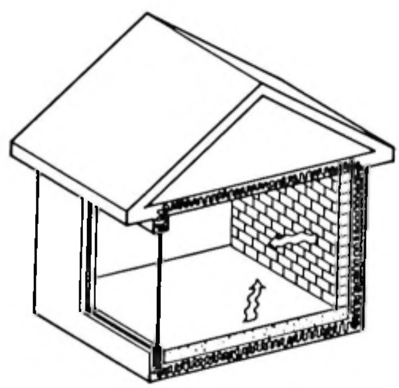

Figure 2.89

Advantages

- They are conceptually the simplest of all passive systems, and therefore can be the easiest system to build using standard construction materials and techniques.

- Even with the larger expanses of south glass that are frequently used, Direct Gain systems do not radically alter a home's appearance. This is, in part, due to the fact that the basic design of the glazing system is meant to be an extension of the conventional glazing area.

- Concerns about the privacy of living in a "glass house" make it likely that the movable insulation will be used at night (see Movable Insulation).

- Direct Gain systems provide natural daylighting, as well as views to the outside. The daylighting benefit can help to reduce lighting energy consumption.

- The additional costs associated with Direct Gain homes are usually less than other passive systems.

Disadvantages

- The large expanse of south facing glazing can cause glare and privacy problems.

- The great increase in sunlight entering the room can accelerate fading and degradation of fabrics not selected for their resistance to solar exposure.

- The day-to-day routine of putting movable insulation in place, by whatever means, and taking it down in the morning could meet with homeowner resistance.

Design Considerations

- Thermal mass heat storage components are usually made of heavy weight construction materials such as concrete, concrete masonry units, brick, stone, or solid wood. These materials often double as structural components for the home, as in the case of a concrete floor slab or a masonry wall. Water and phase change materials can also be used as thermal mass, but they cannot be used as structural components of the home. Whatever type of thermal mass material is being used, it is generally better to spread the mass over a large surface rather than concentrate it in a smaller area. Thus, for example, it is more desirable to design the mass to cover 400 square feet at 4-inches thick than to cover 200 square feet at 8-inches thick. It is also more desirable to expose as much of the mass surface area as possible to direct sunlight. Dark colors will help make the mass more effective both in absorbing excess heat and in releasing it later than the heat is needed. It is especially important that floor and wall surfaces which receive direct solar gain have a dark color. Color is not as important on other surfaces.

- If both walls and floors are to be used for heat storage, then it is best that the walls be light-colored and the floors dark. Some interior finishes will reduce the heat absorption capability of thermal mass by literally insulating it from sunlight or heat in the room. Paint is acceptable, as is plaster and wallpaper (which reduce performance only slightly). If gypsum board is used, it must be thoroughly glued to the mass surface to ensure total contact for maximum heat transfer. This will require that construction adhesive be spread in a continuous coat over the gypsum before adhering it to the mass surface. Carpeting placed over a mass floor or wall will insulate the mass from available sunlight and heat, and it should be avoided whenever possible. As a homebuilder, however, you may have little say as to the ultimate interior decorating of a home, which means that the homeowner should be informed about the importance of keeping mass surfaces exposed. Insulating materials should be placed on the exterior side of the mass.

- The overall or year-round performance of a Direct Gain system will benefit greatly if shading is provided to limit heat gain in summer (see Figure 2.90). It stands to reason that if an unshaded Direct Gain system increases a home's cooling load, the value of the system, on an annual basis, will be reduced.

- The performance of a Direct Gain system will also be improved if movable insulation is pro-

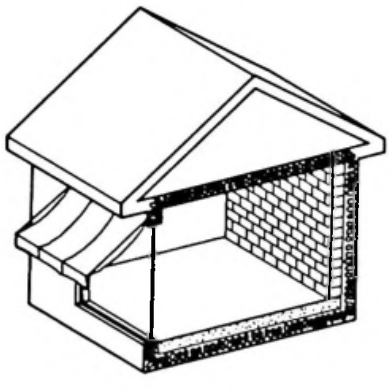

Figure 2.90

Figure 2.90
Direct Gain shading. To protect against overheating during the warmer months, some shading in the form of awnings, overhangs, or vegetation should be provided.

vided (see Figure 2.91). With the large expanses of glazing (typically double-glazing is specified) usually used in Direct Gain systems, there is an increase in overall building heat loss because of the reduction in more heavily insulated solid wall area. Movable insulation can triple the R-value of the Direct Gain glazing (from R-2 to R-6), significantly reducing nighttime heat loss. The movable insulation can also be used for shading in summer.

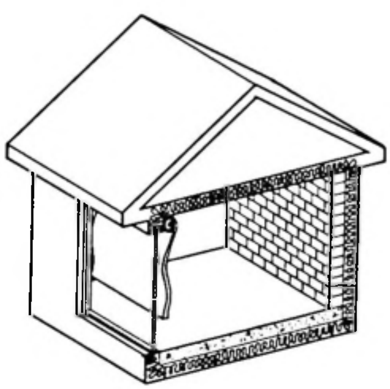

Figure 2.91

Figure 2.91
Direct Gain movable insulation. Heat losses out through the large glazing areas can be substantially reduced by he use of insulated shades, drapes, or shut-ers.

Attached Sunspace

Sunspaces are more than just solar heating systems. By being sizable rooms that can enclose a large floor area, they can also be additional living space of a special sort with their glassed-in walls and roof sections. This quality alone has made them very popular among people seeking more than just heating energy savings. But they can indeed be effective heat-producing systems, providing not only enough heat for the space they enclose, but also delivering heat to the rest of the home. Yet another potential benefit is that they can be used as acutal food and plant growing greenhouses, giving rise to the other names by which sunspaces are known: "Attached Greenhouses" or "Solar Greenhouses."

Energy efficiency is a major factor in the successful operation of a sunspace. Tight construction minimizes air infiltration. Floors sidewalls and solid roof sections are typically well-insulated, and double glazing is used throughout. Movable insulation should be provided to perform the dual function of insulation and summer shading. Thermal mass is typically provided in the floor and back (north) wall of the sunspace to absorb solar heat and prevent overheating (see Figure 2.92). Surplus heat is also delivered into the house through special vents or through open doors or windows.

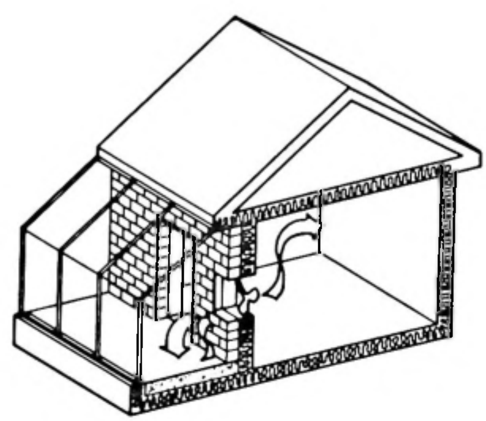

Figure 2.92

igure 2.92
ttached Sunspace eat distribution. xcess heat collected in e Sunspace can be istributed to the adja-nt living spaces rough doors, win-ws, or with low locity fans.

Advantages

- Sunspaces can be used for growing plants and food.

- Even without the sun providing heat, the sunspace is a buffer zone reducing heat loss from the adjacent living space.

- Added sale value and amenity is gained from a sunspace when it is also used as a living space.

- By its unique design (relative to the rest of the home) a sunspace can add significant aesthetic value.

Disadvantages

- Because they can be much more than just a heating system, sunspaces typically have higher costs than other passive systems. Costs can be kept low with the use of less expensive materials, but these tend to degrade in a short time.

- When a sunspace is used as a working greenhouse, certain problems can arise that involve the control of excess humidity, odors, and insects. A provision for running water and drainage must be made in plant growing sunspaces.

Design Considerations

- Thermal mass heat storage elements are usually made of heavyweight materials such as concrete, concrete masonry units, brick or stone. Houses with walls made of any of these materials will already have much of the necessary mass. The mass should be well-distributed throughout the sunspace.

- Mass surfaces which receive direct sunlight should be dark-colored for better heat absorption.

