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ABSTRACT

Presented is part three of a training program designed to educate students and individuals in the importance of conserving energy and to provide for developing skills needed in the application of energy-saving techniques that result in energy efficient buildings. Alternatives are provided in this program to allow for specific instruction in energy-saving methods and procedures, or for integration with construction courses. It may also be used for self-paced instruction. The materials are divided into three parts: (1) Understanding and practicing energy conservation; (2) Determining amount of energy lost or gained in a building; and (3) Determining which practices are more efficient and installing materials. Major topics presented in each of these three parts include determining which practices are most efficient and economical, installing energy-saving materials, and improving efficiency of equipment. (Author/DS)

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June 1980

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Education Division
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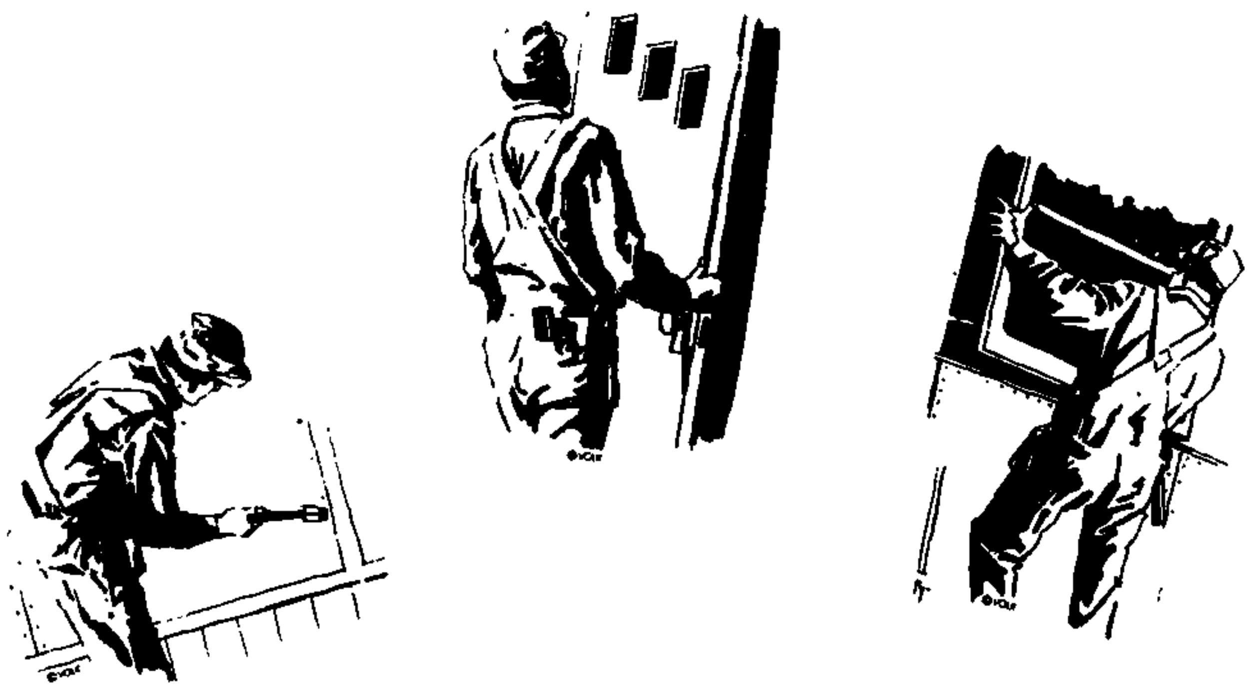
Providing for Energy Efficiency in Homes and Small Buildings

Part III



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Office of Consumer Affairs
Education Division
Washington, D.C. 20585

Providing for Energy Efficiency in Homes and Small Buildings

Part III

June 1980

Prepared by:
American Association for
Vocational Instructional Materials
Under Contract No. EX-77-R-01-6065

PROVIDING FOR ENERGY EFFICIENCY IN HOMES AND SMALL BUILDINGS

This instructional program was developed for the Department of Energy under Contract No. EX-77-R-01-6065 by the American Association for Vocational Instructional Materials.

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Contents

Page

I. DETERMINING WHICH PRACTICES ARE MOST EFFICIENT AND ECONOMICAL . . . 11
- A. What Site to Choose . . . 12
  1. Types of Climate . . . 12
  2. Effect of Climate and Geographic Location . . . 13
  3. Effect on Convenience . . . 14
  4. Effect on Energy Use . . . 14
- B. What Design to Use . . . 14
  1. Design Features that Affect Energy Use . . . 16
  2. Effect of Climate and Geographic Location . . . 21
  3. Effect on Convenience . . . 23
  4. Effect on Energy Use . . . 23
  5. Effect on Cost Benefits . . . 23
- C. What Materials of Construction to Use . . . 24
- D. What Type and How Much Insulation to Use . . . 25
  1. Types of Insulation . . . 25
  2. Effect of Climate and Geographic Location . . . 29
  3. Effect of Construction Methods . . . 30
  4. Effect of Insulation Quality . . . 34
  5. Effect on Energy Use . . . 34
  6. Effect on Cost Benefits . . . 34
- E. What Type of Vapor Barrier to Use . . . 34
  1. Polyethylene Film . . . 34
  2. Aluminum Foil . . . 35
  3. Paints and Other Finishes . . . 35
- F. What Type and How Much Weatherstripping and Caulking to Use . . . 35
  1. Types of Weatherstripping and Caulking Available . . . 36
  2. Effect on Energy Use . . . 36
  3. Effect on Cost Benefits . . . 36
- G. What T[illegible] of Windows to Use . . . 41
  1. Types of Windows . . . 41
  2. Effect of Climate . . . 42
  3. Effect of Insulating Quality . . . 43
  4. Effect on Energy Use . . . 44
  5. Effect on Cost Benefits . . . 46
- H. What Type of Doors [illegible] Use . . . 46
  1. Types of Doors . . . 46
  2. Effect of Climate . . . 46
  3. Effect of Insulating Quality . . . 47
  4. Effect on Energy Use . . . 48
  5. Effect on Cost Benefits . . . 48
- I. What Type of Heating Equipment to Use . . . 49
  1. Types of Heating Equipment . . . 49
  2. Effect of Type of Energy Available . . . 52
  3. Effect of Efficiency of the Unit . . . 54
  4. Effect on Energy Use . . . 55
  5. Effect on Cost Benefits . . . 55
- J. What Type of Air Conditioning to Use if Needed . . . 57
  1. Types of Air Conditioning Equipment . . . 58
  2. Effect of Climate . . . 59
  3. Effect of Efficiency of the Unit . . . 60
  4. Effect on Energy Use . . . 61
  5. Effect on Cost Benefits . . . 61
- K. What Type of Ventilation to Use . . . 62
  1. Types of Ventilation . . . 62
  2. Effect of Climate . . . 66
  3. Effect of Efficiency . . . 66
  4. Effect on Energy Use . . . 66
  5. Effect on Cost Benefits . . . 66
- L. What Type of Lighting to Use . . . 67
  1. Types of Lighting . . . 67
  2. Effect on Energy Use . . . 68
  3. Effect on Cost Benefits . . . 68
- M. What Type of Water Heater to Use . . . 70
  1. Sizes of Water Heaters . . . 70
  2. Types of Water Heaters . . . 70
  3. Water Temperature Requirements . . . 71
  4. Compatibility with Alternate Systems . . . 71
  5. Effect on Cost Benefits . . . 71
- N. What Type of Plumbing to Use . . . 72
  1. Water Consumption . . . 72
  2. Type of Plumbing Equipment . . . 72

II. INSTALLING ENERGY-SAVING MATERIALS . . . 75
- A. Installing Insulation in the Structure . . . 75
  1. Installing Insulation in the Ceiling . . . 75
  2. Installing Insulation in the Floor . . . 83
  3. Installing Insulation in the Walls. . . . 86
  4. Installing Insulation in the Basement and Crawl Space . . . 89
- B. Installing Vapor Barriers . . . 91
  1. Installing Vapor Barriers in New Construction . . . 91
  2. Installing Vapor Barriers in Existing Buildings . . . 92
- C. Installing Weatherstripping and Caulking . . . 93
  1. Installing Weatherstripping . . . 93
  2. Installing Caulking . . . 96
- D. Installing Storm Windows and Doors . . . 97
  1. Installing Storm Windows . . . 97
  2. Installing Storm Doors . . . 101

III. IMPROVING EFFICIENCY OF EQUIPMENT . . . 103
- A. Improving Efficiency of Heating Systems . . . 104
  1. Fireplaces . . . 104
  2. Stoves . . . 106
  3. Forced Air Systems . . . 106
  4. Hot-Water Systems . . . 107
  5. Heat Pumps . . . 107
- B. Improving Efficiency of Cooling Systems . . . 108
- C. Improving Efficiency of Ventilating Systems . . . 108
- D. Improving Efficiency of Lighting Systems . . . 108
- E. Improving Efficiency of Plumbing Systems . . . 109
  1. Installing Insulation Around Hot Water Pipes . . . 109
  2. Installing Insulation Around Hot Water Heaters . . . 110
  3. Installing Pressure Reducer and Other Water-Saving Devices . . . 110
  4. Checking for Leaks . . . 111
- F. Improving Efficiency of Appliances and Equipment . . . 111

BIBLIOGRAPHY . . . 113

Tables

		Page
I.	Energy-Saving Characteristics of Building Materials	24
II.	Comparisons of Insulation Qualities	26
III.	Thickness of Insulation Needed for Certain R-Values	32
IV.	General Recommendations for Efficiency in Residences	33
V.	Characteristics of Different Types of Weatherstripping	37
VI.	Characteristics of Different Types of Caulking	39
VII.	Comparisons of Heating System Efficiencies	54
VIII.	Some Comparisons of Energy Uses in Home Heating	55
IX.	Relative Energy Use in Home Heating by Different Methods	56
X.	Energy Cost for Home Heating	57
XI.	Vent Area in Square Inches Required for Attic Floor Measurements	62
XII.	Recommended Rating of a Power Ventilator for Attic Dimensions	65
XIII.	Light Recommended for Specific Tasks	69
XIV.	Energy Comparison For Incandescent Bulbs and Fluorescent Tubes	69
XV.	Lumen Outputs of Standard and Long-Life Incandescent Bulbs	69
XVI.	Suggested Water Heater Sizing Guide (Gallons)	70
XVII.	Daily Water Needed for a Family of Four	72

Preface

This is a training program designed to educate students and individuals in the importance of conserving energy and to provide for developing skills needed in the application of energy-saving techniques that result in energy-efficient buildings.

Upon successful completion of this course of instruction, a student will be able to perform at the job entry level.

Alternatives are provided in this program to allow for spec. fic instruction in energy-saving methods and procedures, or for integration with construction courses. It may also be used for self-paced instruction.

When used in the classroom, the unit can be integrated with the building construction curriculum, or it can be taught separately.

A teacher guide and student workbook are available to supplement the basic manuals. The resource person should consult the teacher guide and follow procedures given therein.

The material is divided into three parts:

PART ONE: UNDERSTANDING AND PRACTICING ENERGY CONSERVATION IN BUILDINGS.

PART TWO: DETERMINING AMOUNT OF ENERGY LOST OR GAINED IN A BUILDING.

PART THREE: DETERMINING WHICH PRACTICES ARE MOST EFFICIENT AND INSTALLING MATERIALS.

Part 3

Determining Which Practices are Most Effective and Installing Materials

Selecting and installing energy-efficient materials and equipment are discussed under the following headings:

I. Determining Which Practices are Most Efficient and Economical.

II. Installing Energy-Saving Materials.

III. Improving Efficiency of Equipment.

I. Determining Which Practices are Most Efficient and Economical

There are many factors which enter into any decision about efficient energy use and economic feasibility in the design, construction and operation of a building. Cheap energy has allowed us to design and construct buildings with little or no regard for the local climate, the nature of materials, or the efficiency of the support systems installed. To some extent, we have even ignored the comfort and health of the persons living and working in these structures by excessive use of artificial heating, cooling and lighting. We have become controlled by our excesses rather than by our senses. We have in most cases wanted more than we needed.

The shortages and, therefore, higher costs of our traditional fuels are causing us to take a more careful look at the way we design, construct, and operate our living and working spaces. We can no longer ignore the concepts of conservation and increased efficiency (Figure 1).

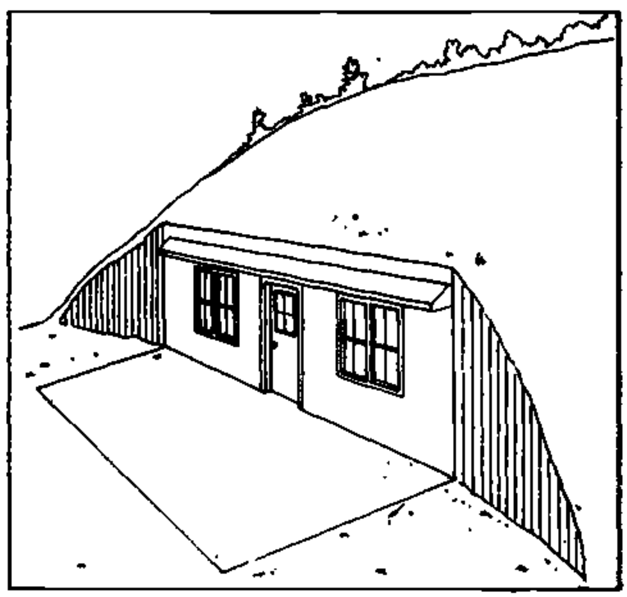


FIGURE 1. Underground house.

This section will consider ways in which building designs, construction methods, and operating systems can be chosen so that energy can be used more effectively and with less expense. The following divisions are included:

A. What Site to Choose.
B. What Design to Use.
C. What Materials of Construction to Use.
D. What Type and How Much Insulation to Use.
E. What Type of Vapor Barrier to Use.
F. What Type and How Much Weather-stripping and Caulking to Use.
G. What Type of Windows to Use.
H. What Type of Doors to Use.
I. What Type of Heating Equipment to Use.
J. What Type of Air Conditioning to Use if Needed.
K. What Type of Ventilation to Use.
L. What Type of Lighting to Use.
M. What Type of Water Heater to Use.
N. What Type of Plumbing to Use.

A. What Site to Choose

Wherever you choose to live or work, you cannot help but experience the weather--sunshine, wind, rain, temperature and humidity. These elements of climate along with the geography, or nature of the land and vegetation around us, should determine how we select a building site to obtain maximum comfort and efficiency. To save energy, some residences are now constructed underground (Figure 1).

From this section, you will be able to describe how climatic conditions and geographic location may affect your choice of building sites. A discussion of climate and its effects will follow under these headings:

1. Types of Climate.
2. Effect of Climate and Geographic Location.
3. Effect on Convenience.
4. Effect on Energy Use.

1. TYPES OF CLIMATE

Webster's Dictionary defines climate as "the average course or condition of the weather at a place over a period of years..." Since weather is the momentary state of the atmospheric environment at a particular location, climate could be defined as the sum total of all the weather that occurs at any place.

Wind, precipitation, sunlight, temperature, and humidity are all factors of the weather. Combinations of these elements give each climate zone its normal weather characteristics.

A review of the climatic conditions in the U. S. will be helpful. The United States is typically divided into four climatic zones: cold, temperate, hot-arid, and hot-humid. The areas of the United States which exhibit the general characteristics associated with each zone are shown in Figure 2. The boundary between regions is not as abrupt as indicated. Climatic characteristics vary both between and within regions. It is not unusual for one region to exhibit at one time or another the characteristics common to every other region.

Cold regions: A wide range of temperature is characteristic of cool regions. Temperatures of minus 30°F (-34.4°C) to plus 100°F (37.8°C) have been recorded indicating hot summers and cold winters. Persistent winds year round are generally out of the NW and SE. Northern locations with cool climates receive less sunshine than southern locations.

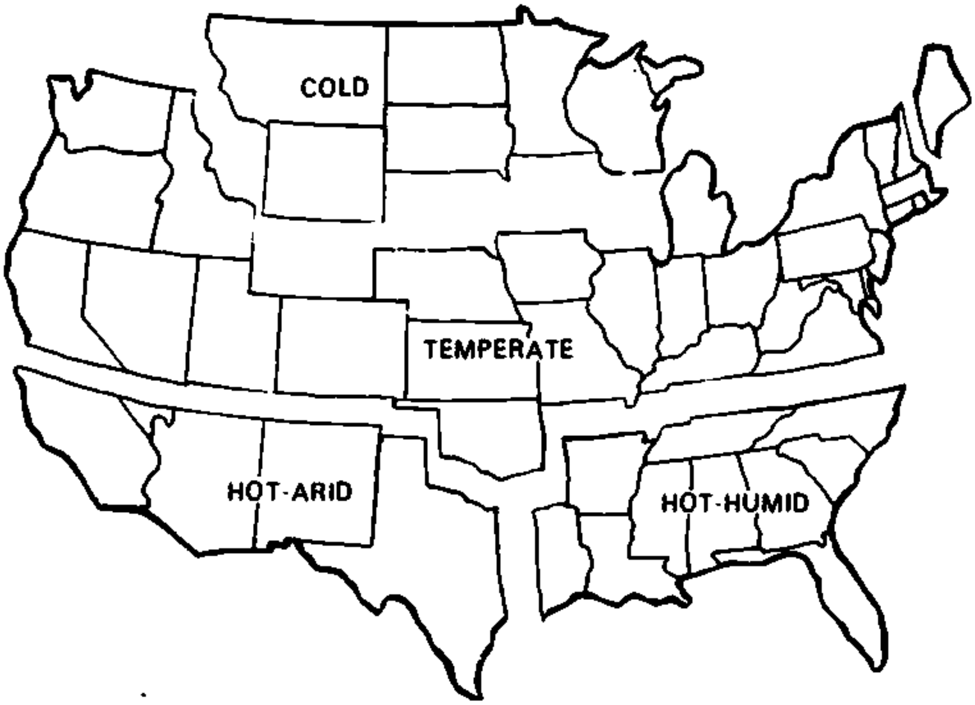


FIGURE 2. Climatic regions of the conditions in the United States.

Temperate regions: Seasonal temperatures provide an equal distribution of overheated and underheated periods. Seasonal winds from the NW and S along with periods of high humidity and large amounts of precipitation are common. Intermittent periods of sunny days are followed by extended periods of cloudy, overcast days.

Hot-arid regions: Hot-arid regions are characterized by clear sky, dry atmosphere, extended periods of overheating, and wide day to night temperature range. Wind direction is generally along an E-W axis with day and evening variations.

Hot-humid regions: High temperatures and frequent rains are characteristic of hot-humid regions. Wind velocities and direction vary throughout the year and during the day. Hurricanes with wind velocities up to 193 km/h (120 mph) may be expected from E-SE directions.

2. EFFECT OF CLIMATE AND GEOGRAPHIC LOCATION

The effect of climate on building location is very important. Of primary concern is the orientation of the building to make the best use of solar radiation and wind direction.

The "sol-air" effect recognizes that solar radiation and outdoor temperature act together to influence the overall heat gain through the surfaces of a building. Since the outdoor air temperatures are lower in the morning and peak in the mid-afternoon, a house should be oriented somewhat east of due south in order to take advantage of the early morning sun when heat is most needed. In the summer, the principal heat gain comes in the afternoon, from the west and southwest, so the house should face away from this direction to minimize the solar heat gain in that season. The optimum orientation will vary for different regions and building sites depending upon heating and cooling needs and other factors such as the wind (Figure 3).

3. EFFECT ON CONVENIENCE

You may be limited in choice as to the geographic location of the building. However, you may be able to select a site that will give you the benefit of natural resources. Look for the following site characteristics:

- Advantage of sunlight.
- Advantage of shade.
- Advantage of prevailing winds.
- Protection from cold winds.

4. EFFECT ON ENERGY USE

Naturally you will use more energy in heating a building in cold climates. In warm climates, the energy used for air conditioning may be more than for heating.

B. What Design to Use

Design means planning to meet a specific need. When designing a home or other building, it is necessary to determine how the space or shelter is going to be used. A family uses a home for several activities, each of which has certain space and comfort requirements. An energy-efficient home or building is one which provides the required space and comfort to its occupants at a reasonable cost and without harmful effects on the immediate environment.

In this section you will be introduced to several basic design features which, with careful consideration, will make the most of the regional climate and site location. The following topics will help you to determine what design to use for an energy-saving building.

1. Design Features that Affect Energy Use.
2. Effect of Climate and Geographic Location.
3. Effect on Convenience.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

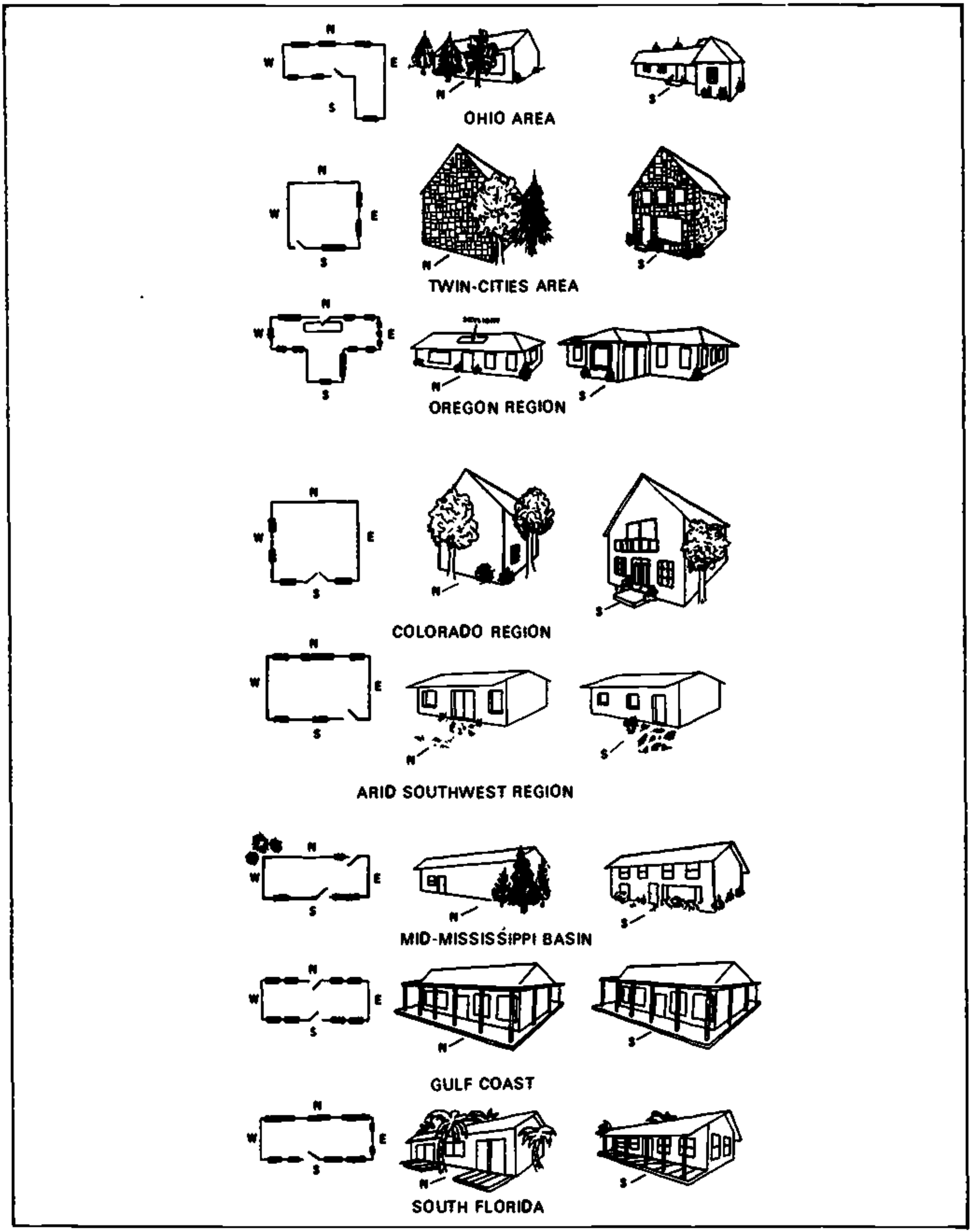


FIGURE 3. Optimum orientation of building in climatic zones of the United States.

1. DESIGN FEATURES THAT AFFECT ENERGY USE

Several design features of a building need to be considered to make it energy-saving. The design features considered here include:

a. Shape and Volume

The square floor area of a building affects the cost--both initial outlay and continuing maintenance and operation. Larger buildings require more construction materials and a larger capacity for heating and cooling equipment than smaller buildings, as well as more fuel to maintain a comfort zone within the building.

The optimum shape is one which has minimal heat gain in summer and minimal heat loss in winter. Therefore, the form of a building depends upon the climatic region. Three factors help determine optimum shape: (1) volume-to-surface ratio; (2) solar exposure; and (3) potential for insulation. The volume-to-surface ratio of homes is important, but cannot be considered alone in determining the shape. It might appear that a cubicle house would have the least heat loss and gain because it is compact, but this is not the case. The optimum shape for thermal impact for every climate is a rectangle with differing degrees of elongation along the east-west direction. Figure 4 illustrates the optimum range for each climate as determined by Olgyay. However, Olgyay did not consider the potential for insulation.

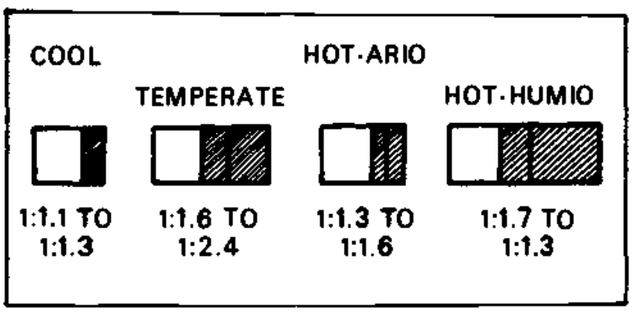


FIGURE 4. Optimum Building Shapes for Climate Zones (Ratio of width to Length).

The National Association of Home Builders (NAHB) has shown that the potential for insulation is a very important factor in determining the optimum shape of a home for thermal efficiency. A two-story house may not have any less heat loss or gain than a one-story house of the same square area. The fact that ceiling areas are more effectively insulated than walls makes the one-story house equally as efficient as a two-story house.

The volume effect (as the volume of a cube increases, its volume-to-surface area ratio increases) plays a more important role in larger buildings such as apartment houses or office buildings. An interior space may have a lower heating and cooling load because it has less surface exposed to the weather. Figure 5 illustrates volume-to-surface areas.

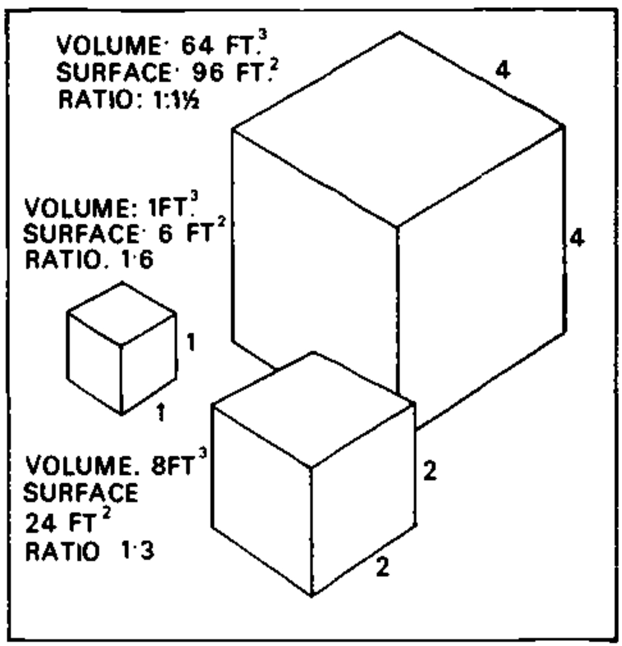


FIGURE 5. The surface area exposed to outside affects energy use. Note energy loss is reduced in both cold and hot-arid climates by "square" designs.

b. Foundations

Footings and foundations connect a building to the ground. The masonry or concrete of which most foundations are made has very poor thermal resistance qualities, thus allowing heat to flow into the ground below. The type of foundation used will determine the location and type of insulation required. The type and amount of insulation to use on various foundations will be explained in "Part D. What Type and How Much Insulation to Use." Various types of foundations and their functions are discussed and illustrated here.

(1) ISOLATED PIERS AND POST FOOTINGS are the simplest and usually the cheapest (Figure 6). In cold climates, the exposed underside of the floor must be insulated. In warm climates, insulation provides ventilation and separation from ground moisture.

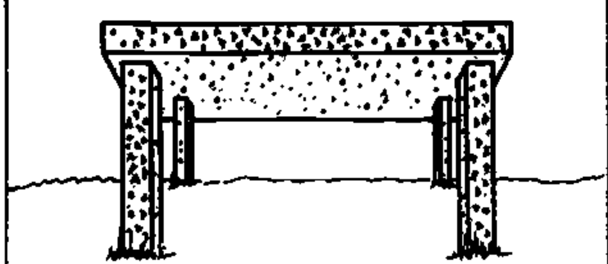


FIGURE 6. Foundation on piers.

(2) CONTINUOUS FOOTINGS AND FOUNDATION WALLS are the most expensive and complicated (Figure 7). They allow for a warmer floor and can provide a basement for a heating system, working space and storage. Unheated areas require an insulated floor above, heated areas, an insulated wall and slab perimeter.

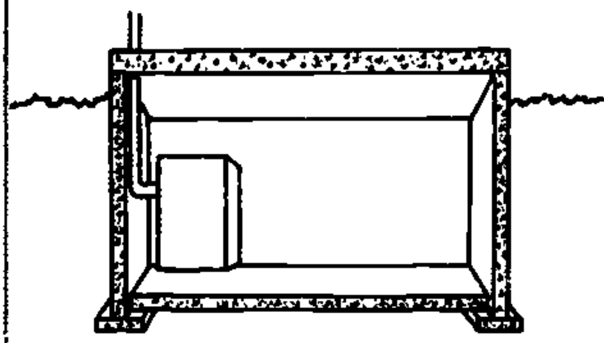


FIGURE 7. Enclosed basement.

(3) SLAB arrangements are simple and quick to build (Figure 8). In cold climates, they require a deep layer of well-drained soil to act as support and insulation under the slab or vertically on the edge of frost walls. Slab foundations are best on flat sites and well-drained soils.

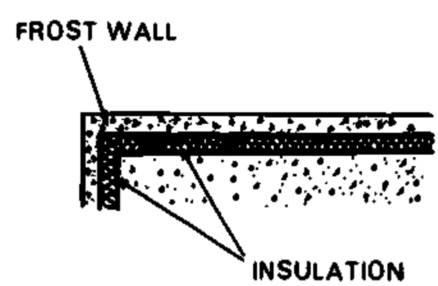


FIGURE 8. Slab foundations reduce energy loss through floors.

c. Roofs

Roofs are either (1) flat or (2) pitched.

(1) FLAT ROOFS are useful for catching and retaining rainwater in arid climates, the sun's rays on solar panels or snow for added insulation in cold climates (Figure 9). The space may also be usable for decks or gardens. However, flat roofs do not readily shed water. If you are not using it for one of the above reasons, do not consider one. The energy saving is not sufficient.

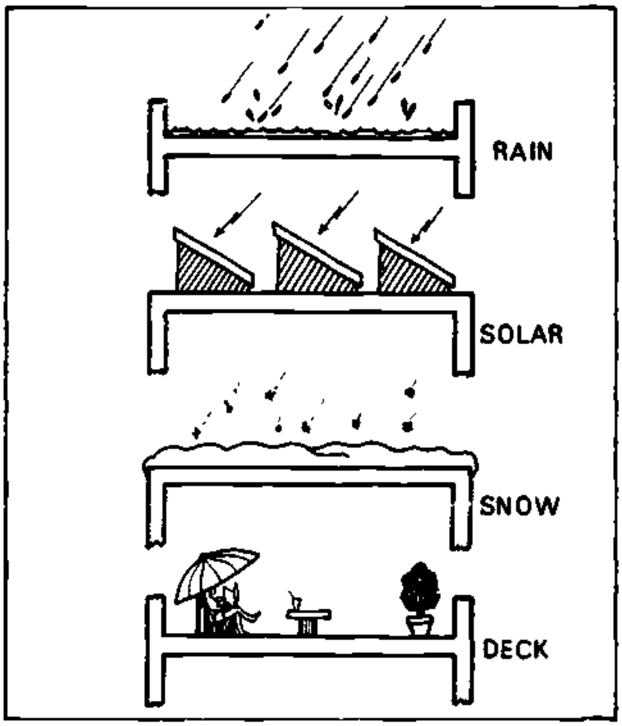


FIGURE 9. Applications of flat roofs.

(2) PITCHED ROOFS which shed water best are termed low-pitched or steep-pitched (Figure 10). Steep-pitched roofs are good for shedding snow and may also enclose space as a diagonal wall.

In structures like A-frames and domes, the surface forms both the roof and the wall (Figure 11).

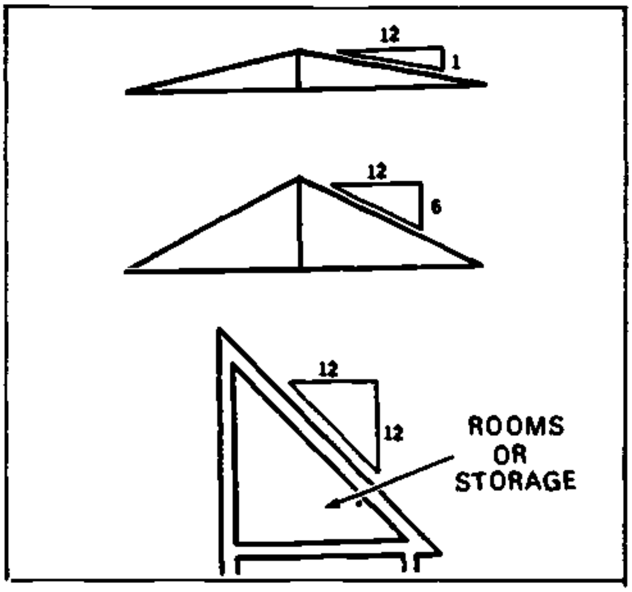


FIGURE 10. The pitch of your roof may be important to energy efficiency.

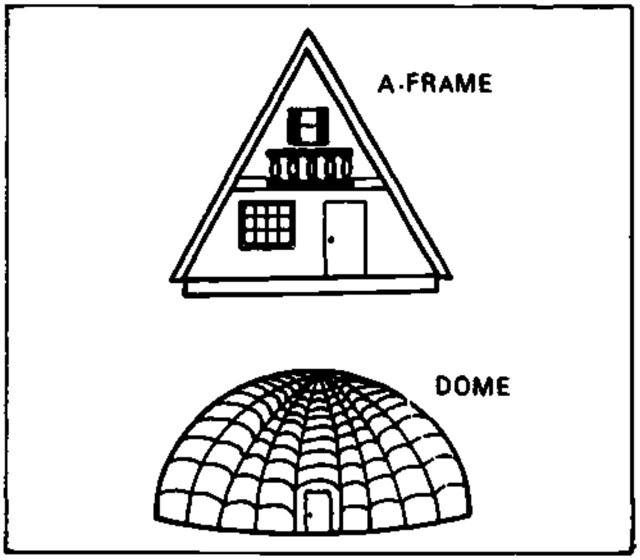


FIGURE 11. A-frame and dome roofs must be well-insulated to conserve energy.

(a) A low-pitched roof (between 1:12 and 6:12) will shed water, and the lower pitches will retain snow for insulation. The inside area can provide additional space as a sloped ceiling.