- Sunspaces are either *sitebuilt* or *prefabricated*. Site built sunspaces are typically framed with wood. They are often custom designed to meet specific site conditions and design requirements. Prefabricated sunspaces come as complete off-the-shelf units that are framed with preformed metal structural members or wood. Prefabricated units are typically fully engineered and ready for relatively quick assembly. Better quality units are weathertight and require little maintenance. They may, however, be more difficult to insulate than sitebuilt sunspaces. Site-built units can have an advantage in being adaptable to a wide range of design requirements and therefore more easily integrated into the design of the home. Careful detailing is required with site-built units to ensure that they will maintain a tight seal against the weather. To maintain their energy-efficiency, periodic inspections may be required to ensure that caulking and other seals are still intact.

- Most sunspaces are double-glazed with glass, though some prefabricated units use plastic glazing. Site-built units commonly use standard double layer patio door replacement glass, which is tempered for extra strength and safety.

- It is best that the east and west "endwalls" of a sunspace be of solid, insulated construction. Glazed endwalls will typically lose more heat in winter than they collect, and they can make the sunspace more vulnerable to summer overheating. The walls of the home can be designed to "wrap around" the sunspace and form its endwalls. Insulated roofs may also be beneficial in cold climates (see Figure 2.93).

- Because of their high ratio of glazed area to floor area, sunspaces are especially prone to summertime overheating. Having proper shading is one solution, particularly on a glazed roof section that will receive most of the high-angle summer sun. A variety of shading devices can

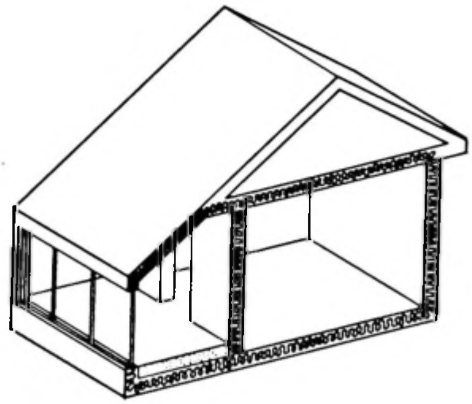

Figure 2.93

be adapted to sunspaces, and many prefabricated units have optional integrated shading systems (see Figure 2.94). Providing for ventilation during warm weather is another important design requirement. Even well shaded sunspaces can overheat. Operable windows and/or doors in the sunspace can equalize the inside and outside temperatures.

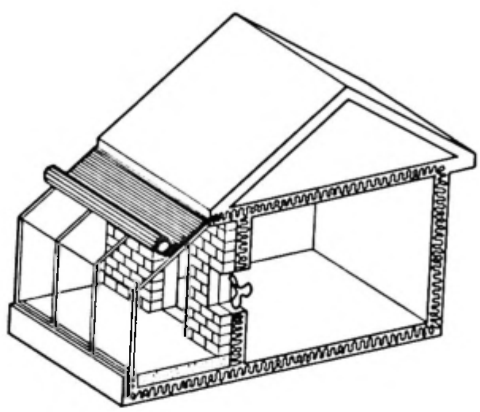

Figure 2.94

• The presence of movable insulation will substantially improve the overall energy performance of a sunspace (see Figure 2.95). By reducing nighttime heat loss there is less of a need to provide the sunspace with supplementary heat. Movable insulation will also make the space more comfortable during cold nights, making it more useable as a living space even during these periods. In some climates sunspaces without movable insulation may actually be net energy losers.

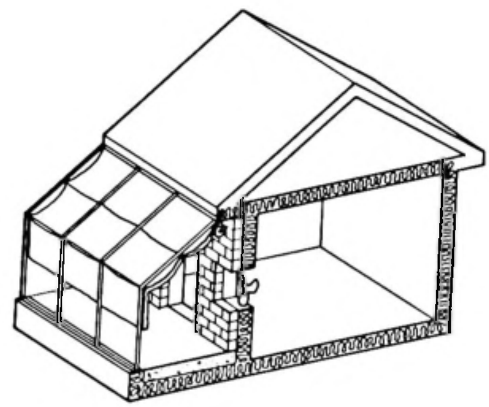

Figure 2.95

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ed Sunspace le insulation. sses out through e glazing areas substantially re- y the use of in- shades, drapes, rs.

Guide to PEAR ATTACHED SUNSPACE Input

The effects that sunspaces have on energy use can be estimated using the PEAR computer program (see Table 4 of the User's Manual).

Equipment

All of the options that have been discussed thus far are designed to make the home more efficient, reducing the amount of energy consumed by mechanical heating and cooling systems. Yet opportunities for further energy savings also exist in the selection of mechanical systems. Some newly developed systems now available are significantly more efficient than those available a few years ago, rewarding the new homebuyer with, in many cases, substantial energy savings. In addition, a number of add-on controls and other components are available to further improve system efficiency.

The discussion below is an overview of the most commonly specified equipment available today. It is important to point out, however, that in recent years there has been a great deal of activity in the research and development of new energy-saving systems and components that are constantly being introduced into the marketplace. This work is ongoing, and there will continue to be new developments. Equipment suppliers can provide up-to-date information on the availability of these new products.

Equipment Efficiency

Except in the case of heat pumps, heating and cooling energy is typically provided by separate pieces of equipment. The "primary" sources of energy for heating systems are electricity, fuel oil, natural gas, and liquified petroleum gas (LP-Gas). Most cooling systems use electricity.

Efficiency ratings for heating and cooling systems are useful for comparing one system to another. Currently two types of efficiency ratings are in use, *steady state* and *seasonal efficiency*, and it is important that they not be confused with each other.

Steady state efficiencies for individual pieces of equipment are determined while they are operating at some constant rate under controlled conditions. Thus steady state is essentially a measure of an instantaneous efficiency, and does not reflect what the system's efficiency would be under actual stop-and-start conditions encountered in the home. A system that is operating under such actual conditions will have a lower overall efficiency than the steady state value. This is the second type of efficiency designation, seasonal efficiency, or a measure of the system's performance taken over an entire heating or cooling season. This rating is really the most useful when it comes to specifying equipment.

In heating systems, oil-and-gas-fired furnaces and boilers are rated in terms of their *Annual Fuel Utilization Efficiency* (AFUE). Electric furnaces and resistance heating systems are rated by their *Seasonal Efficiency* (SE), and electric heat pumps in heating are rated by what is called a *Heating Seasonal Performance Factor* (HSPF). Central air conditioners and heat pumps in cooling are rated by a *Seasonal Energy Efficiency Ratio* (Seer). It is important to point out that all of these terms indicate *relative performance*, that is, they are useful in comparing one piece of equipment to another of the same type. All of the above ratings refer to the efficiency of the central part of the system, such as the furnace or boiler itself, without considering the energy losses due to the distribution part of the system. Distribution losses, for example, through ducts and pipes, are considered in the *system* seasonal efficiency. Some systems, such as baseboard electric heaters, have no actual distribution system, so their seasonal and system efficiencies are the same. In most cases, the system seasonal efficiency will be a few percentage points below the equipment seasonal efficiency.

Equipment Specification

There are a few general guidelines to be kept in mind that will help in making better choices.

- The selection of a piece of equipment can be the most important decision affecting a home's energy use. Even a difference of just 10 percent in seasonal efficiency can make a substantial difference in a home's energy consumption. The equipment seasonal efficiency rating is available on a fact sheet which can be provided by the equipment supplier.

- Obviously when two pieces of equipment are compared that use the same energy type, the one with higher efficiency will result in lower annual energy costs. But, when comparing pieces of equipment that use different types of energy such as a gas boiler and an oil-fired unit, differences in local energy cost between the two energy sources must be considered in estimating the total energy cost.

- Some utilities provide incentives for using particular pieces of equipment. The local utility can provide further information on such incentive programs.

- When selecting equipment, you should also be aware of factors such as maintenance requirements and the expected service life of the unit. These factors can be significant in estimating the costs and benefits to the homeowner. Durability and low maintenance cost will certainly be more attractive to the homeowner, even in the face of a higher initial cost.

Sizing

One factor that can greatly affect both seasonal efficiency and the first cost of a home is the sizing of the equipment. The bottom line of course is that the equipment should be sized to provide adequate heating or cooling under the most adverse weather conditions. In the past systems were often oversized relative to the actual need. This was done either by overly conservative calculation or by a desire to provide a larger "margin of safety" to ensure that there would always be enough heating or cooling capacity for the home.

However, oversized equipment operates at a lower seasonal efficiency than equipment sized to match the home's actual heating or cooling requirements. In addition, if the equipment is larger than needed, the total cost of the home will also rise. Most equipment suppliers, and particularly manufacturers, are now in a position to provide useful, up-to-date guidance on equipment sizing.