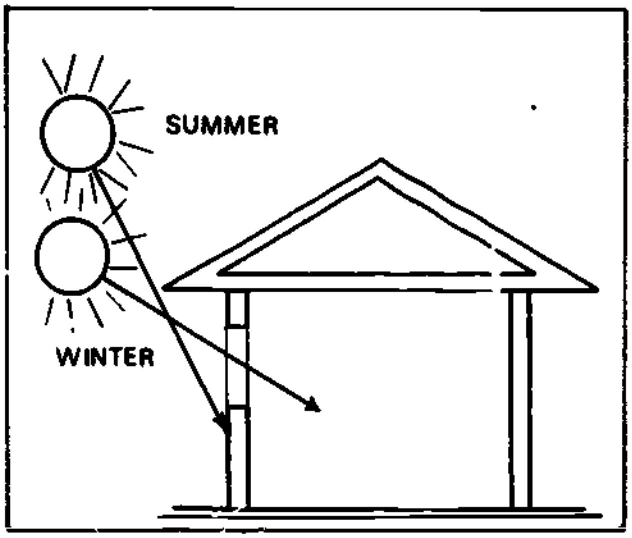


FIGURE 12. Roof overhang can be advantageous in saving energy.

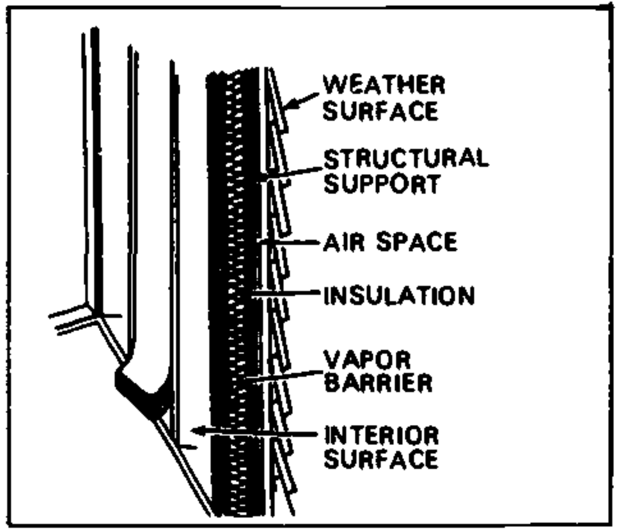


FIGURE 13. Wall should be designed to retain heat in winter and to prevent solar heat gain in summer.

(b) A steep-pitched roof (6:12 to 12:12 and above) will shed almost everything. That's the reason for the pitch. Since it requires more material to form the larger surface, it is more expensive. These roofs can provide additional rooms or storage. Steep pitches (45°) are also good for placing solar collectors in northern climates.

(3) ROOF OVERHANG is a common method of protecting windows and walls from summer sun and allowing winter sun to enter. Overhands can also shield entrances (Figure 12).

(4) ROOF COLOR is also important. ASHRAE and HUD studies indicate that light-colored roofing material is best; however, ceiling or roof insulation greatly affects the interior heating and cooling load. A dark-colored roof may only slightly reduce the heating load while substantially increasing the cooling load in southern climates.

d. Walls

A well-designed wall will serve two major functions: (1) retain heat inside the building and prevent cold air outside from entering; (2) prevent unwanted solar heat gain in summer, which would require energy to remove. Conduction and infiltration through walls can be reduced by using insulation, making walls airtight, and by minimizing the undesirable effects of wind and sun.

Energy-conserving walls will have these elements (Figure 13):

- A weather surface--to shed water and protect the other wall elements from moisture and air infiltration.

- Structural support--to support the wall and other building elements.

- Insulation--to prevent conduction of heat in either direction.

- Air space--to provide ventilation within wall elements and serve as increased insulation.

- A vapor barrier--to prevent moisture from entering the wall and to help prevent infiltration.

- An interior surface--to provide a wearing surface for interior activities and some insulation value.

Additional information on insulation and other materials will follow in Sections C and D.

e. Windows

Although windows and doors allow greater heat loss or gain than walls, they are necessary and can be improved by their location and construction. Eight times as much heat will pass through one unit area of window area as will pass through one unit area of wall area (Figure 14), assuming that the wall is insulated and the window has a storm window.

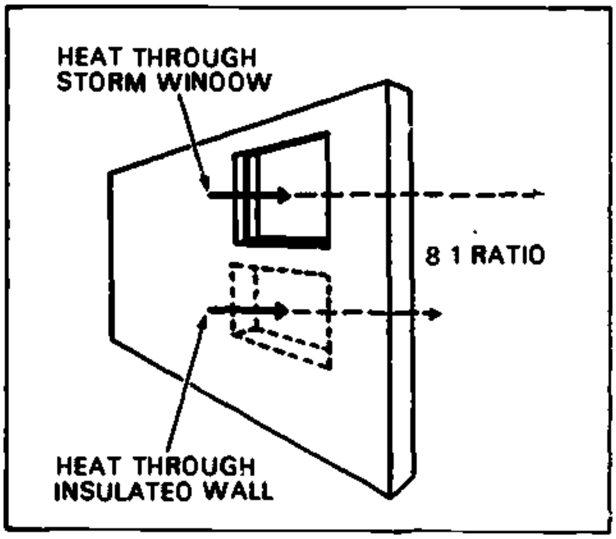


FIGURE 14. Glass is a poor insulator.

Heat loss and gain through windows and doors can be reduced by storm panels, weatherstripping, double-glazing, vestibules, shading devices, and wise placement. The loss of heat through various window constructions will be covered in Section G.

Windows can be planned to provide natural light, the benefit of solar heat, natural ventilation, and a view to the outdoors. All of these functions will reduce the need for and cost of energy for these operations (Figure 15).

(1) WINDOWS FOR SOLAR HEAT GAIN (Figure 15).

- The largest windows should face the east-southeast as this is the warmest exposure and causes the least heat loss.
- Small windows on the west or windows with shading devices will help to control the low-lying sun.
- Either no windows or small protected windows on the northwest and north are best.
- Properly designed southern and south-western windows have the best potential for controlling solar heat gain both in cold and warm months.

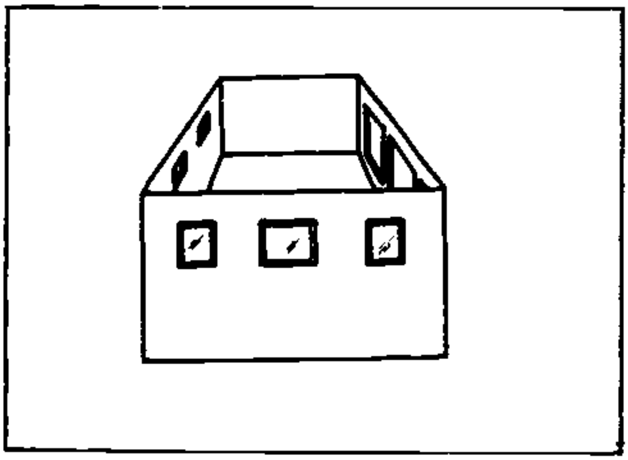


FIGURE 15. Windows can be designed to save energy.

(2) WINDOWS FOR NATURAL VENTILATION:

- Plan window openings for cross-ventilation.
- Air flow openings of the same size for inlets and outlets will provide good ventilation. Larger outlets provide faster air flow.
- Desired air flow can be directed by: (a) a combination of openings, (b) lower wall placement for better cooling, (c) using exterior features to deflect air flow, (d) window deflectors.

(3) WINDOWS FOR NATURAL LIGHTING AND OUTDOOR VIEWS:

- Natural light is available on all exposures--the north being the easiest to control.

- Control east and west exposures with vertical windows.

- Southern exposures offer the most light. Control of the sun angle is best accomplished with horizontal windows placed high on the wall.

- Roof mounted skylights offer good possibilities for lighting interior spaces.

- Window size and placement can be used to provide light for specific areas and to frame specific views.

f. Doors

We can treat the heat loss through doors about the same as we do windows. The most common method is to add a storm door. A better method is to form an air lock and cut down on drafts by adding a vestibule. When possible, doors should be placed on the south or southeast. If doors are in an exposed location, overhangs, baffles or plantings can protect against the wind. Doors can also provide a degree of light and ventilation if properly chosen and placed.

Even a 5.1 cm (2 in) solid door with wood storm door has a heat loss 3.5 times greater than a typical wall.

2. EFFECT OF CLIMATE AND GEOGRAPHIC LOCATION

In addition to the climatic regions shown on the map in Figure 2, a building has a microclimate of its own which affects the building's location and design. Local climatic conditions must be evaluated in conjunction with regional weather data to determine the type of design to use for a particular site.

Weather characteristics and their relationship to structural design are discussed as follows:

a. Temperatures.
b. Sunlight or Solar Radiation.
c. Precipitation and Humidity.
d. Wind.

a. Temperatures

Temperature range is the major factor which determines the amount of heating and cooling which may be needed to maintain comfort (Figure 16). The design, shape, and materials of a building change considerably for temperature extremes. A normally tolerable temperature range is between 60 and 85°F (15 and 30°C). If the average falls above or below this zone, heating or cooling is generally required. People, however, become accustomed to individual climates and temperatures which means that tolerance levels vary slightly from one location to another.

Buildings must be designed to reduce the energy transfer through the building shell.

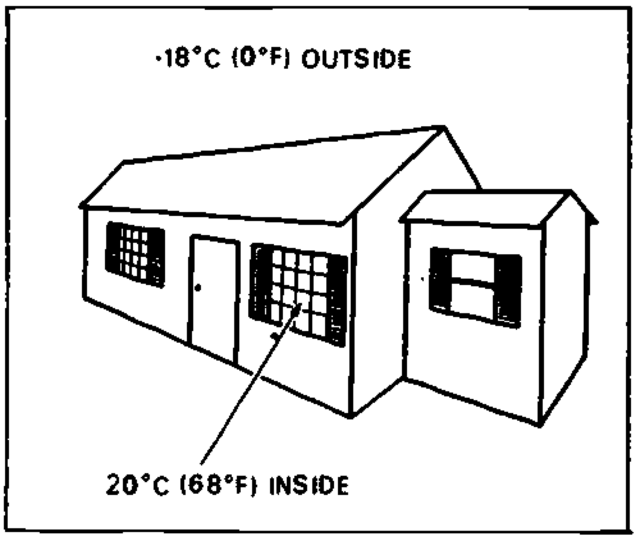


FIGURE 16. Temperature difference is the major consumer of energy in buildings.

b. Sunlight or Solar Radiation

Sunlight, or solar radiation, intensity on a building or area is affected by shade trees, cloud cover, air pollution, latitude, seasonal patterns and altitude.

Efficient use of the sun's heat and light will require attention to shading and window area of buildings (Figure 17). The seasonal percentage and probability of sunshine will help to predict monthly heating loads and storage capacities needed for various heating systems, especially solar.

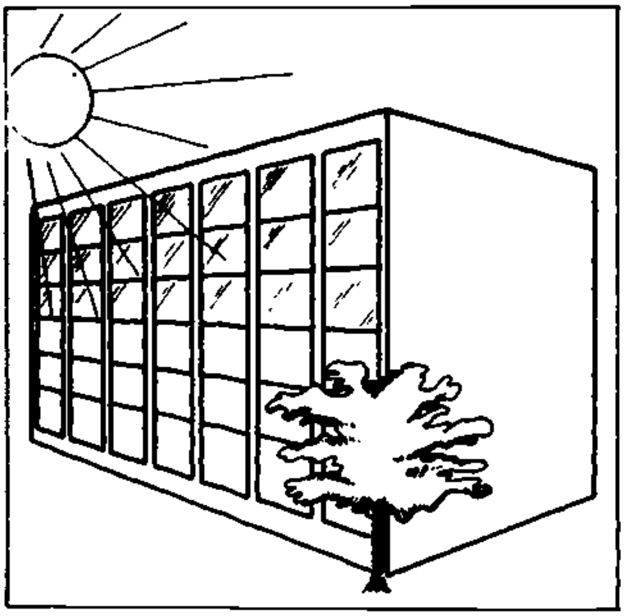


FIGURE 17. Buildings are designed to make effective use of the sun.

c. Precipitation and Humidity

The amount of precipitation in the form of rain, fog, snow, hail, and night moisture varies dramatically within the same geographical area. Vegetation, water resources, sunlight, erosion, and flooding are all affected by the quantity and frequency of precipitation. Buildings may need to be placed above ground, without basements or on higher ground to avoid surface water. Rain storms and other forms of precipitation often provide a welcome cooling effect in many areas.

Humidity is usually associated with precipitation. Humidity is water moisture suspended in air and is measured as the percentage of the air saturated by water. At 100% relative humidity (RH) for a given temperature, the air cannot hold additional moisture.

Our comfort is directly influenced by humidity. Cold, damp air feels much colder than cold, dry air; and hot, damp air is stifling compared to hot, dry air.

When designing for humid areas, it is good to allow for air circulation, consider dehumidifying, and to be aware of possible wall condensation and mold growth.

Lack of humidity, or very dry air, causes excessive evaporation of moisture, resulting in dry skin and other discomfort. A comfortable relative humidity range is between 20 and 60%.

Humidity control is essential to an energy-efficient building (Figure 18). If the air is cool and damp, more heat is required. If the air is hot and humid, more cooling is required.

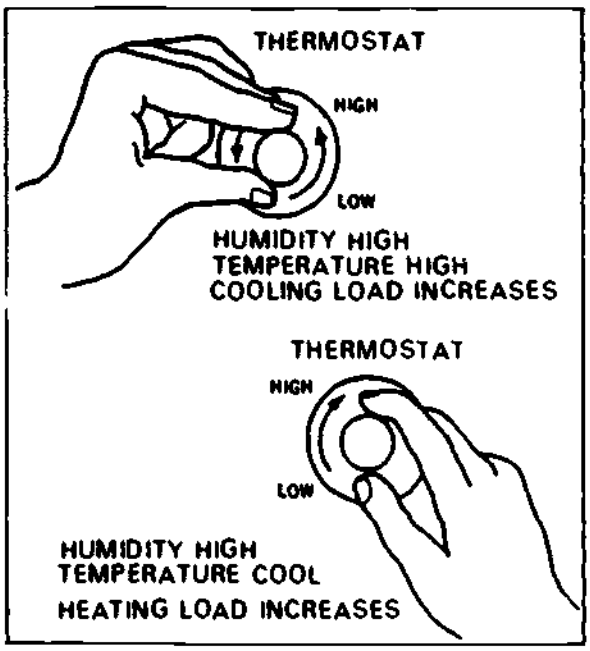


FIGURE 18. Humidity high, temperature cool, heating load increases. Humidity high, temperature high, cooling load increases.

d. Wind

Air motion in winter storms or seasonal wind causes heat loss in buildings. Humidity and ground moisture are also affected. However, wind can often be used to good advantage for cooling and air exchange. Maximum building comfort and energy efficiency may call for opening to, or shielding from, the wind at various times. By knowing the seasonal and daily wind patterns, you can plan the orientation and shape of buildings, fences, earth forms, and plantings to take best advantage of the forces of the wind (Figure 19).

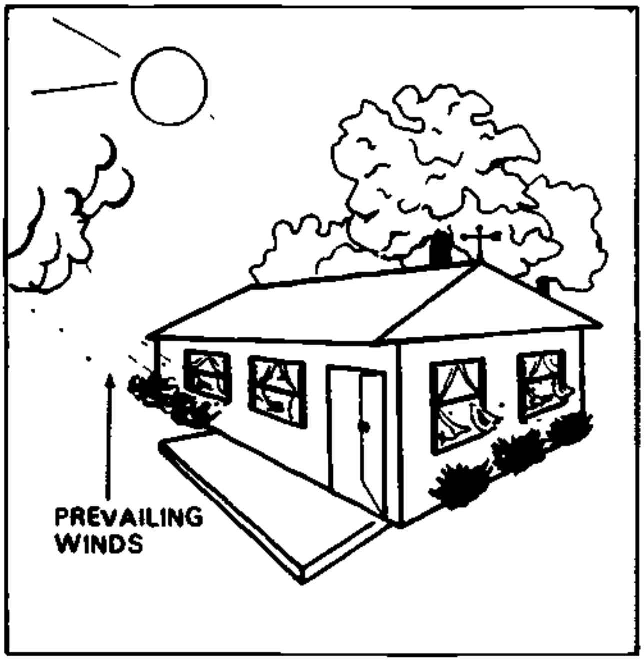


FIGURE 19. The designer can use prevailing winds to an advantage.

3. EFFECT ON CONVENIENCE

Very little, if any, convenience is sacrificed when designing for efficiency. Smaller heated or cooled areas may be desirable. But they may be utilized without reducing convenience appreciably.

4. EFFECT ON ENERGY USE

The design of the house is the most crucial element in saving energy. It is the designer who estimates the heat loss and gain in a building and provides for the most efficient and cost effective methods of construction. One of the main concerns is to incorporate the use of passive solar energy when practical.

5. EFFECT ON COST BENEFITS

An energy-efficient building costs little more initially and, in most cases, no more in the long run. Energy is saved and in most cases money is saved.

The cost of heating and cooling a building corresponds to the amount of energy used. Therefore, you can expect to pay more for energy in climate areas of extreme heat or cold.

You have already learned that the greater the difference in temperature, the more energy is consumed.

Refer to "Part Two, Section F" for procedures on computing cost benefits.

C. What Materials of Construction to Use

Several factors require consideration when selecting appropriate materials to build a structure which will not only be energy-efficient but also durable and attractive.

Each construction material has its advantages and disadvantages. Some are good for only one specific use while others serve several functions. Material requirements also vary with interior or exterior use.

The choice of materials to construct an energy-efficient building should be based on effectiveness against weather, degree of insulation, durability of the surface (both inside and out), local availability, ease of construction based on skill of labor available, attractiveness and cost.

In all buildings, a combination of materials will be needed to do the job. Table I will help you select building materials. The quality and suitability for various purposes are included. Installation difficulty and cost are indicated as well.

TABLE I. ENERGY-SAVING CHARACTERISTICS OF BUILDING MATERIALS

Construction Material	Insulation Capacity	Infiltration Resistance	Heat Storage Capacity
Aluminum	Low	High	Low
Asphalt shingles	Low	High	Low
Brick	Low	High	High
Concrete	Low	High	High
Earth	Medium	High	High
Glass	Low	High	Low
Gypsum Board	Medium	High	Low
Insulation	High	Medium	Low
Steel	Low	High	Low
Stone	Low	High	High
Wood	Medium	Medium	Low

D. What Type and How Much Insulation to Use

Insulation is one of the most important considerations when constructing or renovating a building. The amount of insulation you use and where it is placed affects not only your winter and summer fuel and electric bills, but your comfort as well.

The function of insulation is to slow the transfer of heat from the warm side of a wall, ceiling or floor to the cold side. As you already know, some materials resist the flow of heat better than others. Thermal conductance (U) or rate of heat transfer can be measured. Those materials which resist the flow of heat are called insulators. Insulation materials are rated by R-values (resistance to energy flow).

Insulation for buildings is made so that air is trapped in many small pockets in the materials. The tiny fibers in fiberglass, for instance, create thousands of small "dead air spaces" in the material. Also, when plastic foam is applied as insulation, thousands of tiny closed cells filled with nonconductive gases are formed. The movement of heat through these materials is slow because the trapped air spaces or closed cells are so small that the heat cannot easily move from the warm side to the cold side by convection.

Insulators are usually compared to each other by using the term resistance. The higher the resistance or R-Value of a material, the better it insulates. The R-value of a material is specified for a certain thickness of that material. Adding the R-values for each element of a wall, for instance, will give us the total resistance to heat flow for that part of the building. The higher the total resistance the better that part of a building will be in saving energy both winter and summer.

Both the builder and the homeowner have basically the same materials to choose from when selecting insulation. However, some materials should be installed by professionals. From this section, you will be able to list factors to consider in the selection of building insulation. They are discussed under the following headings:

1. Types of Insulation.
2. Effect of Climate and Geographic Location.
3. Effect of Construction Methods.
4. Effect of Insulation Quality.
5. Effect on Energy Use.
6. Effect on Cost Benefits.

1. TYPES OF INSULATION

Insulation comes in various forms and is made from several materials. In addition to considering its insulating quality, we must know if it is fire resistant, and vermin and insect proof. Table II compares several insulation materials.

There are several features that are important when considering the insulators that are commercially available; cost, resistance factor per inch of thickness, fire rating and durability. Let us first look at the forms of insulation that are available:

Blankets. Blankets come in rolls, usually from 41 to 61 cm (16 to 24 in) wide, and are unwound and cut to fit in place between wall studs or ceiling and floor joists.

Batts. Batts are similar in size to blankets but are precut to specified lengths.

Boards. Boards are precut to standard sizes and are usually applied with a mastic as perimeter insulation around the foundation or over existing walls for renovation work.

TABLE II. COMPARISONS OF INSULATION QUALITIES

Insulation Materials	Form	Approx.* R-Value Per Inch Thickness SI	US	Fire Resistant	Vermin Proof	Insect Proof	Moisture Resistant	Other Problems
Insulation Sheathing	Board	.35	(2.0)	No	-	-	Little	
Vermiculite Perlite	Loose-Fill	.37 .47	(2.1) (2.7)	Yes	Yes	Yes	No	Settling.
Fiberglass	Blanket Batt Loose-fill	.45 to .62	(2.6 to 3.5)	Yes	Yes	Yes	No	Skin irritant when handled; develops odor when damp.
Rock Wool (Mineral Wool)	Blanket Batt Loose-fill	.53 to .58	(3.0 to 3.3)	Yes	Yes	Yes		Skin irritant when handled.
Cellulose Fiber	Loose-fill	.65	(3.7)	When treated	When treated	When treated	Somewhat	
Polystyrene (styrofoam)	Board	.97 .70	(5.5) Blue (4.0) White	No	Yes	Yes	Yes	Punctures easily.
Urea-Formaldehyde	Foam, Blown or Sprayed on	.70	(4.0)	No	Yes	Yes	Yes	Some shrinkage--3 to 6%.
Polyurethane	Foam, Blown or Board	1.14	(6.5)	No	Yes	Yes	Yes	

*R-Values vary with manufacturers.

Loose-fill. This type of insulation comes as a loose granular material in bags and can be poured or blown into place between joists or behind walls.

Blown Insulation. This is a pneumatically blown type of insulation which is installed under pressure behind walls and between joists in ceilings and floors by professionals.

Now, let's look at the qualities that the various commercial insulators have. They are discussed as follows:

a. Loose-Granule, Mineral-Based

The most common of these are vermiculite and perlite, available as loose-fill insulation at moderate cost (Figure 20). The resistance is about SI 0.44 (US 2.5) per inch of thickness. These materials are fireproof and will not deteriorate from moisture, rot or insect problems. However, settling can be a problem, particularly when they are placed in a vertical position between wall studs.

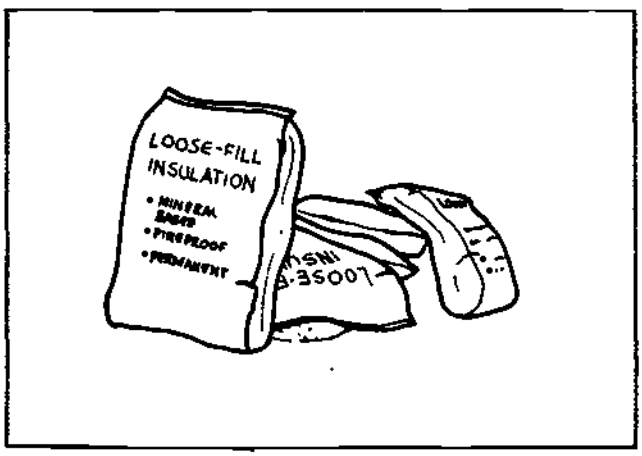


FIGURE 20. Loose-granule, mineral-based insulation is fireproof and will not deteriorate.

b. Fiberglass

Fiberglass is perhaps the most common of all insulators today; it is available in rolls, batts and loose-fill (Figure 21). The resistance of fiberglass is SI .41 to .62 (US 2.6 to 3.5) per inch of thickness. It is fire and vermin proof, moderate in cost and easy to install. The result is that the material is compressed a bit and loses some of its insulation value. It is a skin irritant when handled.

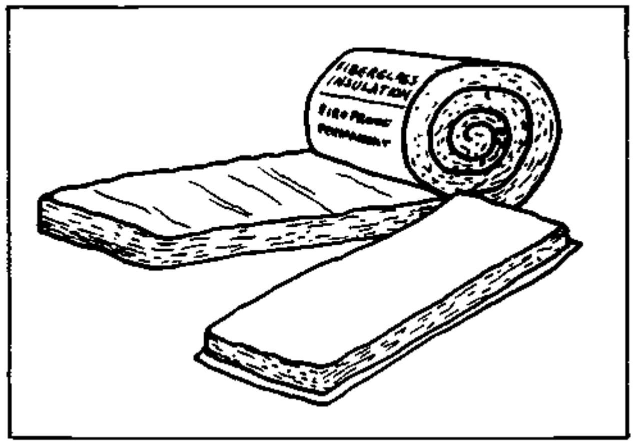


FIGURE 21. Fiberglass insulation cover is fireproof and will not deteriorate.

c. Mineral Fiber

Rock or mineral fiber is much like fiberglass except that the material is made from melted rock and slag instead of glass (Figure 22). Its cost and R-Value are nearly the same as fiberglass. Like fiberglass, mineral fiber can irritate the skin when handled.

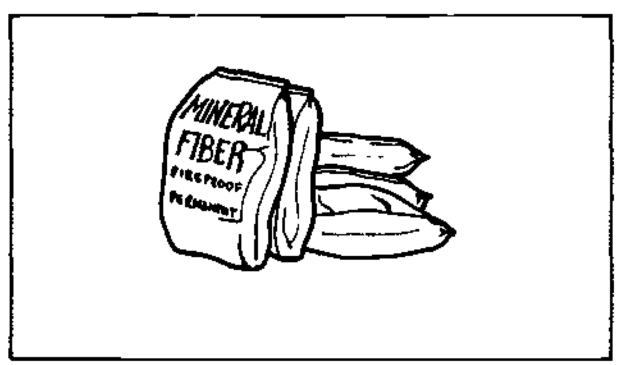


FIGURE 22. Rock wool is fireproof and permanent.

d. Insulation Sheathing

This is a material commonly made from wood fibers and is usually applied on exterior walls as a backing for siding (Figure 23). It comes in various thicknesses, usually between 1.3 and 2.5 cm (1/2 and 1 in). The resistance is about 2 per inch of thickness, and though it is water repellent, extended exposure to moisture will cause damage through mildew and rot. It is not fire resistant.

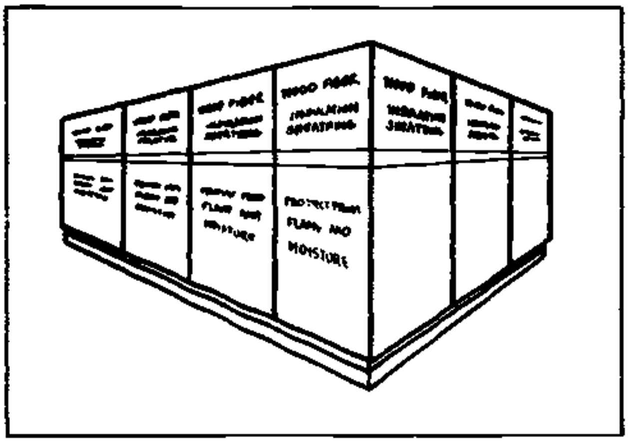


FIGURE 23. Insulation sheathing is made from wood fibers and is subject to rot if exposed to moisture.

e. Cellulose Fiber

These fibers are often made from recycled paper and when properly treated--are fire resistant (Figure 24). It does not irritate the skin. In its loose-fill version, cellulose has a fine consistency, permitting blow-in installation through small access holes. Just make sure that the label carries the brand name and treatment certification of a reputable manufacturer.

f. Plastic Insulation

The most common type of plastic insulation is polystyrene which comes either as a blue "closed-cell" form board or as white granule boards with the granules heated and pressure treated so they adhere together (Figure 25). The resistance per inch is about SI 0.97 (5.5) for the blue and SI 0.71 (US 4.0) for the white. Polyurethane, on the

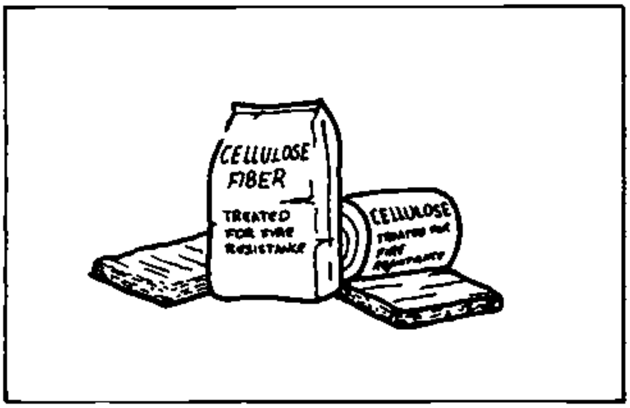


FIGURE 24. Cellulose fiber is supposed to be treated by the manufacturer for fire and vermin resistance.

other hand, comes as a closed-cell foam board. In either case, its resistance value is about SI 1.14 (US 6.5) per inch. Polystyrene and polyurethane tend to be expensive. Although both are good insulators and do not attract moisture or vermin, there are extreme fire hazards involved. Both will burn very rapidly and give off toxic gases; therefore, they should never be installed where they will be exposed. They can be covered with wallboard, exterior siding, or other material as specified by local codes. Since it is moisture resistant, it can be used below grade. It is often used around foundations and crawl spaces and has been used as a base for providing extra insulation under a poured concrete slab.

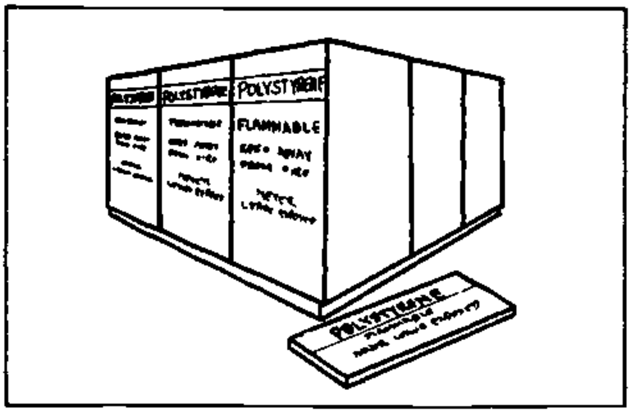


FIGURE 25. Polystyrene insulation is good insulation but it should always be covered by other building materials.

g. Urea-Formaldehyde

This is a moderately priced, foamed-in-place insulation. It is chemically stable, non-toxic, and will not attract moisture or insects. It is fire resistant. This material shrinks between 1.8% and 3.0% when it sets, creating small spaces between the studs. If the rest of the wall is tight, the shrinkage does not present a problem. The resistance of this material is about SI 0.71 (US 4.0) per inch of thickness. It requires a competent installer to insure good results (Figure 26).

NOTE: There has been some problem with improper installation with this material. Be sure and check out the success of your manufacturer before using this material. If you do use it, follow directions specifically.

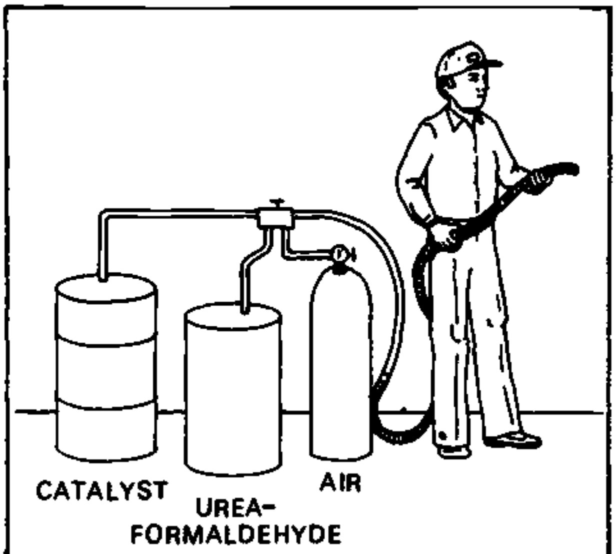


FIGURE 26. Urea-formaldehyde is fire resistant and will not attract moisture or insects.

2. EFFECT OF CLIMATE AND GEOGRAPHIC LOCATION

Although seasonal temperature variations are common to all climatic regions of the United States, each area generally has more seasonal cold or warm weather than another. Temperature is accompanied by moisture variations, wind and other elements.

Your choice of the type and amount of insulation to use depends on climate, energy costs, insulation costs, and other factors such as building features.

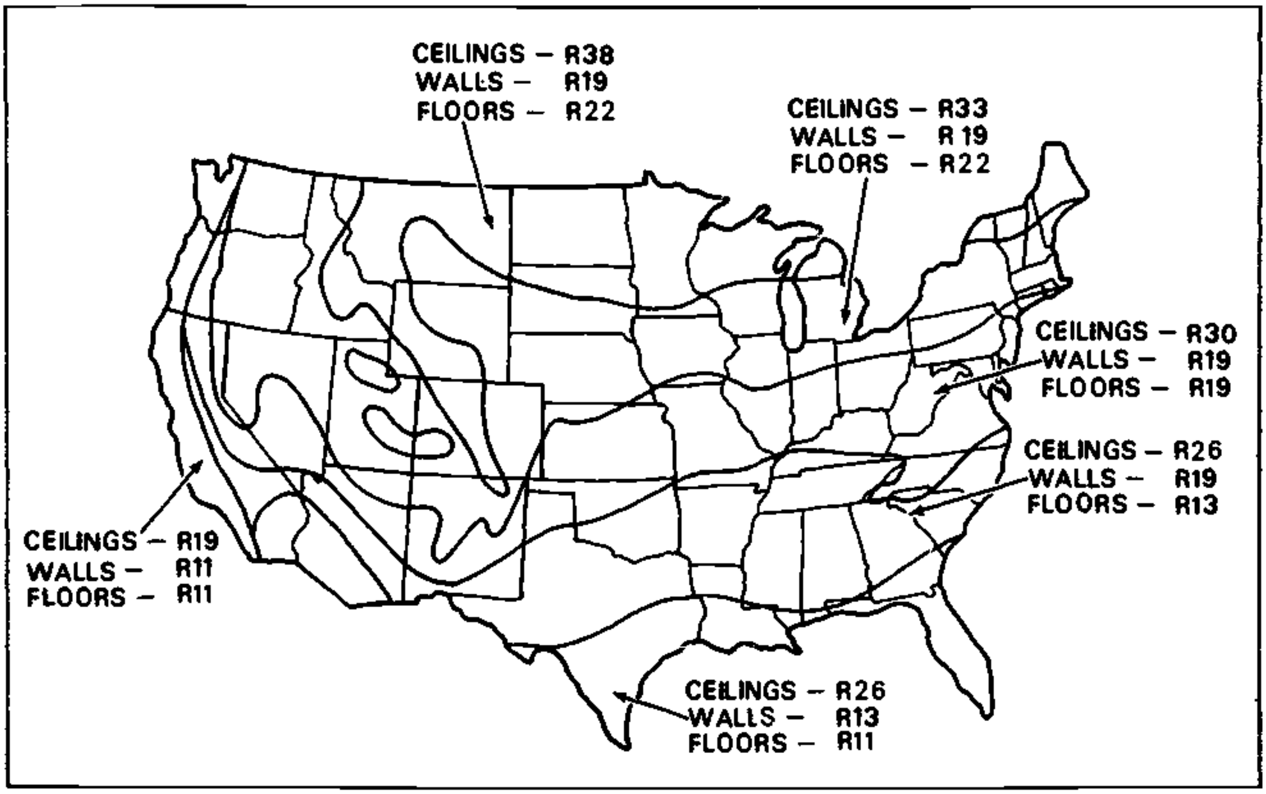


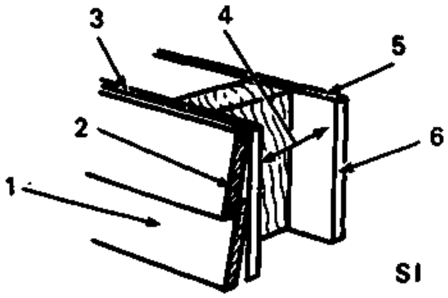
FIGURE 27. This map shows minimum insulation recommendations for ceilings/walls/floors in six (6) different insulating zones of the United States. The "R-Value" guidelines are for the economical amounts of insulation to have, considering climate, energy costs, insulation price, and other factors (Owens-Corning).