It is worth noting at this point that energy conservation options which increase the thermal integrity level of the house have the potential for allowing the downsizing of the mechanical equipment, with resulting first cost and operating savings. More insulation in the ceiling, walls or floor, windows with multiple panes and movable insulation in cold climates, windows with tinted or reflective glass and proper shading in hot climates, infiltration protection measures, passive solar heating techniques, all reduce the heating and/or cooling loads and may permit the selection of lower capacity space conditioning equipment.

Distribution

Although more difficult to quantify, the seasonal efficiency of the mechanical system is also affected by the distribution system (e.g. the ductwork and hot water pipes). The proper design and installation of this part of the system is extremely important for achieving the maxium overall system efficiency. Ductwork delivers heat from central furnaces and heat pumps, and cooling from central air conditioners and heat pumps, while central boilers use pipes to deliver hot water to heaters in each room. Both types of distribution are discussed below.

Studies have shown that a poorly designed and installed duct system can reduce seasonal efficiency by as much as 35 percent. This could easily negate the benefits of having a more efficient piece of equipment. Careful layout, detailing, and installation, adherence to industry standards and compliance with state and local mechanical codes are obviously important.

Since ducts carry heated or cooled air moved by blowers, the ducts themselves are considered to be pressurized. Any leaks will therefore result in energy losses as the heated or cooled air may escape before being delivered to the living spaces of the home. Insulation is also important to retain the heat and cooling in the ductwork. Higher levels of insulation (usually R-5 to R-10) are typically needed when ductwork is run outside the insulated envelope of the house, such as through an unheated crawl space. Duct insulation can be wrapped around metal or other

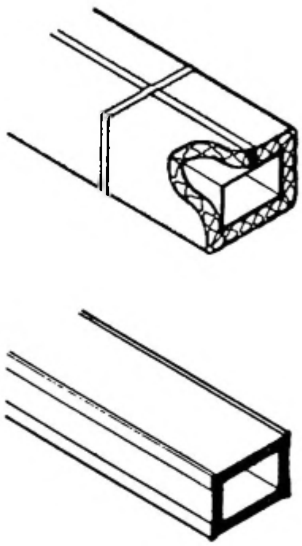


Figure 2.96

ductwork or some types of flexible ducting are available already wrapped with insulation, and "ductboard" is a duct material that is itself made of an insulating material (See Figure 2.96). Consult your suppliers for more detailed information.

Losses can also be reduced by minimizing bends in the distribution system and keeping ductwork length as short as possible (see Figure 2.97).

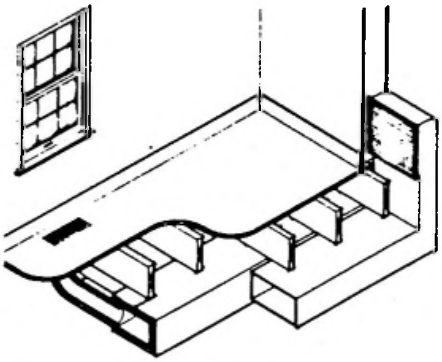


Figure 2.97

Hot water pipes for boiler systems should also be carefully laid out and installed. As with air ducts, hot water pipes should whenever possible be run within the conditioned spaces of a home. Pipes should also be properly insulated to minimize the loss of heat on the way to room heaters (see Figure 2.98).

Thus in any system, *all* the piping that carries hot water should be insulated. In addition, the cold water supply pipes should be insulated for at least the first six feet away from the boiler. This avoids heat loss by conduction of heat from the boiler into this cooler pipe. If it turns out that some piping must be run outside the house, insulation should be increased to between R-5 and R-10. There are currently a variety of pipe insulation materials, and product information

Figure 2.96
Insulated ductwork. Metal ducts can be wrapped in insulation batts or blankets, or ducts fabricated from rigid insulating materials can be specified to reduce distribution heat losses.

Figure 2.97
Duct distribution systems. Specifications of different size and shape ducts will be appropriate within a given system.

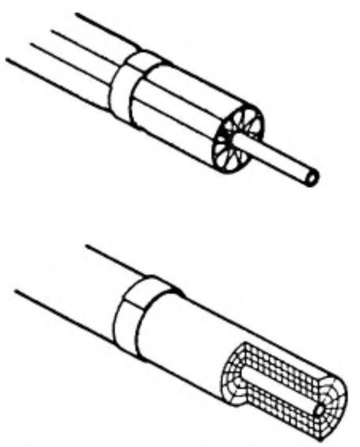


Figure 2.98

should be available from local mechanical equipment suppliers. An important safety consideration to be remembered when installing pipe or duct insulation is to keep it away from sources of high temperature, such as the heater itself or the exhaust flues.

Controls

The basic device that controls the amount of heating or cooling supplied to the home is of course the thermostat. Since it is operated by the homeowner, it is only briefly discussed here, but it should be noted that simply by lowering the temperature setting (setback) during the heating season and raising it (set forward) during the cooling season can result in significant, no-cost energy savings.

The *setback* strategy described is usually done at night during the heating season. Standard wall thermostats can be manually reset in the evening or an *automatic setback thermostat* can be used instead. The automatic thermostat is essentially a convenience device allowing the homeowner to program the length of the setback period and amount of the setback. If such a device is supplied in a new home, the ultimate owner should be provided with instructions for its use. Even though automatic setback thermostats are slightly more expensive than standard units, the value of the energy they can save in most parts of the U.S. will quickly exceed the added cost. When the house design incorporates significant amounts of thermal mass, night setback may not be necessary. Equipment manufacturers should be consulted for specific recommendations.

Figure 2.98
Hot water pipe insulation. Water pipes used for distribution in hydronic systems should be insulated with either batts or blankets, or rigid foams.

To be most effective, the thermostat should be located four to five feet off the floor on an inside wall that is out of direct sunlight and away from cold drafts. PEAR estimates the energy savings due to the night thermostat setback option (see the User's Manual).

Heating Systems

Common types of heating systems being installed in new homes are electric, gas and oil furnaces or boilers, vented gas space heaters, electric baseboard units, and electric heat pump systems. Fireplaces and woodstoves have also maintained their popularity in some parts of the country. Radiant electric systems are also encountered. Each of these system types is discussed below with guidelines that can aid in selecting the right system.

While only the most common heating systems are described below, there are a number of other heating systems popular in some areas of the country. These include systems such as multifuel furnaces and boilers and integrated space heating/water heating systems. These systems can be effective in reducing overall annual energy costs when properly installed and operated.

Electric Heating

Electric heating systems come in a variety of different types, including: electric furnaces (hot air) and boilers (hot water), electric heat pumps with electric resistance back-up elements, baseboard electric units and electric radiant systems. Electricity use is measured in kilowatt-hours per year (abbreviated kWh/yr).

Electric Furnaces operate by heating air taken from the home and distributing it through ducts and an array of vents and registers. The seasonal efficiency of electric furnaces is typically 100 percent.

Heat pumps also use duct systems to distribute heat. The two basic types of heat pumps are referred to as *split systems* and *self-contained* systems (see Figures 2.99 and 2.100). In general, for those units currently available, split systems have higher seasonal efficiency ratings than self-contained units.

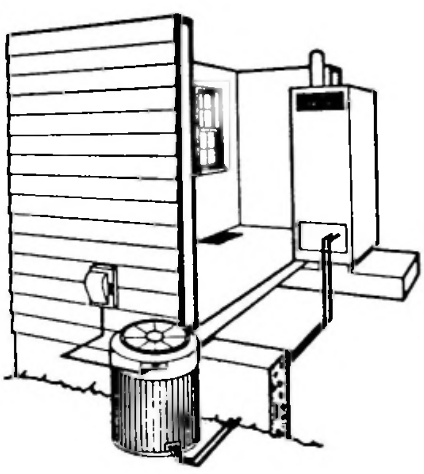


Figure 2.99

Heat pump heating efficiency is expressed by the Heating Seasonal Performance Factor (HSPF) which quantifies the amount of heat delivered for every watt consumed, at standard test conditions. The HSPF rating appears on the EnergyGuide label.