Many insulation recommendations have been made by housing agencies, contractors, and insulation manufacturers. The map in Figure 27 shows minimum insulation recommendations (R-Value) for six insulating zones of the United States.

More specific information can be had by finding the number of degree days for your area and referring to Table IV, or make a survey of your building.

3. EFFECT OF CONSTRUCTION METHODS

You know that heating and cooling requirements vary from one region of the United States to the other. And, even though building materials are quite similar throughout the country, construction methods do vary from one climate to another. In the case of insulation, the temperature variation in a given region or location is the basic reason for the construction method used. We need to realize that an ordinary wall without insulation is seldom sufficient to provide comfort in either warm or cold climates. Walls, ceilings, and floors seldom provide enough resistance to heat transfer without some form of insulation. Therefore, the selection of insulation provides the opportunity to make a building energy-saving and comfortable.



	SI	US
1. THIN AIR FILM ON OUTSIDE WALL	.34	(.2)
2. WOOD SIDING MATERIAL	.14	(.8)
3. INSULATING SHEATHING ½ INCH THICK	18	(1.0)
4. AIR SPACE BETWEEN STUDS	.18	(1.0)
5. GYPSUM WALLBOARD ½ INCH THICK	09	(.5)
6. THIN AIR FILM ON INSIDE OF WALL	.12	(.7)
RTOTAL	0.75	(4.2)

FIGURE 28. R-value for a wall section without insulation.

Older buildings present greater limitations on insulation selection than new structures.

A typical building construction method is the use of a standard 5.1 x 10.2 cm (2 x 4 in) stud wall. Let's first look at such a wall without insulation. You can add the resistance (R) of each element of this wall to find the total resistance (Figure 28).

Since we want a total resistance close to SI 3.5 (US 20), we can see that an uninsulated wall provides only about 20% of the insulating quality we desire.

Next, fill the 8.9 cm (3 1/2 in) air space between the studs with the different insulations discussed earlier. Replace the value of 1.0 with the R-Value of 8.9 cm (3 1/2 in) of each of several choices. See Table III for R-Values per inch. Now, a standard 5.1 x 10.2 cm (2 x 4 in) stud wall filled with 8.9 cm (3 1/2 in) of insulation has the following resistances:

	SI	US
Vermiculite or Perlite	2.1	11.9
Fiberglass	2.4	13.7
Mineral wool	2.4	13.7
Cellulose fiber	2.7	15.4
Polystyrene (white)	3.0	17.2
Urea-formaldehyde	3.1	17.7
Polyurethane	4.6	25.9

To bring your wall's insulation value up to an R 3.5 (20) for most of these insulators, it would be necessary to add more insulation. To do that, you would have to provide more space.

Two methods are used.

a. 15.2 cm (6 in) Stud Walls.
b. 10.2 cm (4 in) Stud Walls.

TABLE III. THICKNESS OF INSULATION NEEDED FOR CERTAIN R-VALUES

R-VALUE		BATTS OR BLANKETS				LOOSE FILL (POURED-IN)					
		Glass Fiber		Rock Wool		Glass Fiber		Rock Wool		Cellulosic Fiber	
SI	(US)	CM	(IN)	CM	(IN)	CM	(IN)	CM	(IN)	CM	(IN)
1.9	(11)	9-10	(3.5-4)	7.6	(3.0)	13	(5.0)	10	(4.0)	7.6	(3.0)
3.3	(19)	15-16	(6-6.5)	13	(5.25)	20-23	(8-9)	15-18	(6-7)	13	(5.0)
3.9	(22)	16	(6.5)	15	(6.0)	25	(10.0)	18-20	(7-8)	15	(6.0)
5.3	(30)	24-27	(9.5-10.5)	23	(9.0)	33-36	(13-14)	25-28	(10-11)	23	(9.0)
6.7	(38)	31-33	(12-13)	27	(10.5)	43-46	(17-18)	33-36	(13-14)	25-28	(10-11)

Table III can help you determine the amount of some of the more common insulations to use in order to obtain suggested R-Values.

a. 15.2 cm (6 in) Stud Walls

Increase wall thickness by using 5.1 x 15.2 cm (2 x 6 in) wall studs and add more insulation.

Now, with an actual 14 cm (5 1/2 in) for insulation, recalculate the total wall resistance for various insulators.

Note! Some local codes do not allow this construction for dry wall. Check your code.

	SI	US
Vermiculite or Perlite	3.0	16.9
Fiberglass	3.5	19.7
Mineral wool	3.5	19.7
Cellulose fiber	3.5	22.4
Polystyrene	4.4	25.2
Urea-formaldehyde	4.9	27.7
Polyurethane	6.9	38.9

Thus, with 5.1 x 15.2 cm (2 x 6 in) stud walls, we have achieved an approximate R-20 or better for most of the insulations. This construction method would allow us several choices of insulation based on cost rather than on R-Value.

Using 5.1 x 15.2 cm (2 x 6 in) studs on 61 cm (24 in) centers rather than 5.1 x 10.2 cm (2 x 4 in) studs on 40.6 cm (16 in) centers will increase our materials cost only slightly. Because wood conducts heat so much faster than the insulations we've listed, the heat loss due only to the spread-out arrangement is reduced by about 5%. The additional 5.1 cm (2 in) of space that the 5.1 x 15.2 cm (2 x 6 in) provides for insulation reduces the heat loss to the point where the total saving is about 35%.

b. 10.2 cm (4 in) Stud Walls

One inch of polystyrene (white) will increase the total R-value by .07 (4).

Where polystyrene is used for sheathing corner braces must be installed.

TABLE IV. GENERAL RECOMMENDATIONS FOR ENERGY EFFICIENCY IN RESIDENCES (HUD, 1978)

Winter Degree Days	Heating Fuel	Ceilings R		Walls R		Floors Over Unheated Spaces R		Foundation Walls of Heated Spaces R		Layers of Glazing: Windows and Glass Doors	Storm Door or Thermal Door
		SI	US	SI	US	SI	US	SI	US		
0 - 1000	Electricity	3.3	(19)	1.9	(11)[a]	7.9	(11)	-	-	1	No
	Fossil Fuel or Heat Pump	3.3	(19)	1.9	(11)[a]	-	-	-	-	1	No
1001 - 2500	Electricity	3.9	(22)	2.3	(13)[a]	2.3	(13)	-	-	2	No
	Fossil Fuel or Heat Pump	3.3	(19)	1.9	(11)[a]	-	-	-	-	1	No
2501 - 4500	Electricity	5.3	(30)	2.3	(13)[a]	3.3	(19)	1.2	(7)	2	No[c]
	Fossil Fuel or Heat Pump	3.9	(22)	2.3	(13)[a]	2.3	(13)	1.2	(7)	1	No[c]
4501 - 7000	Electricity	5.3	(30)	2.3	(13)	3.3	(19)	1.2	(7)	3[b]	Yes
	Fossil Fuel or Heat Pump	5.3	(30)	2.3	(13)	2.3	(13)	1.2	(7)	2[b]	No[c]
7001 or more	Electricity	7.0	(38)	2.3	(13)	3.3	(19)	1.2	(7)	3[b]	Yes
	Fossil Fuel or Heat Pump	5.3	(30)	2.3	(13)	3.3	(19)	1.2	(7)	2[b]	Yes

[a]Recommended only when wall covering is removed and an adequate vapor barrier is installed.
[b]Insulating frames should also be provided if replacement sashes are installed.
[c]Storm or thermal door is recommended if the primary door is hollowcore or over 25% glass.

4. EFFECT OF INSULATION QUALITY

Construction features of ceilings, walls and floors of a building suggest a particular form of insulation to use. Some of the insulation qualities are more important in one location than another.

The chart listing "Types of Insulation" indicated most of the qualities we desire in an insulation material. Installation methods often let us use high R-Value insulations even though they may not be totally fire or moisture resistant. In order to reach a suggested R-Value for a given section of a building, the R-Value of an insulation becomes our major concern. With the resistance value known, we then select the amount of insulation to do a particular job.

5. EFFECT ON ENERGY USE

Naturally, the more insulation you use, the more energy you will save—assuming it is installed properly. There is no point in adding more than you need for cost effectiveness, however.

6. EFFECT ON COST BENEFITS

Follow procedures in "Part Two. Section F" for computing cost benefits. General recommendations are given in Table IV.

E. What Type of Vapor Barrier to Use

Vapor barriers are an essential part of the insulation story. Insulation in a wall, ceiling or floor must be protected by a vapor barrier applied to the warm (heated) side of the insulation. Without it, moisture from the house air will enter the insulation, condense and cause serious damage.

Some insulation is sold with an attached vapor barrier. Others require a separate application. Here are some common vapor barrier materials:

1. Polyethylene Film.
2. Aluminum Foil.
3. Paints and Other Finishes.

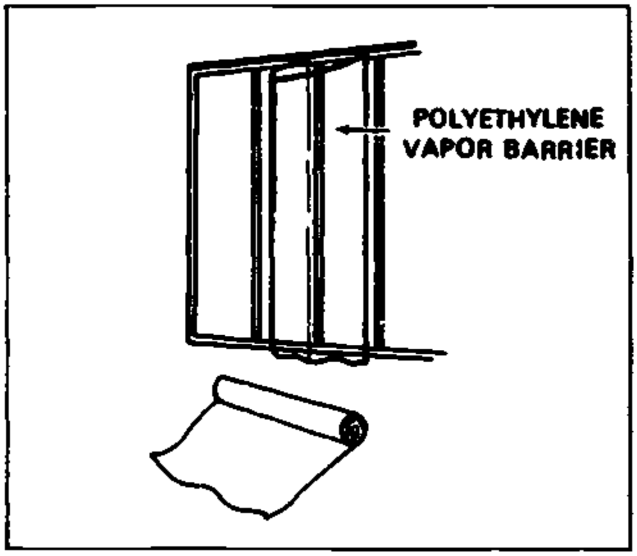


FIGURE 29. Polyethylene film is a good vapor barrier. Use thickness of .5 to 1.5 mm (4 to 6 mils).

1. POLYETHYLENE FILM

When insulation without a vapor barrier is installed between studs or rafters, polyethylene is placed (laid or stapled) on the warm side (Figure 29). It is available in convenient rolls in thicknesses from .05 to .15 mm (2 to 6 mils) and in widths from 0.9 to 6.1 m (3 to 20 ft). One tenth mm (4 mil) or thicker plastic is generally used for vapor barrier purposes.

2. ALUMINUM FOIL

Aluminum foil vapor barriers, usually part of insulation rolls or boards, are placed so that they are toward the warm, interior living space. Joints should be taped with aluminized tape to make a tighter air and vapor seal.

In the case of foil-backed gypsum board, the foil side is placed against the wall studs or ceiling rafters which are insulated with a non-vapor barrier material.

3. PAINTS AND OTHER FINISHES

Various paints and other water resistant finishes may be used on interior room surfaces as a moisture barrier when other methods are not feasible--such as in older buildings where interior walls and ceilings are not being replaced. Aluminum paint, rubber base paints, varnish and some urethane finishes serve this purpose.

F. What Type and How Much Weatherstripping and Caulking to Use

Weatherstripping and caulking can have dramatic results in terms of both comfort and energy saving. These are two jobs that home or building owners (or renters) can do themselves and at little cost.

Weatherstripping and caulking are perhaps the most important jobs you can do to save energy in buildings.

Weatherstripping is placed around windows and doors in such a way that they can close more tightly than before, yet can still be opened. Weatherstripping is usually applied with either nails or glue. Sometimes it is self-adhesive, with a paper peel-off back.

There are many different kinds of weatherstripping on the market, most of which do an adequate job. You will want to choose weatherstripping on the basis of ease of application, appearance and expense.

Caulking is used to fill cracks around the frames of windows and doors. It can seal cracks under eaves (if not for ventilation), around flashing, between bricks and in basement walls.

The ideal caulking will adhere to both sides of the opening to be closed and remain resilient to permit movement between the two materials without cracking. Usually the more expensive caulkings do a better job of sealing and last longer.

From this section, you will be able to describe the types of weatherstripping and caulking and explain how they can be used to make buildings more energy-efficient. This information is presented under the following headings:

1. Types of Weatherstripping and Caulking Available.
2. Effect on Energy Use.
3. Effect on Cost Benefits.

1. TYPES OF WEATHERSTRIPPING AND CAULKING AVAILABLE

Weatherstripping and caulking are described under the following headings:

a. Weatherstripping.
b. Caulking.

a. Weatherstripping

Of the several types of weatherstripping, all are available to the consumer (Table V). Although different situations call for different types of material, most can be used for either doors or windows.

Types of weatherstripping include felt-fabric strips, metal strips, and wide, flexible weatherstripping for garage doors.

There is transparent weatherstripping which is pressed on to the outside of the window along the frame and trim. There is flexible, putty-like material that is easy to apply and suitable for windows which are rarely, if ever, opened, such as in the attic or basement.

For outdoor entrances, there are special strips of plastic that are attached to the bottom of each door itself. They're called threshold sweep strips. There are also metal thresholds with gasket strips which are usually screwed into place.

Some weatherstripping depends upon the compression of a resilient material between one or two moving surfaces; others depend upon a mechanical interlocking of two parts. Table V lists the types of weatherstripping and their characteristics.

b. Caulking

Although the air leaks around windows and doors can be sealed with weatherstripping, other cracks can exist which allow the passage of heated or cooled air. Caulking is used to seal cracks between similar or dissimilar building materials. Cracks between two different materials are called "moving joints" because the joint expands and contracts due to the fact that different materials expand and contract at different rates depending on changes in temperature, moisture, or pressure.

A number of small cracks can add up to a lot of leakage, which is energy lost. Moisture can enter and cause rotting. Insects and other pests can also enter and cause problems. Thus, caulking is sometimes just as important as weatherstripping.

Caulking comes in several forms (Table VI). The most popular is the cartridge due to its ease of application with a caulking gun. Caulk also comes in squeezable tubes as well as cans for application with a putty knife. Another type is called rope caulk because it consists of strands of caulk packaged in a roll.

Buying caulk in bulk is most economical for industrial users or contractors. However, since shelf life is short, the homeowner should buy only the amount that will be used in one season.

Table VI lists the types of caulk and their various characteristics.

2. EFFECT ON ENERGY USE

A crack or crevice that allows air to pass reduces the effectiveness of your insulation. Weatherstripping and caulking will increase the efficiency of your building.

3. EFFECT ON COST BENEFITS

You can't go wrong on spending money for weatherstripping and caulking. You will save enough on energy bills to recover it.

TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Pressure-Sensitive, Adhesive-Backed Foam	Polyurethane foam with vinyl cover in roll OR closed-cell vinyl foam.	Easy to install. Cushioning effect--noise reduction in closing. Good seal.	Avoid painting--causes loss of resiliency. 1-3 yr life--not durable. More effective on doors.	Low to medium.
Metal Spring	Bronze, copper, stainless steel, or aluminum.	Excellent seal. Very durable.	Requires patience for installation.	Medium.
Self-Sticking	V-shaped or single roll strip.	Easy to install.		
Felt or Self-Sticking	Variety of widths and thicknesses in a roll.	Easy to install. Various colors.	Variable life--may stick to door finishes.	Low.
Serrated Metal	Felt or vinyl-backed metal roll.	Easy to install.		Medium.
Tubular Gasket (rolled vinyl) Foam-Filled Tubular Gasket	Flexible vinyl in tubular form with or without metal backing.	White or gray. Easy to install. Very good, durable seal.	Cannot be painted or it will lose flexibility. Extra strength, holds shape. Extra insulating value.	High.
Interlocking Metal	Two interlocking pieces--strip.	Tight seal. Best available for doors.	Difficult to install due to alignment and cutting. Maintenance requires straightening of bent pieces.	High.
Casement Window Gasket	Vinyl roll.	Easy to install--slip on lip of window.	Gray only.	Medium.

TABLE V. CHARACTERISTICS OF DIFFERENT TYPES OF WEATHERSTRIPPING (CONTINUED)

Type of Weatherstripping	Material/Form	Advantages	Problems	Cost
Jalousie Gaskets	Clear vinyl. U-shaped track.	Easy to install-slip on.		Medium.
Door Sweeps	Wood and felt or wood and foam or metal and vinyl strips.	Easy to install. Effective seal against drafts.	Must clear carpet.	Medium.
Thresholds	Vinyl insert in metal base strip OR two-piece interlocking strip.	Generally best seal for exterior doors.	Often requires removal of old threshold or cutting of door.	High.

TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Oil Base	Adheres to most surfaces--prime porous surfaces.	Not for use on moving joints. As oil dries out, caulk shrinks; 1 to 7 year life--prolong life by painting after drying.	Low
Latex Base	Long life up to 10 years (some are guaranteed for 20 years). Adheres well to most surfaces--prime or paint metal and porous surfaces. Dries quickly. Can be painted in 15-30 minutes--accepts most paints.	Shrinks some--apply a big bead of caulk and use it to fill only narrow cracks.	Medium
Butyl Rubber	Should last up to 10 years if properly applied. Can be applied indoors or out, on metal or masonry. Can be painted with any type of paint after curing for a week.	Shrinks a little--apply a wide bead and cover only small cracks.	Medium
Polyvinyl Acetate (PVA)		Loses flexibility when it dries--use only for small holes indoors.	High
Silicone Seal	Excellent sealant--can last for at least 20 years. Adheres to just about any surface and shrinks very little. Ideal for moving joints--stretches up to 7 times its cured width.	Usually cannot be painted--some come in various colors.	High
Nitril Rubber	Long lasting--15 to 20 years. Extremely good for high moisture areas. Adheres well to metal, masonry and other unprimed surfaces. Can be painted after 10 to 20 minutes --painting is not necessary.	Shrinks considerably--do not use on moving joints or cracks over 1/8". Does not adhere well to painted materials.	High

TABLE VI. CHARACTERISTICS OF DIFFERENT TYPES OF CAULKING (CONTINUED)

Type of Caulk	Advantages/Application	Problems/Solutions	Cost
Neoprene Rubber	15 to 20 year life span. Especially good for use on concrete walls and foundations. Moderate shrinkage--can be used on moving joints less than 1/4 inch. Accepts paint but not needed.	Dries tack-free in about 1 hour but takes from 1 to 2 months to cure fully. Ordinary solvents are of no help in removing neoprene rubber--use either MEK or tolulene with caution.	High
Polysulfide	Over 20-year life on moving joints. Thoroughly shrink resistant.	CAUTION: Toxic until cured--up to 3 full days before tack-free. Special primer required on porous surfaces such as wood or masonry. Tolulene and MEK will clean away excess--follow directions on label.	High
Hypalon	Excellent caulk made to last up to 20 years. It can be used on moving joints. Will adhere to any surface. Easy to work with.	Not in general distribution. Requires priming before use on porous materials --check label.	High
Polyurethane	Can be used on moving joints. Will last up to 20 years. Will adhere to any surface, no priming needed. Easily applied.	Requires 24 hours to become tack-free and up to two weeks to cure. Not in many retail outlets. Use paint thinner or acetone for cleanup.	Low
Rope Caulk	Can be used on wide gaps. Does not dry out. Does not shrink. Easily applied--seasonal use is possible on storm windows.	Considered only a temporary solution to air leaks. Cannot be painted.	Low

G. What Type of Windows to Use

There are several types of windows for both homes and commercial buildings. The type of window selected is a matter of owner/builder preference. The right window in the right place gives a home natural light, fresh air, good looks and convenience.

The major decision related to energy-saving, however, is the number of layers of glass to choose for a particular climate. There are choices between insulated glass or storm windows and even justification for triple glazing in some locations. From this section, you will be able to list the factors for selecting types of windows for energy efficiency.

1. Types of Windows.
2. Effect of Climate.
3. Effect of Insulating Quality.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF WINDOWS

Builders have a choice of several types of windows. Window sash is made primarily of wood or metal with some plastics being used for weather protection. We will discuss both the prime windows and storm windows. The original (or inside) windows in a home are referred to as prime windows--the first windows. Storm windows are secondary windows.

The various types of prime windows used in houses and other small buildings are shown in Figure 30.

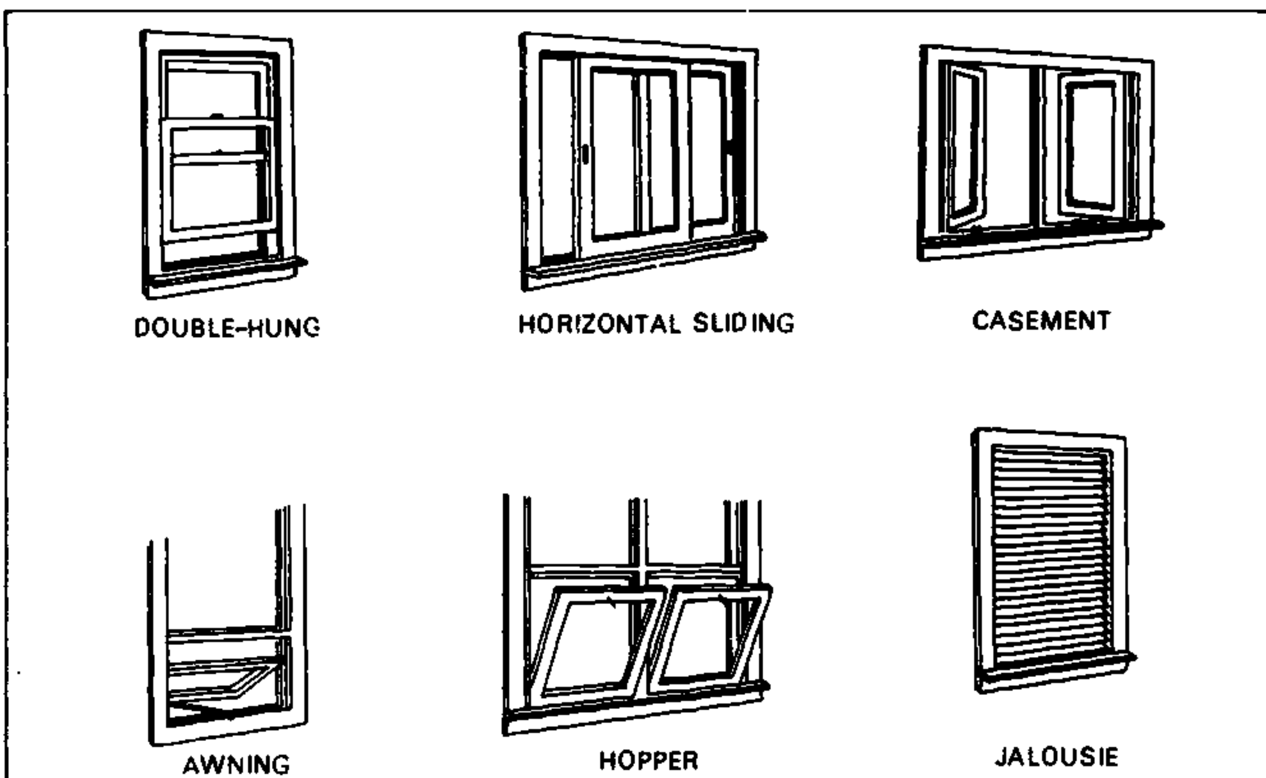


FIGURE 30. Types of windows.

a. Double-Hung Windows

The conventional double-hung window usually has two sashes which operate vertically. They are found in most homes and are adaptable to any architecture.

Double-hung windows usually have a separate wood or metal-frame storm window attached on the outside of the window casing. Metal-frame storm windows are lighter in weight and easier to handle. They are often sold as combination storm-screen units which allow for self-storing of the screen or second glass. The higher heat conductivity of metal, however, makes them about 20% less efficient than wood-frame units.

b. Horizontal Sliding Windows

The sashes in this type of window slide horizontally. Usually there are two movable sashes; sometimes one is fixed. These windows may be equipped with insulating glass, a conventional storm window attached to the outside frame, or a storm panel that attaches directly to the window sash.

c. Casement Windows

Casement windows swing outward on hinges attached at the side. A storm window must be attached directly to the sash or on the inside frame. If an inside storm is used, no ventilation is possible during the heating season.

d. Awning Windows

Hinged at the top, they are manufactured as a single unit or as several sashes stacked together in one frame. When open, the sashes project at an angle like awnings. Inside storm sash or storm panels must be used, with the same limitations as described for casement windows.

e. In-Swinging (Hopper) Windows

These can be either bottom-hinged hopper windows or top-hinged windows such as those often used in basements. They can be equipped with a storm sash on the outside or a storm panel attached to the prime window. Both out-swinging and in-swinging windows offer adjustable ventilation. When used with fixed-sash, they provide air flow for picture windows.

f. Jalousie Windows

A series of small horizontal glass slats make up a jalousie window. They are held by an end frame, pivot in unison like a venetian blind and open outward. Jalouise windows are not satisfactory as prime windows for an area to be heated as they are very difficult to seal, even with the use of a storm panel on the inside.

2. EFFECT OF CLIMATE

Our elements of weather--sunshine, temperature, wind, moisture--must all be considered when selecting and placing windows.

Since windows are a source of heat gain and loss, we will want to place windows on the south and southeast side to receive solar radiation for warming in the winter and to avoid cold winds from the north-northwest.

Glass is a good conductor of heat; therefore, the greater the temperature difference between the interior and exterior surfaces of the glass the greater the heat loss or gain. Extremes in temperature require the use of insulating air spaces between two or more layers of glass to make windows less conductive.

The infiltration or air leakage around a window frame or sash is also affected by temperature and moisture. Wood reacts to moisture variations by swelling or shrinking. The result is a crack or space around the window or frame for air to leak in or out.

Condensation is another problem. The source of condensation, or "sweating" on windows is humidity, or invisible water vapor in the air. A cold window surface allows the water vapor in the air to condense rather than be absorbed. By "insulating" our windows through the use of storm windows or thermo-layers, we increase the inside temperature of the glass surface and reduce condensation. Humidity control within the building is also an important factor.

3. EFFECT OF INSULATING QUALITY

In a well-insulated house with as little as 10% of the wall area in glass, as much as 25% of the total heat loss may be through the glass. In the summer, glass admits the radiant energy of the sun which is converted into heat. Storm windows or multi-pane windows reduce the heat loss or gain by more than half (Figure 31). They are discussed as follows:

a. Storm Windows

Storm windows are usually more efficient and economical than insulating glass (factory sealed) for the following reasons:

- The storm window provides a separate seal of the cracks around the window.
- The air space between the two layers of glass is greater, providing more insulation.
- Using a storm window does not require replacement of good prime windows to obtain an insulating sash.

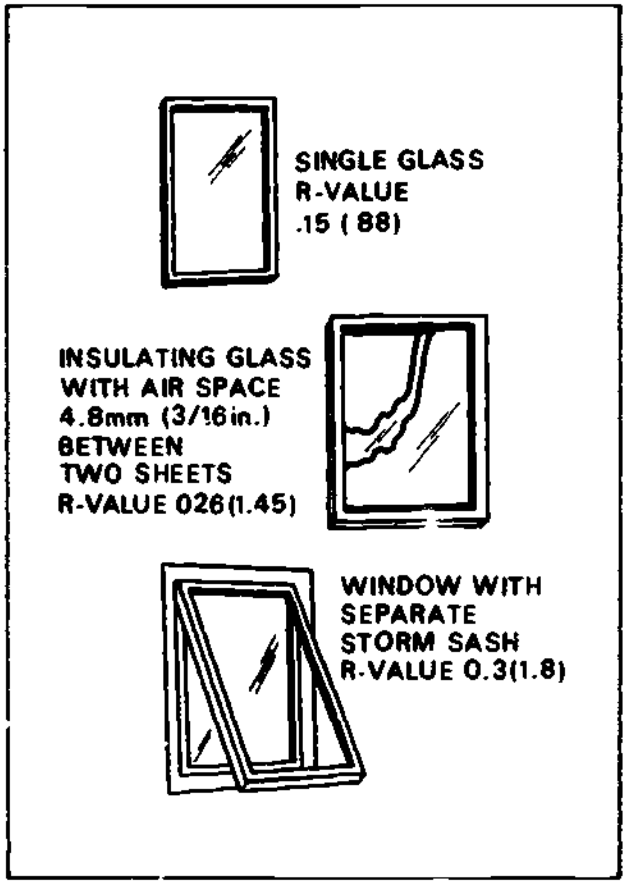


FIGURE 31. R-Values for window with storm sash or double-insulated glass.

b. Multi-Pane Windows

Multi-pane windows are sometimes referred to as insulated windows. They have two or more panes of glass with an air space between.

For additional insulation, add a storm window to a double pane glass or use triple glazing.

<u>Triple glazing</u> (insulating glass plus a separate storm sash, or new factory-sealed triple unit) can often be justified in areas with 6,000 or more seasonal degree days in houses that are also centrally cooled. They may also be justified when using electric heating. Figure 32 illustrates the R-values for triple glazing.

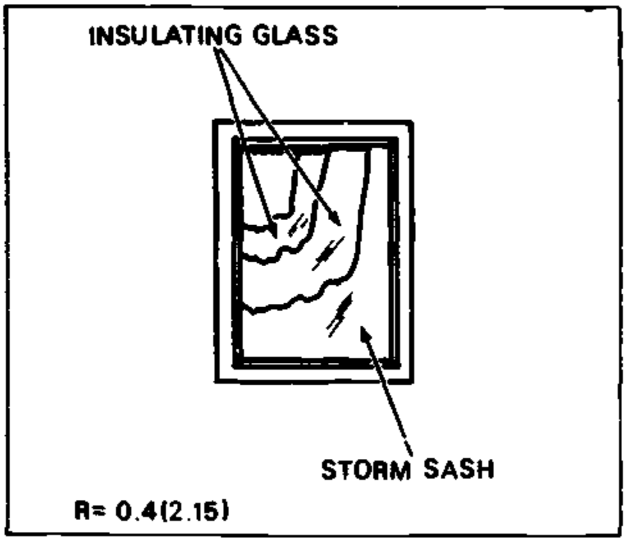


FIGURE 32. R-Values for triple glazing.

Triple glazing is also an effective barrier for noise and is sometimes used for this reason alone in houses near airports, for example.

An increase in comfort for room occupants usually accompanies the use of storm windows or insulating glass. This fact is illustrated in Figure 33 which shows the dramatic increase in the inside temperature of the surface when two or more layers of glass are used.

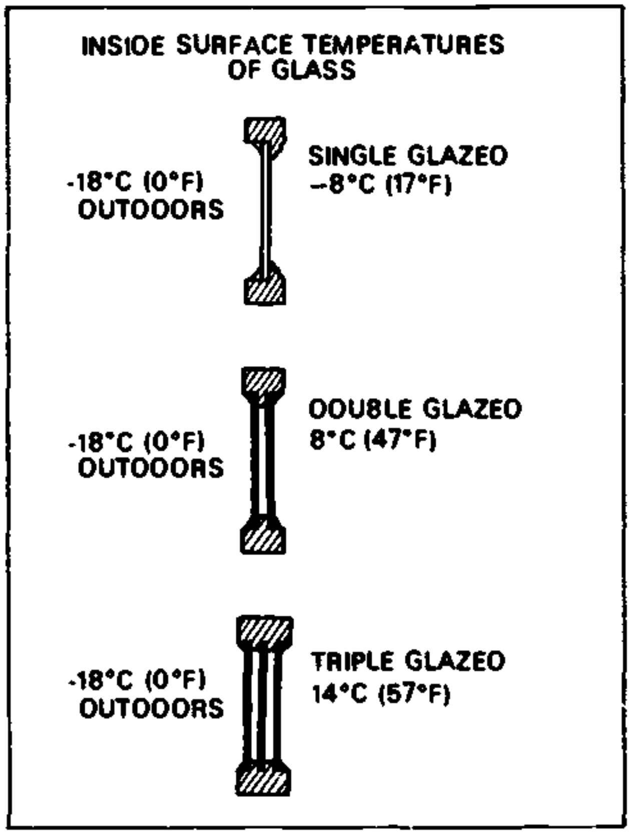


FIGURE 33. Inside temperatures of glass for single-glazed, double-glazed and triple-glazed windows.

The problem of moisture condensation can be almost eliminated with the use of insulating glass and storm windows and weep holes. When the outdoor air is 22°C (0°F), moisture condensation will occur on the glass when the relative humidity inside the house is only 12%. With insulating glass, condensation will not occur until the relative humidity is 30%. With insulating glass and a storm window, condensation will not occur until the relative humidity is 37%.

4. EFFECT ON ENERGY USE

It has already been stated that windows can be the biggest cause of home energy loss. They may be costing a home or building owner up to a third of his heating and air-conditioning expense.

Poorly designed, improperly installed and used, or old, deteriorated windows can lose energy in two important ways. They are as follows:

a. Excessive Heat Conduction

Glass is not a good insulator against heat conduction. Heat will travel through a glass window pane quite easily (Figure 34). One square meter (foot) of single-pane glass conducts at least ten times as much heat as one square meter (foot) of insulated wall.

Just as an example, each ordinary .9 x 1.5 m (3 ft by 5 ft) window can loose the equivalent of over a .5 liter (pint) of heating oil, or about seven cents-worth, every day. And we haven't considered the effect of leakage yet.

b. Air Leakage (Infiltration)

If our .9 by 1.5 m (3 ft by 5 ft) window has a crack just 1.6 mm (1/16 in) wide all around its frame, that crack adds up to 84 cm^2 (13 in^2) --just like having a hole in your wall the size of a brick (Figure 35). If you have twelve windows like this in your home, you've got the equivalent of a hole the size of 12 bricks! This is the reason that a large portion of heat loss from a house is due to air leakage. Even the smallest cracks can add up!

Air leakage and conduction together can account for as much heat loss through a .9 by 1.5 cm (3 ft by 5 ft) window as a hole in the wall the size of four bricks. Twelve bad windows means you have the equivalent of a hole in your wall the size of 48 bricks. That means you're trying to heat and cool your home with a .5 by .9 m (1 1/2 ft by 3 ft) hole in the wall directly to the outside (Figure 35). Be careful about shutting off all air to combustion type furnaces.

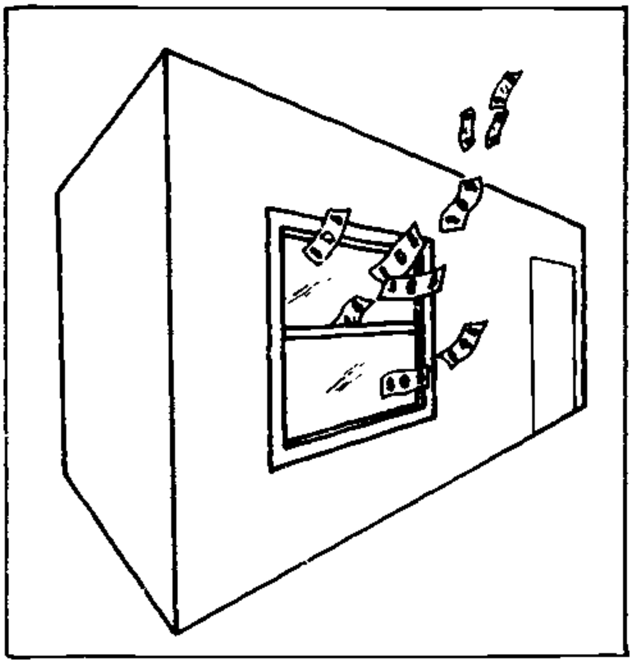


FIGURE 34. Glass is not a good insulator of heat. When heat is lost, money is lost.