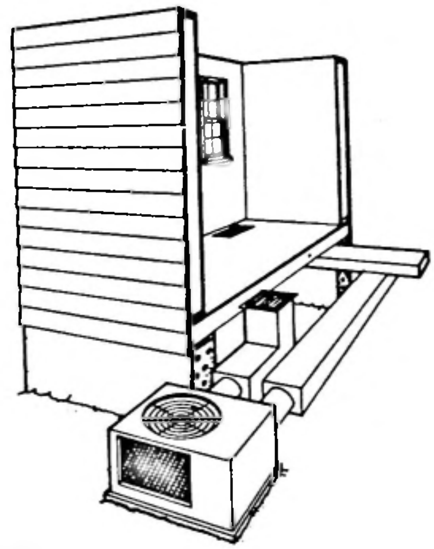


Figure 2.100

However, the HSPF does not tell the whole story. Heat pumps literally draw heat from the outside air, so the colder it gets, the more difficult it becomes for the unit to extract heat. As the efficiency of the heat pump decreases, supplementary heating becomes necessary. The backup heater is generally composed of one or more electric resistance coils, which supplement the heat pump operation until they entirely take over the task of space heating. Since resistance heating is about 1.5 to 3 times less efficient than heat pump heating, prolonged operation with electric resistance backup may substantially increase the operating costs of the system. The actual seasonal efficiency of the heat pump, as impacted by the electric resistance backup, varies by climate zone. This seasonal efficiency is lower than the rated HSPF, which does *not* include backup heating. The manufacturer, mechanical engineer or contractor should be consulted on the proper heat pump seasonal efficiency for any given location.

If the backup heater uses oil or gas, the heat

Figure 2.99
Split system heat pumps. In split system heat pumps, efficiency is increased.

Figure 2.100
Self-contained heat pumps. The entire heat pump unit is located outside requiring that conditioned air (heating or cooling) be ducted into the home.

pump is switched off when it cannot satisfy any longer all heating requirements. From that moment on, the backup heating system supplies all of the space heating. Although this system can be very efficient, the combined first cost of both heat pump and furnace must be considered.

One advantage of heat pumps is that they can be used for both heating and cooling (see Cooling Equipment below). In fact they are generally less cost-effective than other systems if they are just used to provide only heating or cooling. Part of the savings, of course, comes with purchasing one unit to supply both the heating and cooling needs, rather than buying separate heating and cooling equipment.

Proper installation of heat pumps at the site is important. For example, a heat pump located in the sun will have a different performance (seasonal efficiency) than one shaded all day long. Of course, the manufacturer's or distributor's installation instructions should be followed closely to ensure a successful installation.

With many currently available heat pump systems conventional nighttime thermostat setback will not be effective. The manufacturer should be consulted for guidance on precisely which equipment and controls can be used to accomplish night thermostat setback.

Baseboard Electric Resistance heaters are typically placed along the walls in each room to be heated. Each room can be controlled by an individual thermostat eliminating the need for a central thermostat. This ability to "zone control" offered by baseboard systems allows for more precise control over comfort levels throughout the home. For example, the living room can be set at a higher temperature than a den if the den is not in use. Night setback is also possible on a room-by-room basis. The zone control and setback capability can result in significant energy savings when compared to a home that is controlled by a single thermostat.

The seasonal efficiency of baseboard units is 100 percent if the entire home is kept at the same temperature. If, however, some of the rooms are left at a lower temperature (that is, zone controlled) for certain parts of the day total energy use may be reduced by 10 to 30 percent relative to a non-zoned home. Proper operation of the zoned system is, of course, left up to the homeowner.

It should be noted that electric baseboard systems have no duct heat losses and do not contribute to increased air infiltration.

Radiant Electric Systems
These systems can achieve 10 to 30 percent energy savings when compared to central electric furnaces. The savings are obtained by maintaining lower temperatures in unoccupied spaces. Radiant panels can quickly raise back the temperature of the space when desired. As with electric baseboards, there are no duct losses or increased infiltration.

Natural Gas and Liquified Petroleum (LP-Gas) Heating
Both natural and LP-Gas are commonly used in home furnace (hot air) and boiler (hot water) systems. Natural gas is delivered to homes through municipal pipelines and is typically measured in units called therms, with annual use being measured in therms per year (abbreviated therms/yr) or hundreds of cubic feet per year (CCF) where 1 CCF = 100 CF. 1 CCF is also roughly equal to 1 therm, depending on the heat content of the gas used.

LP-Gas also known as "bottled gas," is usually delivered to homes by a tank truck and stored in an on-site tank. It is usually measured in gallons, with annual use being measured in gallons per year (abbreviated gallons/yr).

Efficiencies for gas equipment are estimated by an AFUE rating, which can usually be found on the equipment specification sheet available from the distributor or supplier. The AFUE typically ranges from 65 to 85 percent for mechanical draft and power burner systems to as high as 95 percent for condensing furnaces and boilers. A two percent increase in AFUE is possible if the system uses gas-saving pilotless ignition, with another five to six percent increase if flue dampers are specified with systems that are not sealed combustion. The use of a night setback thermostat is also a viable option with gas systems. Specification of sealed combustion units, that is, equipment using outside air for combustion rather than indoor air, will reduce air infiltration, thereby decreasing the home's overall heating energy needs (see Air Infiltration). Direct-vent gas-fired space heaters present the additional advantage of zonal control, which can result in savings of 10 to 30 percent relative to a gas-fired, non-zoned heating system. Consult your supplier for more details on the variety of available equipment and product options.

Oil Heating

Fuel oil is also used in both furnaces and boilers. Like LP-Gas, it is delivered to homes by tank trucks and stored in on-site tanks. Oil is measured in gallons per year (abbreviated gallons/yr). As with gas systems, oil equipment efficiency is estimated by an AFUE, which is typically somewhere between 65 and 85 percent.

Oil system AFUE ratings are little different from those for gas systems. Efficiencies can be raised by the use of a flue damper, and annual use can be cut with nighttime thermostat setback. Again, specification of sealed combustion units can reduce total energy use in the home by reducing the air infiltration rate.

Wood-Burning Stoves and Fireplaces

In recent years the popularity of home woodstoves and fireplaces has increased dramatically, largely in response to the cost increases for other heating energy sources. Depending on the selling price, wood fuel can be more economical than the other sources. However only by making careful comparisons of local energy costs can you actually determine where wood as an energy source stands on the cost ladder. Selection of the right equipment and proper installation and operation are also factors that affect annual energy use and therefore annual cost. Low-quality equipment, for example, could result in more energy waste than savings. Improper installation and use can actually increase heating requirements. But accompanying the recent surge in the use of stoves and fireplaces, has been the development of basic guidelines for efficient use of these systems.

Fireplaces, for example, draw in a great amount of room air to maintain combustion of the wood. This can add to the home's average air infiltration rate, meaning higher heating costs. One solution here is to supply the fireplace with combustion air directly from the outside (see Figure 2.101).

Another improvement for fireplaces is covering the fireplace opening with special glass doors. These will limit to some extent the intake of room air by the fireplace, while the glass in the doors will still allow radiant heat to warm the room. Prefabricated metal fireplaces are usually available with these doors (see Figure 2.102). They can also be fabricated for built-in fireplaces. In all cases the doors should be tight-fitting.

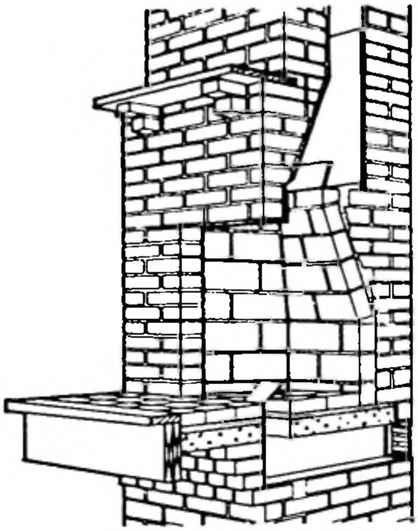


Figure 2.101

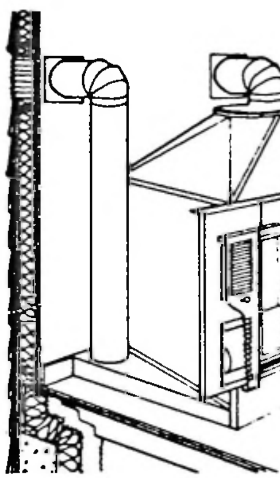


Figure 2.102

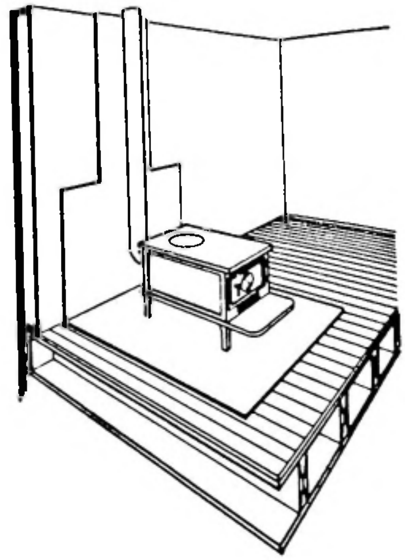


Figure 2.103

gure 2.101
ealed combustion eplaces. Site-built sonry fireplaces can designed with 100% tside air combustion increase efficiency.

ure 2.102
efabricated fire- ces. Sealed com- stion, factory-built eplaces are available h glass doors and culating fans to re- e losses up the mney and increase erating ciency.

ure 2.103
e standing stoves. d fuel burning s should be in- d so that heat can te in all directions.

e 2.104
for stoves. types of energy nt flues can be ed to increase rall performance d stoves. lated flue is ifactured with a of rigid insula- etween two skins. air flue is man- ired with one air spaces be- metal layers. ir-cooled flue ufactured with layers allow- to be drawn e outermost moving heat flue gases within the liv- .

Most wood-burning stoves have a solid metal single- or double-door for fuel loading, instead of a glass door. Heat from a stove radiates from all sides, top and bottom, so it is important that the stove be installed so as not to block that radiation (see Figure 2.103). The combustion air requirements for most stoves are somewhat less than for fireplaces, and consequently there is usually no need to supply outside combustion air. Their draw of room air will not be great enough to substantially increase heating requirements.

Both stoves and fireplaces should be equipped with a flue damper. Some stove units come equipped with a damper. The damper essentially controls combustion air intake by controlling the exhaust air flow up the chimney. In many cases the flue is set at the smallest opening without inhibiting exhaust to rise and without limiting combustion. Several different types of flues are available which can also increase the efficiency of wood stove units (see Figure 2.104). In addition there may be specific requirements for the

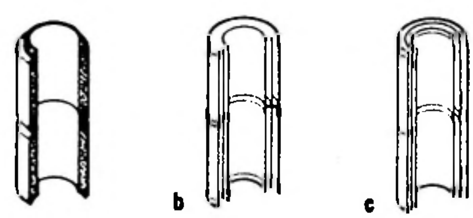


Figure 2.104

wide variety of stoves and fireplaces now available, and careful study of their individual specifications and instructions is necessary.

Cooling Systems (Electric)
In the warmest areas of the country a cooling system will be an integral part of the home design. Both central and individual room units are popular, with the preference in recent years being for central systems. When home heating is accomplished with a furnace-air duct system, the addition of a central air conditioning unit can be done with relative ease. Homes that are heated by hot water radiators or baseboard electric systems do not of course have the advantage of an existing duct system, which can make individual room air conditioners more desirable when providing a cooling system. But since window or wall air conditioners are usually installed by the homeowner and not the homebuilder, they are less likely to be used as a feature to promote the sale of a home. The same is true for *evaporative coolers* (also known as "swamp coolers") as they too are usually installed by the homeowner. It should be noted that evaporative coolers are *only* appropriate for use in hot, dry climates as they do add to a home's humidity level. They are very popular, for example in the southwestern U.S. where they provide effective cooling without excess humidity.

Thus, with the above exclusions, the two primary cooling equipment options that homebuilders usually provide are heat pumps and central air conditioners.

Electric Heat Pumps
As discussed, there are two basic types of heat pumps now available, the split system and the self-contained. Both types can be used for heating and cooling, although in general, for those units currently available, split systems have higher seasonal efficiency ratings than self-contained units.

Efficiencies for heat pumps vary by location, but actually the variance is much greater for the heating mode than for the cooling mode. The cooling mode efficiency is expressed as the Seasonal Energy Efficiency Ratio (SEER) and appears on the EnergyGuide label.

In its cooling mode, the heat pump uses the same duct system used for heating to distribute cool air. And as was discussed in "Heating Systems" proper installation is important for ensuring proper operation. For example, a heat pump located in the sun will have a different performance (seasonal efficiency) than one shaded all day long. Of course, the manufacturer's or distributor's recommendations should be closely followed to ensure a successful installation. Proper sizing is also important for best efficiency and for minimizing annual energy costs which are measured in kilowatt-hours per year (abbreviated kWh/yr). Always follow the manufacturer's instructions with regard to installing the unit and designing the duct system.

Central Air Conditioners can also be either self-contained or split systems and are installed in homes equipped with a duct distribution system for heating. Otherwise, adding a complete duct system just for cooling could prove too costly in addition to the cost of a separate heating system.

Like heat pumps, the efficiency of a central air conditioner is expressed as a SEER rating and energy use is tallied in kWh/yr. Air conditioners operate more efficiently in cooling that heat pumps, because heat pumps must also accomodate heating requirements. SEERs appear on the EnergyGuide labels.

The following table displays typical seasonal efficiency ranges for the equipment and energy types reviewed in the preceding discussion. These ranges are intended for information purposes only and cover the equipment most often specified. Lower and higher efficiencies are also produced by some manufacturers. When real equipment costs are being measured against performance, accurate seasonal efficiency values should always be obtained from manufacturers' and suppliers' fact sheets and used in energy consumption calculations. An explanation of the range of efficiencies allowed by PEAR can be found in Table 4 of the User's Manual.

Equipment Type Heating	Seasonal Efficiency Indicator	Typical Efficiency Range
Electric Furnace	Seasonal Efficiency (SE)	1.00*
Electric Heat Pump	Heating Seasonal Performance Factor (HSPF)**	5.5 to 9*
Baseboard Electric	Seasonal Efficiency (SE)	1.00****
Electric Radiant Panel	Seasonal Efficiency (SE)	1.00****
Gas Furnace	Annual Fuel Utilization Efficiency (AFUE)***	65* to 95
Gas Boiler	Annual Fuel Utilization Efficiency (AFUE)***	65* to 90

Equipment Type Heating	Seasonal Efficiency Indicator	Typical Efficiency Range
Vented Gas Space Heater	Various	Not Covered by FTC Labeling program. See manufacturer's literature for comparative efficiencies.
Oil Furnace	Annual Fuel Utilization Efficiency (AFUE)***	75 to 90
Oil Boiler	Annual Fuel Utilization Efficiency (AFUE)***	75 to 85
Equipment Type Cooling	Seasonal Efficiency Indicator	Typical Efficiency Range
Electric Heat Pump	Seasonal Energy Efficiency Ratio (SEER)	7.2 to 13
Central Air Conditioner	Seasonal Energy Efficiency Ratio (SEER)	5.8 to 15

*These values do not take into account the effect of duct or pipe losses which can reduce efficiency by roughly 5 to 10 percent when most of the ductwork is within the envelope of the structure. This range can be much higher for ductwork running outside the building shell.

**HSPF does not account for backup heating. Please consult the mechanical engineer, distributor or contractor for location-specific seasonal efficiency.

***Consult the mechanical equipment supplier, distributor or contractor for efficiency of specific equipment. Each piece of equipment should carry an energy fact sheet with these values.

****Thermostat setback in unoccupied zones can result in 10 to 30 percent energy savings due to overall lower temperatures being provided to the conditioned space. The local electric utility or gas utility, as appropriate, should be contacted for an accurate estimate of those savings.

Fans

Fans have a proven ability for providing cooling at a lower cost than other mechanical cooling equipment. And they are often viewed by homeowners as a useful amenity. Their economy and attractiveness to homeowners has made them quite popular in recent years, particularly in the southern and eastern parts of the U.S.

The energy savings that fans can provide comes when they can be used instead of an air conditioner or heat pump to provide cooling. They reduce the cooling requirements by exhausting hot air from the home and by simply creating a flow of air in the living space, which has a cooling effect on the occupants.

There are many types and styles of fans that can be used in homes. Two of the more popular types are the "casablanca" type ceiling fan and the whole-house fan. Ceiling fans are effective on a room-by-room basis, which could mean that several would be needed to serve an entire house. In most cases just one or two ceiling units are needed in the major living spaces of the home.