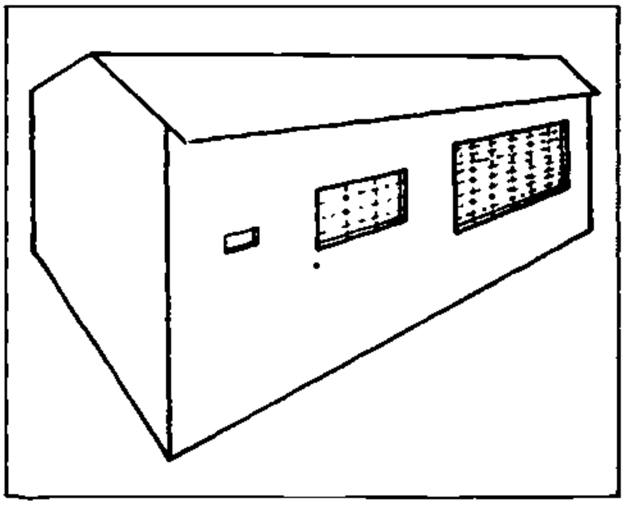


FIGURE 35. Cracks around windows are equivalent to holes in the walls.

The amount of energy and money your windows are losing depends entirely upon the type and condition of the windows and the location of your home. If your windows are in pretty good shape—that means minor air-leakage, you will still be losing energy through conduction. If your windows are old and loose-fitting, you have air leakage as well as conduction problems. This is particularly true if you have a fireplace with an open flue.

5. EFFECT ON COST BENEFITS

Refer to Table IV for general recommendations.

H. What Type of Doors to Use

Aside from beauty and durability, exterior doors should be selected with their insulating quality in mind. Interior doors do not have this requirement.

Exterior doors in common use for most living spaces and commercial buildings are either of wooden or metal construction. Glass area varies in doors and can greatly affect the insulating value of a door. Metal frame doors with insulating glass, thermo-barriers, and good weatherseals can be as effective as storm doors. Fiberglass doors are just beginning to enter the market.

From this section, you will be able to describe the characteristics of doors under the following headings:

1. Types of Doors.
2. Effect of Climate.
3. Effect of Insulating Quality.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF DOORS

Doors, like windows, affect heat loss and gain by both conduction and air infiltration. Once the air infiltration factor is solved with caulking and weatherstripping, the insulating value of the door becomes significant. Three main types of doors are used in light building construction. They are as follows:

a. Hollow-Core Doors

Most hollow-core doors used today consist of a solid wood frame with a veneer of birch, or mahogany. They are used mainly for interior doors but sometimes are used as an exit door to an attached garage.

b. Solid-Wood Doors

Solid-wood doors are commonly made from pine, oak, or maple.

c. Steel-Clad, Foam-Center Doors

Most modern builders use steel-clad exterior doors for building entrances or exits (Figure 36). These doors have a urethane foam insulating core.

To function as a good thermal barrier, doors need good weatherstripping and thresholds.

2. EFFECT OF CLIMATE

Doors need protection from the elements of weather to do their job most efficiently. Doors can do very little, however, to add heat from radiation as do windows. Their main job is to keep the cold air out. To remain in good condition, doors should be protected by overhangs, vestibules or storm doors. Placement on sides other than the north exposure will protect against most winter storms. Landscaping can provide shelter for entrances which would otherwise receive the full force of wind and snow.

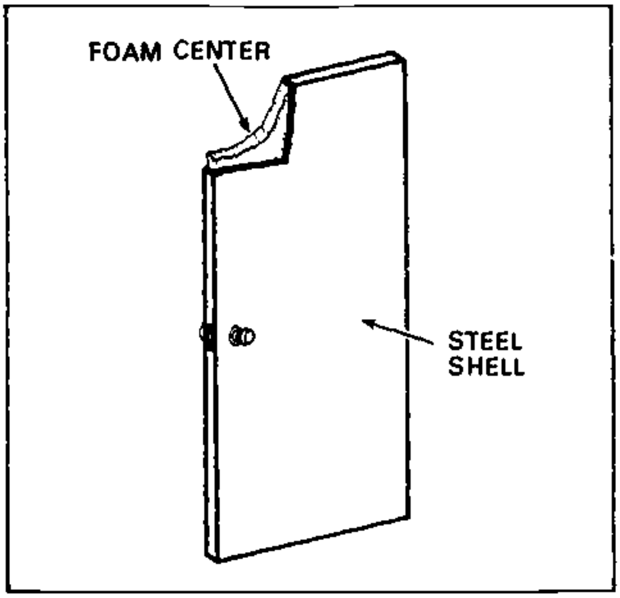
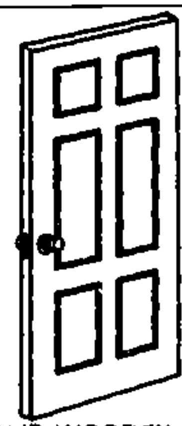


FIGURE 36. A steel-clad, foam-center door has good insulating quality.



SOLID WOODEN DOOR

THICKNESS CM	(IN)	R-VALUE SI	(US)
2.5	(1)	.27	(1.56)
3.2	(1¼)	.32	(1.82)
3.8	(1½)	.35	(2.04)
5.1	(2)	.41	(2.33)

FIGURE 37. R-Values for solid wooden doors.

3. EFFECT OF INSULATING QUALITY

Doors have different insulating qualities. They are discussed as follows:

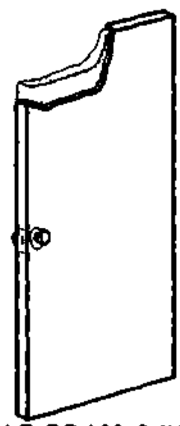
a. Solid Wood Doors

Wooden doors are usually solid core, or solid frame with panels. Solid-wood prime doors alone without storms would have R-Values as shown in Figure 37.

Wood frame doors with panels would have about 60% of the resistance values as a solid door.

b. Steel-Clad, Foam-Center Doors

Metal doors are usually sheet metal over a metal or wood frame with an insulation core. Metal-clad doors with an insulating core would have R-values as shown in Figure 38.



STEEL CLAD FOAM CENTER DOORS

THICKNESS CM	(IN)	R-VALUE SI	(US)
2.5-3.8	(1-1½)	1.38	(7.8)
5.1	(2)	1.92	(10.94)

FIGURE 38. R-Values for steel-clad, foam-center doors.

c. Storm Doors

The most effective step in reducing heat loss through doors is to install a storm door. A wood storm door with about 50% glass area can reduce the heat loss by 45 to 50%. A metal storm door, regardless of the percentage of glass, will reduce the heat loss by only 30 to 35%.

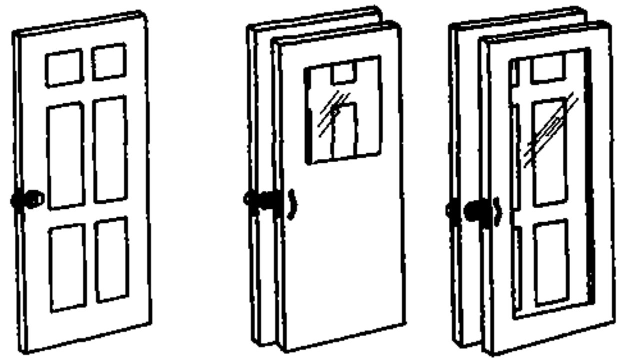


FIGURE 39. R-Values for different types of doors.

The type of storm door that has a wood frame with about an 80% glass area, to better display a prime door, has an insulating value similar to that of a metal storm door.

A comparison of various door arrangements and their R-Values is shown in Figure 39.

4. EFFECT ON ENERGY USE

The better insulated outside doors you have, the more energy you will save.

5. EFFECT ON COST BENEFITS

It pays to have well-insulated outside doors. In extreme climates, your money will be returned in savings on heating and cooling bills. Refer to Table IV for general recommendations.

I. What Type Heating Equipment to Use

Central heating systems are the most common method of heating in the United States. In warmer areas of the country, room or zone heaters are sufficient and more flexible. Our choice of a heating system should depend on several considerations. These include both the heating and cooling required for the climate, the type and cost of fuel available and the efficiency and maintenance characteristics of the system.

In this section, the characteristics of the most common heating systems for new construction and the effect on energy availability will be made. With the different system efficiencies to consider and increasing fuel costs, it is important that these factors be understood before new equipment is purchased since heating and cooling systems represent the largest equipment investment in most buildings.

From this section, you will be able to compare types of heating systems and select the most efficient.

1. Types of Heating Equipment.
2. Effect of Type of Energy Available.
3. Effect of Efficiency of the Unit.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF HEATING EQUIPMENT

Four main types of heating systems and three minor systems deserve our attention. They are discussed as follows:

a. Electric Resistance Systems

Electric resistance systems—either ceiling cable or baseboard type—convert electric current to heat directly and distribute it primarily by radiation. Electric resistance coils can also be used in a furnace to heat air or water for distribution by ducts or radiators.

The several types of electric resistance heating equipment available are (1) ceiling units, (2) baseboard units, (3) wall units, and (4) an electric furnace.

(1) CEILING UNITS. Electric heating cable is usually laid back and forth on the ceiling surface and covered with plaster or a second layer of gypsum board (Figure 40). There is a thermostat in each room.

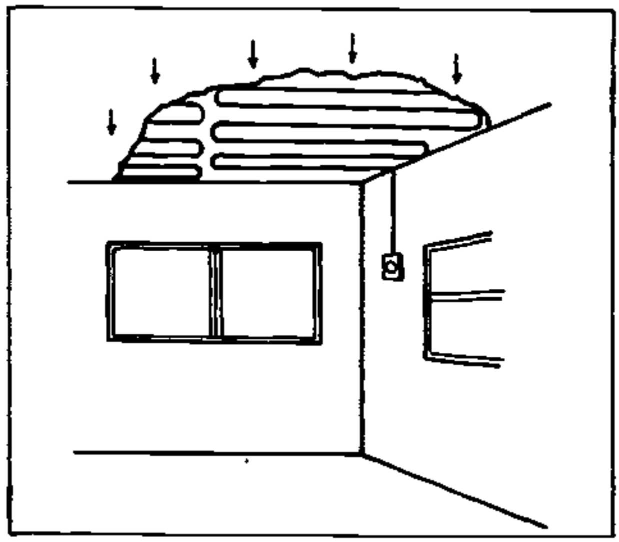


FIGURE 40. Ceiling unit using electric cable for resistance and radiant heating.

(2) BASEBOARD UNITS. Baseboard heaters take little space (Figure 41). They are convenient to install and are popular for new additions. They send out heat by natural convection or fans. Each unit has its own thermostat and requires very little maintenance.

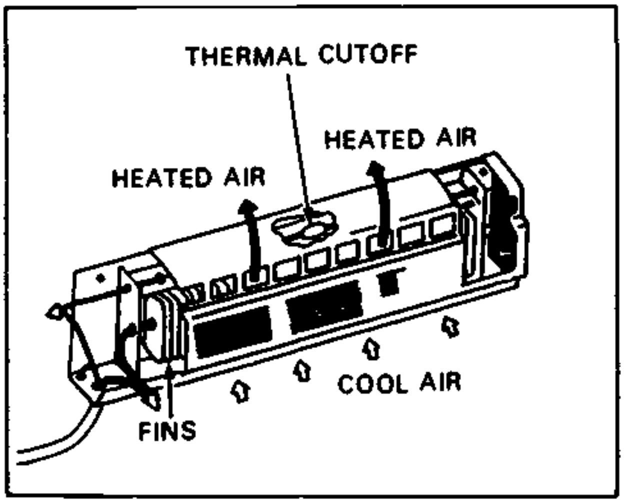


FIGURE 41. Baseboard heater.

(3) WALL UNITS. The electric wall units are designed to be recessed or surface mounted and discharge warm air into a room by means of a fan (Figure 42).

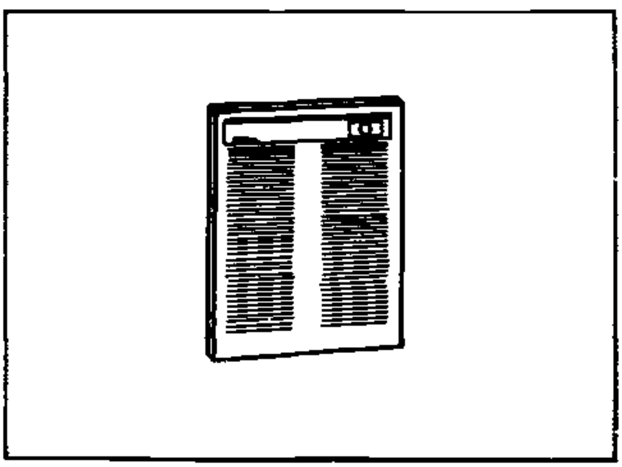


FIGURE 42. Electric wall heater.

(4) ELECTRIC FURNACE. An electric furnace is a very clean operating system since no fuel combustion takes place. Air is blown over heated resistance coils by a fan. Properly installed and insulated ducts will minimize heat loss. The operating costs are usually much higher than other available heating systems. Maintenance is simple and consists primarily of keeping it clean and changing air filters.

b. Gas Furnaces

Natural gas is the most popular source for home heating in areas where gas is available (Figure 43). Natural gas burns cleaner than fuel oil and the furnaces usually have fewer operating difficulties. Any problems typically involve the thermocouple, the pilot, or some aspect of the electrical hookup. The natural gas furnace is less costly to buy and install than an oil furnace but fuel availability and cost may not be any greater advantage than oil in most locations. Gas can provide the heat source for either forced warm air or hot water systems. A chimney flue is required.

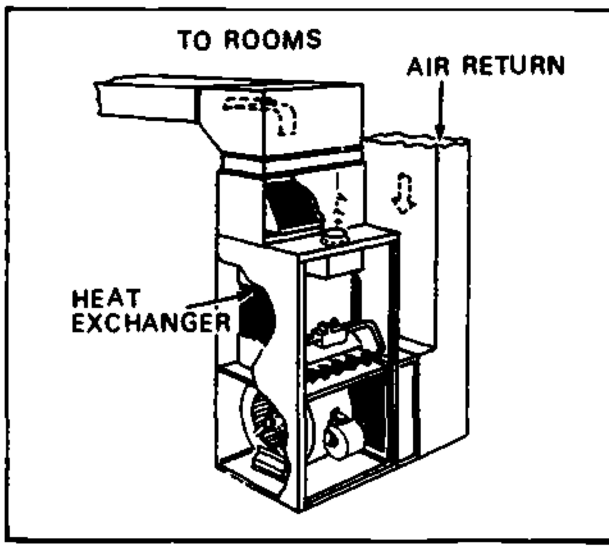


FIGURE 43. A gas-fired, air-circulating furnace.

c. Oil Furnaces

Oil-fired burners are used in many sections of the country as the basic heat source for a warm air heating system. In an oil furnace, a high-pressure spray combines with a blower to send a fine mist of oil into the combustion chamber, where the oil is ignited by an electric spark. Oil burners are generally reliable but must be maintained properly by a professional on an annual or semi-annual basis.

d. Heat Pumps

The heat pump is another form of electric heating. Recent improvements in units produced by the top manufacturers have made them as reliable as other heating systems. Improvements in newer heat pumps also allow them to be useful in colder climates as well as milder climates. However, since it is usually both a heating and cooling system, the heat pump offers few advantages over conventional heating systems in areas where air conditioning during the spring and summer months is not necessary.

Heat pump operation is based on the same principal as the common household refrigerator or air conditioner. Heat is transferred from one place or source at a fairly low temperature to another at a higher temperature. The most widely used heat pump is the so-called air-to-air unit. It absorbs heat from one source of air and discharges it into another.

The heat pump is both a heating and cooling device and would replace both the furnace and central air conditioner in a typical home.

During the heating cycle, heat is absorbed from the outside air even at temperatures as low as -9°C (15°F). This heat is pumped into the house and the inside blower pushes air across it, removing heat from the coil and heating the inside space (Figure 44).

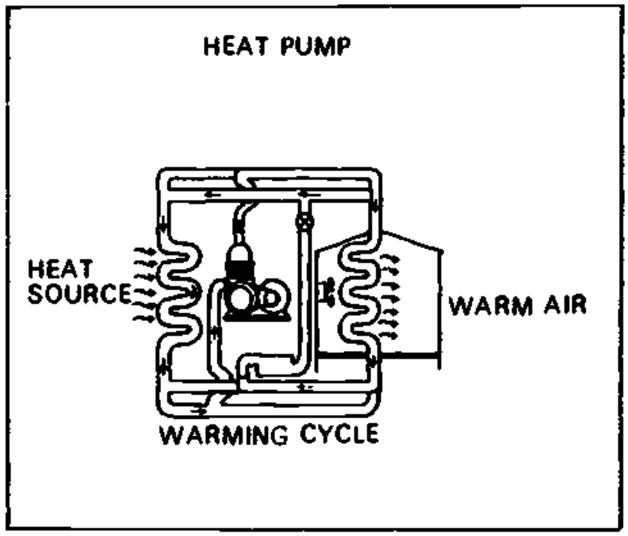


FIGURE 44. Principle of heat pump.

During the cooling cycle, when the house must be air conditioned, cold refrigerant is pumped into the inside heat exchanger coil. A fan blows air from the house across this coil and heats up the refrigerant. Because the refrigerant absorbs heat, it cools off the air.

This refrigerant is a very volatile fluid and as it absorbs heat, it evaporates into a gas inside the coil. This hot gas flows out of the house and into a compressor. The compressor, as its name implies, compresses this hot gas into a super-heated liquid. The hot liquid then flows to the outside heat exchanger coil where another fan blows air across it to remove the heat from the liquid and cool it off.

The significance of the heat pump is its high operating efficiency. For every 1000 joules (Btu) you purchase in the form of electricity to operate the heat pump, you are gaining between 2000 to 3000 joules (2 and 3 Btu) from the outside air for nothing. The heat pump is not a new concept but it is just beginning to gain popularity in parts of the country.

2. EFFECT OF TYPE OF ENERGY AVAILABLE

The major force behind any energy conservation in the home, school or business today is the increasing price of fuel and a concern over its availability in the future. Price controls on natural gas have kept its cost below other heating systems. However, natural gas is increasingly scarce and new hook-ups are not available in many areas.

Oil is also a popular form of home-heating fuel. Due to cost of getting domestic supplies and imported oil, prices are climbing steadily.