Whole house fans are of course meant to serve the home, though by moving that much air they can be a little noisy. They are used instead of the air conditioner by drawing and exhausting outside air.

Whole house fans can be installed high on an exterior wall, though most available units are designed for roof or ceiling installation. Whatever the actual location having it high up in the home places it where the most hot air will tend to collect. This usually makes a ceiling location more effective than a wall installation.

Construction Considerations

- Ceiling fans are often installed in the upper reaches of cathedral ceilings, although wherever they are installed there should be sufficient headroom for safety (see Figure 2.105).

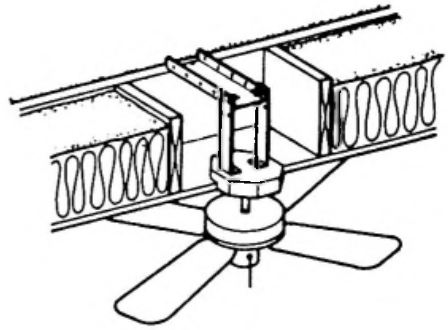


Figure 2.105

Figure 2.105 Overhead fan installation. Special attention should be paid to fan clearance to ensure sufficient headroom. Where necessary, special "low clearance" fans are available and can be specified.

- Ceiling-mounted whole house units require a louvered intake grate that opens by the suction of the fan. In order for the fan to be effective on the exhaust end, there should be at least three feet of vertical headroom above the fan (see Figure 2.106). Wall mounting a whole house fan will require special installation procedures detailed by the manufacturer (see Figure 2.107).

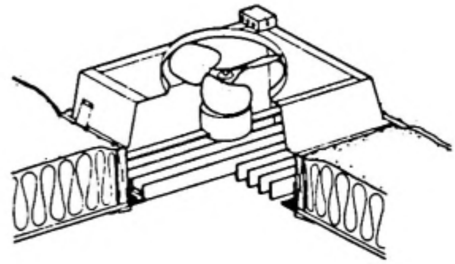


Figure 2.106

Figure 2.106 Whole house fan installation (vented attics). Whole house fans installed in homes with vented attics can be detailed to exhaust warm air through vents located in attic gable ends and ridge vents.

- When a whole house fan is installed in a roof it should be connected to the ceiling vent by a plenum or large duct section that is no smaller than the dimensions of either the fan or the vent (see Figure 2.108). This avoids the problem of venting attic air along with air from the home. When the fan is installed in the ceiling (attic floor), it is critical that the attic be properly

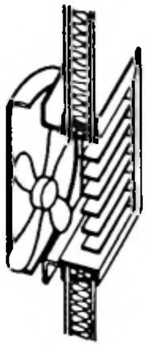


Figure 2.107

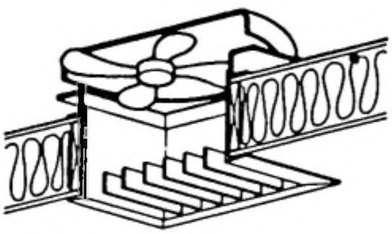


Figure 2.108

vented, either with gable end vents or soffit and ridge vents. Otherwise the exhaust air will have nowhere to go. The sizing of these exhaust vents is important to ensure proper fan operation and effectiveness. Specifications are usually available from the manufacturer.

• During the heating season the fan housing should be covered to prevent unnecessary heat loss. If there is sufficient space between the intake grille and the fan blades, the grille can be removed, and the space filled with a tight-fitting piece of insulation (see Figure 2.109).

• Insulation can also be placed over the fan housing, again with care taken to ensure complete coverage. Some precaution should of course be taken to insure that the fan is not operated when the insulation is in place. This could damage the fan and actually be a fire hazard.

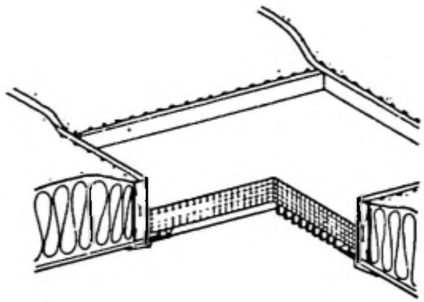


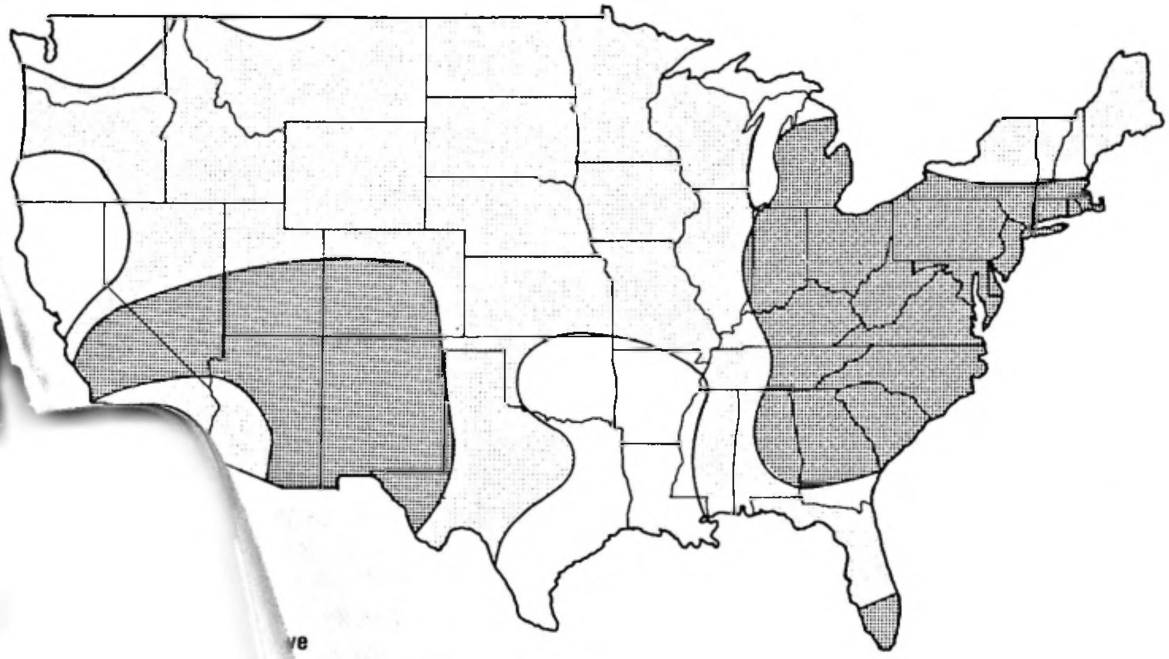
Figure 2.109

• In order for the whole house fan to be most effective in its flushing of heat from the house, as many windows as possible should be open at least 12 inches. Proper sizing should result in a flow that changes the entire volume of house air every two minutes. Larger homes may need more than one fan to accomplish this. Sizing specifications should appear in manufacturer's literature.

Figure 2.107
Whole house fan installation (through the walls). A whole house fan may be installed through the wall. A central location is advisable.

Figure 2.108
Whole house fans installed through the roof. In certain cases, such as cathedral ceilings, the fan may be installed directly through the roof/ceiling using a plenum or duct between intake grille and fan.

Figure 2.109
Insulating the vent grille. Insulation provided above the vent grille during the winter is recommended to reduce heat losses.



… t experience with … estimate their … can be found on … the country into … loderately Effec- … ng the relative … erwise be used … ment. The … Very Effective … ctive next and the leas… ective regions.

The regions, however, do not tell the whole story in terms of cost savings. For example, in a Moderately Effective area with very high electricity costs, the number of dollars saved by using the fan rather than cooling equipment (which would use much more electricity) could be substantial. In fact, these dollar savings could be much higher than those achieved using a fan in a Very Effective area with relatively low electricity costs.

3 Domestic Hot Water and Appliances

Hot Water

Domestic water heating (commonly abbreviated DHW) is the second largest user of energy in a house after space conditioning (heating and cooling). In some highly efficient new residences, water heating costs may even be comparable to space conditioning costs.

There are a few options available that can greatly reduce water heating costs, and therefore the total cost of homeownership. Actually, most of the savings can be achieved by using just three options that are commonly employed to bring down the cost of heating water: flow reduction, water heater tank insulation, and solar water heating systems. These and a fourth option, tankless water heaters, are discussed below.

Energy Saving Options

Flow Reduction

Installing devices in faucets and at showerheads that can reduce rate of water flow is both a popular and effective means for saving energy dollars. Of course, the slower the flow, the less hot water is used. Having a flow rate of 1.5 to 3 gallons per minute (gpm) will reduce energy costs, and there is little loss of convenience due to the slower rate.

Flow reducers are small plastic devices which are inserted into plumbing fixtures such as showerheads and faucets (see Figure 3.1). These devices are relatively inexpensive (compared with the savings they create), easy to install and readily available in plumbing supply and hardware stores.

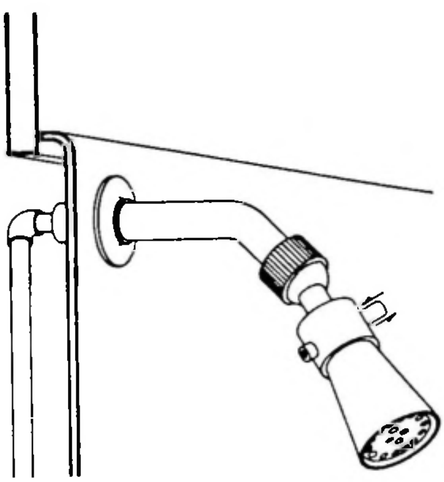


Figure 3.1

Figure 3.1
Flow reducing valves. Reducing water flow at showerheads and other fixtures to 2 to 4 gallons per minute will reduce the amount of DHW energy use.

Tank Insulation

Water heaters for DHW systems are ordered off-the-shelf with insulation provided to reduce heat losses from the tank. Since the water in the tank is kept hot throughout the day and night, it will continually lose heat through the skin of the tank. These losses are reduced by the presence of insulation. Of course, the more insulation, the lower the heat loss. In the past, heaters were manufactured with little or no insulation around the tank. Today, units are available with a range of insulation levels (see Figures 3.2 and 3.3).

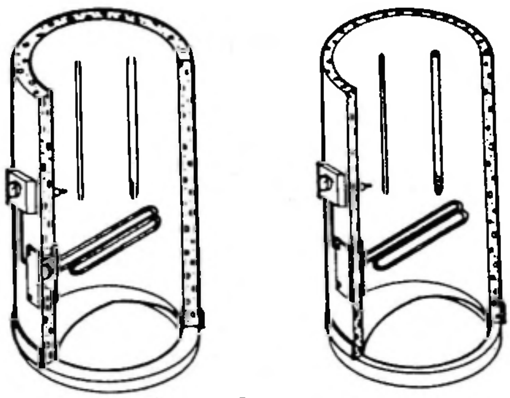


Figure 3.2

Figure 3.2
Insulating DHW heaters (electric). Electric water heaters are available with a variety of insulation types and thicknesses.

Solar DHW Systems

Solar energy adds another dimension to the meaning of energy conservation. While flow reducers and extra tank insulation are both op-

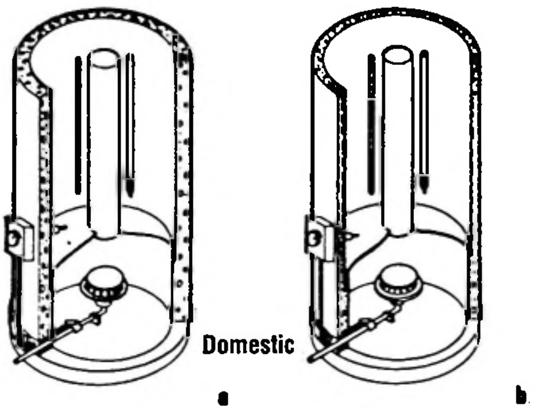


Figure 3.3

tions that *reduce* energy use, a solar DHW system reduces energy use by *adding* heat to the existing system. Solar heat is "free" in the sense that after the system is bought and installed the energy cost associated with its operation is relatively small (some electricity is used for running the pump).

In practice, the amount of heat a solar DHW system can provide varies with the amount of sunlight available and the area of the heat collecting panels that trap solar energy and convert it into hot water. Even homes located in climates that are relatively cloudy have the potential for using solar heat to make a substantial reduction in water heating energy use. As to the size of the panels, one or two *flat plate* collectors is often all that is required. These collectors are typically mounted on a south facing roof where they will not be shaded (see Figure 3.4).

Figure 3.4

In a typical installation the collector panels are connected to the existing DHW system with standard piping and valves and a pump that serves to circulate water between the water heater tank (which now doubles as a solar heat storage tank) and the collector panels (see Figure 3.5). Actual construction detailing, product requirements, and cost can vary widely for solar DHW systems because of the variety of system types currently available.

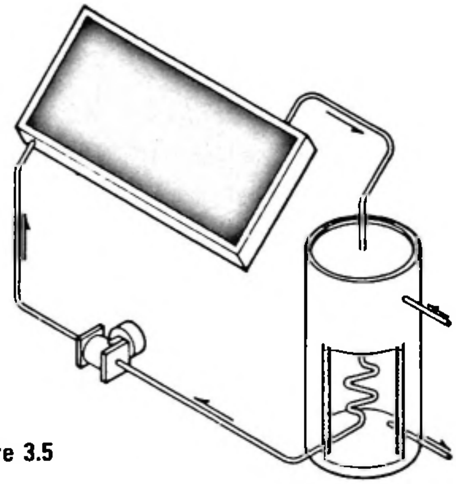


Figure 3.5

The collector panels themselves are typically modular with the area for each panel usually being around 20 to 30 square feet. As mentioned, the energy savings due to the solar contribution will increase with larger collector area, but the additional cost of installing, say, a second panel may or may not be justified by the value of those savings. When selecting and sizing a solar DHW system, all the costs associated with the system should be carefully identified, including installation costs.

Tankless Water Heaters

Another method for decreasing DHW costs is to use a tankless water heater instead of the

Figure 3.3
Insulating DHW heaters (fossil fuel). Gas and oil water heaters may be specified with varying density and thickness of insulation. Units located outside the home should be insulated to the highest levels available to reduce standby losses.

Figure 3.4
Location of solar panels. Collectors can be mounted on the roof using a frame to obtain the optimum angle to the sun or can be mounted directly onto a steep sloped roof.

Figure 3.5
Solar DHW systems. Solar panels are connected to the water tank as a preheat. A back-up resistance heater should be provided.

conventional tank water heater. Tankless units heat the water on demand, thereby eliminating expensive standby losses. Since the Federal Trade Commission has not yet labeled this DHW equipment, its savings, which could be substantial, are not calculated in the Guide. The user is nonetheless encouraged to consult manufacturers' literature and local mechanical engineers and contractors before making a final decision on the domestic hot water system.

Before the energy savings associated with the options above can be estimated, the annual DHW heating costs must be established. These costs are determined with the aid of EnergyGuide Labels. Standard water heaters are marketed with these labels which provide an estimate of the *yearly* energy cost *without* the flow reducer and solar collector energy savings options. Although water heaters are required by law to carry a label, heat pump water heaters are not currently included in this requirement. They are discussed separately later in this section.

These labels are standardized to allow quick, easy comparisons between water heaters. They show an estimate of the annual operating cost of the particular model based on an average energy cost. The labels also show a range of possible annual costs for competing models that have similar *first hour ratings*. The first hour rating is a standard measure of the water heater's ability to supply hot water. (In general, the larger the family, the higher the required first hour rating). Further down on the label a table is provided to show how the annual operating cost will vary with different costs for energy. Actual local energy costs can, therefore, be used with this table to determine the annual costs for hot water heating for a specific heater in a specific location.

A sample EnergyGuide label is reproduced (see Figure 3.6). Although the values on actual labels may differ, the sample label is provided here to illustrate its use. For the gas-fired water heater model it represents, the annual operating cost is estimated to be $198.00, based on an average cost for gas of 62.7 cents per therm. According to the amounts shown to the left and right of the annual cost, $198.00 is closer to the low end of the operating cost scale that goes from $183.00 (for the most efficient unit) to $244.00 (for the least efficient unit). (All the models being compared in this cost range have 48 to 55 gallon first hour ratings.) From the "Yearly Cost" table on the lower part of the label you can see that if the local energy cost is 50 cents per therm, the annual operating cost will be

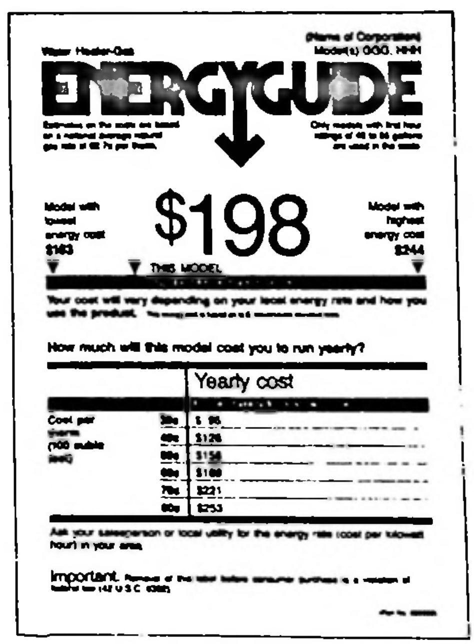


Figure 3.6

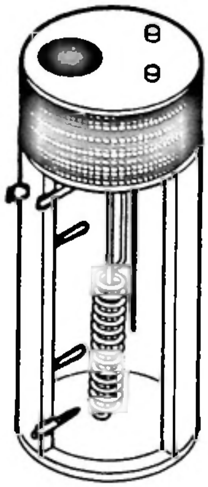


Figure 3.7

$158.00. If your own local energy cost were 55 cents per therm, you could derive an annual cost by finding the halfway point between $158.00 and $189.00 (annual cost at 60 cents per therm). Thus the annual cost at 55 cents per therm is $173.50. The same information is provided on water heaters that use fuel oil or electricity as the energy source.

As was mentioned, EnergyGuide labels are not applied to heat pump water heaters. These domestic water heaters operate on the same principles as do the heat pumps that are used for space heating and cooling. They also have the same high efficiency as do space conditioning heat pumps (see Figure 3.7). In providing domestic hot water heating, heat pump water heaters cool the surrounding air. This can benefit in southern climates where the additional cooling is welcomed. In these areas, the heat pump water heater should be located within the home. In areas where heating is the primary concern, the heat pump water heater should be located in an unheated space, such as a basement. In order to obtain actual efficency and operating costs for the units, consult your local DHW heater manufacturer or supplier.

It should be noted that the efficiency of a given heat pump water heater can be compared to other models of heat pump water heaters and also to any labeled EnergyGuide water heater by consulting the "Directory of Certified Water Heater Efficiency Ratings," which is available from ETL Testing Laboratories, Inc., Industrial Park, Cortland, New York, 13405. This directory is updated every 6 months.

Figure 3.7
Heat pump water heater. In some climates a heat pump water heater will be a cost-effective energy saver.

Appliances

As a group home appliances use somewhat less energy per year than is consumed for space conditioning and domestic hot water heating. However, there are excellent opportunities for selecting energy-efficient and cost-effective appliances that are attractive marketing options. Their very presence in a new home can be a strong selling point to a potential homebuyer. It's true that energy-efficient appliances do generally cost more, but they are often very cost-effective, a fact that should sit well with cost-conscious homebuyers.

The savings created by these appliances are easy to calculate using the EnergyGuide labels already described in the previous sections on space conditioning and domestic water heating. These labels also are currently required on the following appliances:

- refrigerators
- refrigerator-freezers
- freezors
- clothes washers
- dishwashers
- room air conditioners

The procedure to be followed for calculating energy savings is the same for all appliances and will not be affected by either the construction of the home or its location. Simply by making direct use of the information on the EnergyGuide labels, and the local energy cost for electricity (or other energy source), the yearly operating cost for each appliance can be determined.

The federally mandated EnergyGuide label program requires that the six appliances listed above, if they are manufactured after May, 1980, carry a label denoting the estimated cost per year to the homeowner for operating that appliance. The labels also show the range of possible yearly energy costs for competing appliances of similar size and features. By looking at this range you can tell whether more efficient appliances are available and to what extent they are more efficient, as reflected in their lower annual energy cost.

The estimated energy cost that is shown on the top half of the label is based on a "national average" energy cost value. However, on the lower half of the label a list of annual energy costs can be found that reflect a variety of energy costs, one of which is selected as most closely representing the local energy cost where the home is to be built.

The sample label (see Figure 3.8) refers to a 17 cubic-foot refrigerator-freezer. Using a "national average" energy cost of 7.63¢ per kWh, the estimated annual energy cost for operating the refrigerator is $72.00. This amount is closer to the lower end of the operating cost range that runs from $69.00 to $135.00 for other models that are available with this cubic-foot capacity.

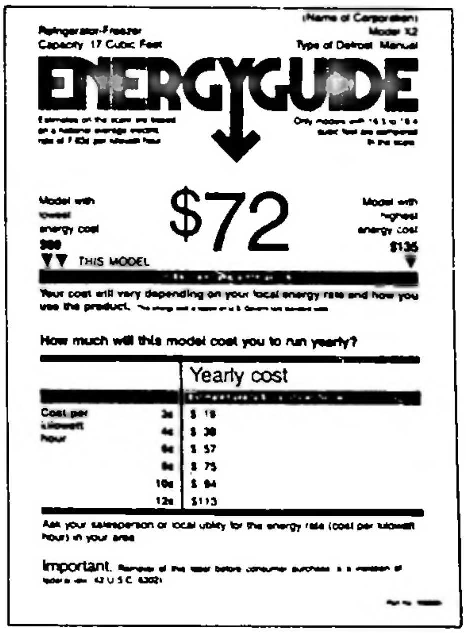


Figure 3.8

Although actual labels found on your appliances may use different values, all labels are to be used in this manner.

Operating costs for all the other appliances that carry the EnergyGuide labels can be derived as easily. In the case of both dishwashers and clothes washers, an estimate of the number of loads to be washed each week will also need to be made. The national average cost figure on the label assumes that there will be 412 loads per year, or eight loads per week for these appliances.

4 Economics

Economics

Throughout this Guide there has been an emphasis on the salability of energy conservation options that can be built into a new home. Homes get sold for a lot of reasons: size, looks, location, price, and so on. But because of the "invisible" nature of most energy conservation improvements, the task is more difficult when it comes to convincing homebuyers and lenders that a home is somehow better because it has better windows, more insulation and extra south glass. They can be shown the energy-saving features, but the only way to convince them *in advance* of actual energy bills, is to show them the numbers.

The numbers have to say "yes" to the bottom-line question that homebuyers and lenders will invariably ask, "Will these energy conservation features really reduce the total monthly cost of homeownership?" Most homebuyers will likely notice immediately that the home is more expensive than one down the street that comes without the conservation features. They see higher payments in possibly all the costs associated directly with owning a home: loan Principal and Interest, Taxes, and Insurance (abbreviated PITI). What must be demonstrated to both buyers and lenders is that you have significantly reduced the fifth major cost that comes with owning a home: Energy. PITI must become PITIE in order to sell energy conserving homes.

Will the PITIE cost of the home be lower? Basically the answer is "yes" for any conservation improvements that save the owner more per year (in reduced energy costs) than they cost in higher mortgage payments. The home-builder prepared to prove such yearly cost savings will have some pretty convincing marketing and financing information that could literally help to make the sale.

PEAR will help provide that information. The "Economics" section describes a simple procedure for estimating the net savings a homeowner can realize by paying more for an energy-conserving home. This procedure is versatile and flexible in that it allows you to compare the dollar-saving value of any of the conservation measures in all three of the energy use categories: space conditioning, domestic hot water heating, and appliances. For example, the money saved by providing a more efficient refrigerator can be compared to the savings created by extra ceiling insulation and to the savings that a solar water heater would bring. And all these comparisons are made on an apples-to-apples basis where the "apple"is always the same bottom line: homeowner dollars saved per year.

For potential homebuyers, this kind of information is very useful and, of course, attractive when significant savings are shown. But it can also be helpful in showing lenders and others in the home financing community that energy-efficient homes are worthy of larger mortgages at more favorable terms. In short, this procedure, described in detail in the PEAR User's Manual, provides the means to develop a multi-purpose marketing tool for selling energy-efficient homes.

(It should be noted that the economic analysis outlined in PEAR's User's Manual is only one of many such techniques that can be employed to evaluate the costs and savings associated with energy conservation. Other methods, such as Life Cycle Cost analysis, can increase the accuracy of the prediction by using more detailed calculations. The reader is encouraged to review other more rigorous economic analysis methods and to apply those which are most appropriate for his or her particular situation.)

★ U.S GPO: 1989 239-152