Only a few homes will be able to count on supplies of wood for all or even part of their heating requirement. It will remain a complementary heat source even with the new stoves on the market and improvements in fireplace efficiency. Coal has diminished in use but will receive greater attention again, both for central power plants and home usage.

Electricity is the most available form of energy but it is already expensive due to the fuel required for its generation, transmission losses and growing demand. Improvement in building construction and insulation will contribute to a more economical use of electricity for heating but at present other fuels are suggested.

Let us look at each major heating energy source more specifically:

a. Oil (All Petroleum-Based Distillate Fuels)

Facts about oil are as follows:

- Most common fuel in use.
- Long-term availability in question.
- Cost increasing steadily.
- Simple to transport and store.
- Thermal efficiency of 40-60 percent.
- Initial cost high due to furnace construction and storage tank.
- Maximum efficiency and safe operation depend upon continuous maintenance.
- Improper burning gives off unpleasant pollutants, sulfur-based compounds and particulate matter.

b. Gas (All Utility Gas and LPG, LNG)

Facts about gas are as follows:

- Availability decreasing.
- Costs increasing.
- Transportation and storage is complex.
- Thermal efficiency good—50-70 percent.
- Relatively simple furnace and vent construction.
- Safety precautions stringent for tank storage.
- Burns clean and produces few noxious by-products.
- Simple operation, adaptable for future use with hydrogen or methane-based system.

c. Coal

Facts about coal are as follows:

- Reserves in America offer greatest availability.
- Use will begin to increase again.
- High heat content.
- Requires substantial furnace and flue construction and a controlled supply of combustion air.
- Requires a carefully designed system and proper burning to avoid CO.

- Gives off carbon and sulfur-based pollutants, particulate matter and ash residue.

- Best for large scale heating and production of electricity.

d. Wood

Facts about wood are as follows:

- Oldest and simplest form of organic matter for burning.

- Carefully selected species have high thermal efficiency, burn cleanly, leave a little ash and produce only minor particulate matter.

- Harvesting is difficult and as expensive as oil when purchased.

- May be useful to those in specific locations where it is plentiful.

- Present fireplaces and stoves are inefficient; however, new furnaces and stoves are about 50% efficient.

- Incomplete burning of wood causes deposits of combustible material in flues and stacks if not cleaned out regularly.

- Pipes, stack, and flues must be carefully designed, built and maintained.

- Fire hazard must be of prime concern in design and location.

e. Electricity (Transmission Medium Rather Than Energy Source)

Facts about electricity are as follows:

- Sources are hydroelectric (water power), nuclear or fossil-fueled (coal, gas, petroleum) generating stations.

- Costs are modest to high, depending on locations.

- All fuel sources have serious drawbacks at present.

- Overall efficiency is low, 25-35%.

- Equipment and installation are very flexible and quite simple.

- Resistance heating coils which deliver heat require protection and care in use.

- Lack of source reliability may make electricity very expensive.

3. EFFECT OF EFFICIENCY OF THE UNIT

Researchers at Oak Ridge National Laboratory have calculated overall efficiencies for the common types of heating systems. Table VII compares heating system efficiency with overall energy efficiency.

You can see from the table just how much the efficiency of a heating system affects the total picture. Burning a petroleum-based fuel in a furnace is more efficient than using it to generate electricity. Electrical generation losses are over two-thirds of the input energy of the fuel used. Although the electric resistive heating system is usually considered to be 100% efficient in its heat conversion, its overall efficiency is about half that of natural gas. Since the consumer pays for the fuel cost of electric generation, the cost of electricity remains high despite the high efficiency of the heating system itself.

The heat pump during the heating cycle is most efficient at 7° or 10°C (45° or 50°F) but its efficiency drops as the temperature drops. At 10°C (50°F) you might have a system efficiency of 300% while at -7°C (20°F) the efficiency may be 200%. Even at this efficiency, the heat pump is cheaper to operate than typical resistance heating. Resistance heating can be used as a back-up for a heat pump when the temperature drops below -9°C (15°F).

Since electricity prices range from as little as 3¢ to 8¢ or more per kwh, operating costs are a major factor in the selection of electric systems versus gas or oil.

TABLE VII. COMPARISONS OF HEATING SYSTEM EFFICIENCIES

Heating System	System Efficiency	Overall Energy Efficiency	
Electric	100%	28.1%	
		- Fuel delivery	95%
		- Electric generation	32.5%
		- Electric transmission	91%
		- Conversion to heat	100%
Gas	60%	55.2%	
		- Delivery	92%
		- Furnace	60%
Oil	55%	50%	
		- Delivery	91%
		- Furnace	55%
Heat Pump	200%*	56% (Temperate Zones)	
		- Delivery, generation, transmission of electricity	28.1%
		- Conversion to heat	200%

*Heat pump efficiency varies with outdoor temperature.

TABLE VIII. SOME COMPARISONS OF ENERGY USES IN HOME HEATING (BILLION JOULES, MILLION BTU PER YEAR)

(OAK RIDGE NATIONAL LABORATORY)

City	Electric[a,b]				Gas[b]			
	Heat Pump		Resistance		60% Furnace Efficiency		40% Furnace Efficiency	
Atlanta, GA	57	(54.0)	119	(112.9)	65	(61.3)	97	(91.9)
Boston, MA	144	(137.0)	268	(253.9)	145	(137.8)	218	(206.7)
Cheyenne, WY	214	(203.5)	337	(319.4)	183	(173.4)	274	(260.0)
Chicago, IL	192	(182.5)	318	(300.1)	172	(162.8)	258	(244.2)
Dallas, TX	43	(40.3)	91	(86.3)	49	(46.8)	74	(70.2)
Kansas City, MO	124	(117.1)	225	(213.3)	122	(115.8)	183	(173.7)
Knoxville, TN	82	(77.5)	104	(155.0)	88	(83.8)	133	(125.7)
Minneapolis, MN	252	(239.1)	378	(357.8)	205	(194.0)	307	(291.0)
Philadelphia, PA	120	(113.7)	230	(218.4)	125	(118.5)	179	(177.8)
Phoenix, AZ	20	(19.1)	46	(43.3)	14	(23.5)	37	(35.3)
San Diego, CA	9	(8.8)	24	(22.8)	13	(12.4)	20	(18.6)
Seattle, WA	105	(99.5)	236	(223.0)	128	(121.0)	192	(181.5)
Washington. DC	98	(92.6)	195	(185.0)	106	(100.4)	159	(150.6)

[a]10,479 Btu/kWhr utility conversion efficiency.

[b]10% transmission and distribution losses (Oak Ridge National Laboratory).

4. EFFECT ON ENERGY USE

Comparisons of energy used by different sources are given in Tables VIII and IX.

5. EFFECT ON COST BENEFITS

Comparisons of costs for home heating with different methods is given in Table X.

TABLE IX. RELATIVE ENERGY USE IN HOME HEATING BY DIFFERENT METHODS (NBS)

City	Heat Pump (kWhr)	Resistance Heating (kWhr)	Natural Gas[a]		Fuel Oil[b]	
			m^3	(10^3 ft^3)	L	(gal)
Atlanta, GA	4,640	9,700	1,543	55.1	1,605	424
Boston, MA	11,770	21,810	3,472	124.0	3,607	953
Cheyenne, WY	17,480	27,430	4,368	156.0	4,538	1,199
Chicago, IL	15,670	25,770	4,102	146.5	4,262	1,126
Dallas, TX	3,460	7,410	1,179	42.1	1,226	324
Kansas City, MO	10,050	18,320	2,918	104.2	3,028	800
Knoxville, TN	6,660	13,310	2,120	75.7	2,199	581
Minneapolis, MN	20,530	30,730	4,889	174.6	5,079	1,342
Philadelphia, PA	9,760	18,760	2,988	106.7	3,104	820
Phoenix, AZ	1,640	3,720	594	21.2	617	163
San Diego, CA	760	1,960	314	11.2	326	86
Seattle, WA	8,550	19,150	3,049	108.9	3,168	837
Washington, DC	7,960	15,890	2,528	90.3	2,627	694

[a] 37 MJ/m^3 (1000 Btu/ft^3)
[b] 38 MJ/L (138,000 Btu/gal)

TABLE X. ENERGY COST FOR HOME HEATING[a] ($/YEAR)

City	Heat Pump	Resistance	Gas[b]	Oil[c]
Atlanta	71.73	139.87	61.25	127.10
Boston	381.12	703.57	284.64	285.85
Cheyenne	288.49	452.73	91.98	359.54
Chicago	240.71	395.84	196.00	337.75
Dallas	36.69	79.17	35.18	97.07
Kansas City	100.53	183.21	75.58	240.13
Knoxville	78.39	156.61	86.68	174.38
Minneapolis	340.17	510.53	218.02	402.51
Philadelphia	231.76	378.23	183.58	245.84
Phoenix	23.46	53.04	24.41	48.77
San Diego	18.28	47.19	14.05	25.71
Seattle	61.57	155.55	158.76	251.02
Washington	189.86	361.31	136.06	208.23

[a]Incremental cost over and above basic electric bill and cost of water heating.

[b]60% system efficiency.

[c]55% system efficiency (Oak Ridge National Laboratory).

J. What Type of Air Conditioning Equipment to Use if Needed

With the high heat and humidity that may be experienced in many parts of the United States in the summer, air cooling or conditioning has become as important as winter heating to many people.

Even though the emphasis should be on conservation, it would be impossible to eliminate the use of air conditioning in many areas. Many locations require cooling to provide comfortable working conditions. At home, cooling of hot-humid air enables people to sleep better and it can mean reduced stress on persons with heart ailments and other medical problems. Air conditioning is often used to prevent deterioration of some clothing, various leathergoods and tools. Research laboratories and various manufacturing processes require air conditioning. The emphasis then is on how to use an air conditioner more efficiently.

From this section, you will be able to list the factors needed in selecting air conditioning equipment. The following topics are included here:

1. Types of Air Conditioning Equipment.
2. Effect of Climate.
3. Effect of Efficiency of the Unit.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF AIR CONDITIONING EQUIPMENT

The typical air conditioning system is composed of four separate devices which make up the complete unit. A gas called a refrigerant is compressed in the compressor. Acting like a giant tire pump, the compressor causes the gas to leave under high pressure and at a fairly high temperature. This hot gas is then cooled in a heat-transfer device called a condenser, which looks like an automobile radiator. As it cools in the condenser, the refrigerant gas changes to a liquid while still at high pressure. The liquid then passes to an expansion valve, which permits the liquid to expand into an evaporator or cooling coil. The expansion process cools the coil and it can now pick up heat from air that is moved across it. In doing so, the refrigerant gas is warmed and then recycled in the compressor. The entire refrigerant is tightly sealed. The usual residential cooling unit has the compressor and condenser located outdoors and the expansion valve and evaporator indoors. Figure 45 shows the air conditioner components.

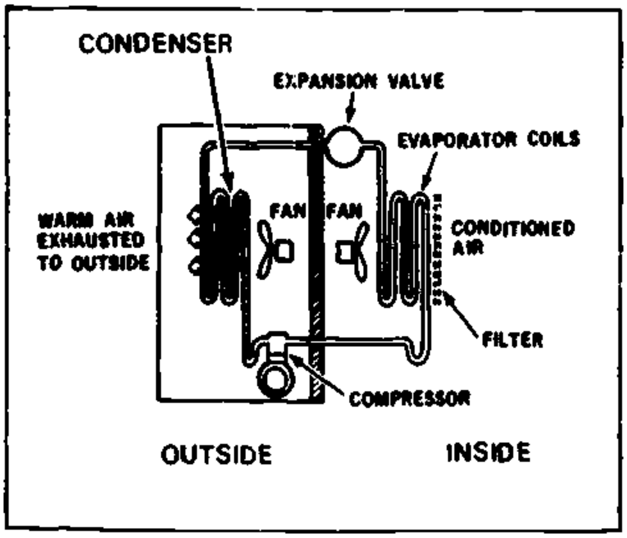


FIGURE 45. How a typical air conditioner operates.

Air conditioners can be installed as part of a central heating system, a separate central conditioning unit or as individual room units. They are discussed as follows:

a. Forced-Air Furnace System

A forced-air furnace system used for both winter heating and summer cooling will have the evaporator located above the furnace casing (Figure 46). As the furnace blower moves warm-room air over the coil, it is cooled and moisture condenses out on the coil. The cooled air then returns throughout the house through the same ducts and registers used to deliver heat. When a heating system is planned to accept a cooling system as well, the blower and ducts need to be larger to accommodate the greater air flow requirement of summer cooling as opposed to winter heating. The delivery of heat to a room is usually through registers located at or near the floor since heat rises. In a combined heating/cooling system, the registers may need to be farther up the walls if cooling is a major concern since cool air settles.

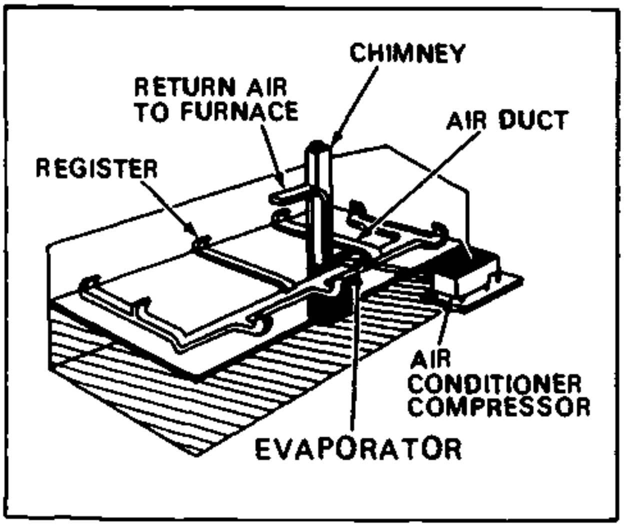


FIGURE 46. Forced-air furnace and air conditioning system combination.

b. Separate Air Distribution System

A separate air distribution system needs to be installed for cooling when hot water or steam heating is used. Often an attic will provide the necessary space for the system and the duct work which can connect to ceiling registers. In this case, a drain line for the moisture condensation from the evaporator leading to the outside is necessary to avoid moisture damage to the ceiling. Heavily insulated duct work and an adequate attic ventilation system are also required for maximum efficiency.

c. Individual Room Units

Air conditioners for individual rooms contain all four parts of the compressor-condenser system in a fairly small package which is installed either in a window or through a wall section (Figure 47). Since these units are in the room they are noisier than central units. They have the advantage of providing cooling when only limited area cooling is required, such as a bedroom for sleeping comfort. People who rent apartments find them convenient when the building as a whole is not cooled.

Check the efficiency rating of your unit. There is a wide variation in operating efficiencies of units.

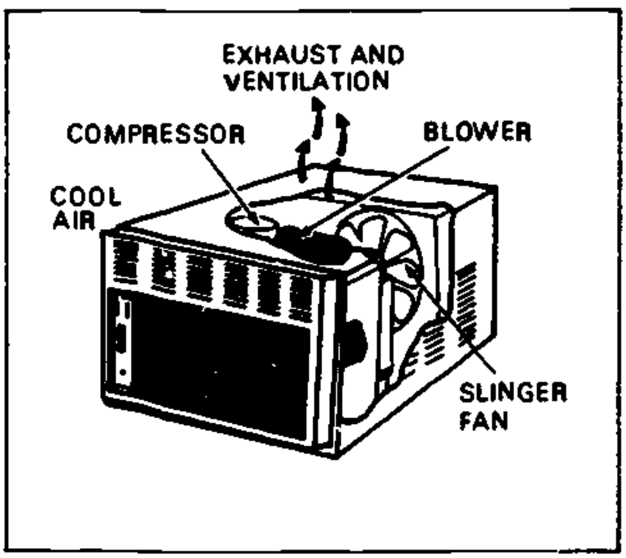


FIGURE 47. Individual room air conditioners.

d. Heat Pumps

Heat pumps, as we indicated, can provide both a winter heating system and a summer cooling system (Figure 48). The operation of the heat pump is like a reversible refrigeration cycle and was illustrated and discussed in Part 1 of the heating section. The initial cost of a heat pump is higher than a conventional heating system but is comparable to a heating system plus central air conditioning.

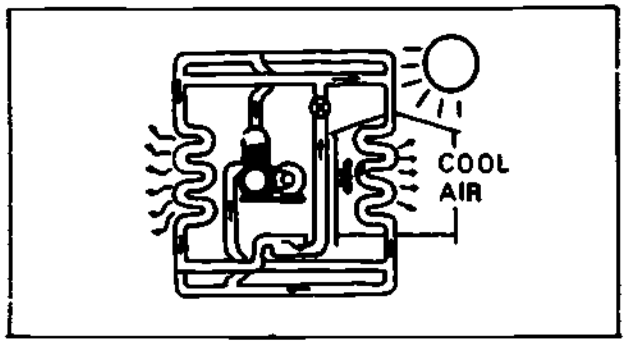


FIGURE 48. Heat pump cooling cycles.

2. EFFECT OF CLIMATE

Variations in climate cause the temperature fluctuations which require heating and cooling by artificial means to create comfortable living and working environments. However, in some regions cooling to some degree can be accomplished without elaborate equipment.

One method of cooling which can be effectively used in hot-dry desert areas takes advantage of the fact that when water is evaporated, heat is removed from the air. A simple evaporative cooling unit housing a continually moistened pad or filter and a fan will draw the dry air through the pad, cool and humidify it. It is possible to cool 32°C (90°F) air at 10 percent relative humidity to a comfortable 21°-27°C (70°-80°F) and provide a relative humidity of about 40 percent. Remember, this works well in dry areas such as the southwest and is not for humid areas. The purpose of air conditioning is not limited to cooling air but involves controlling humidity and even cleaning or filtering it to some extent.

On a national basis, we use about eleven times more energy for heating than for air conditioning. However, on a regional basis many parts of the country must rely on air conditioning to a much larger degree while others consider doing without it. Climate determines the type and amount of air conditioning required or desired. Some examples are given by region.

The effect of climate on air conditioning is discussed as follows:

a. Cold Climates

In cold climates an air conditioning system would not be required except for 2 to 4 weeks of very warm summer weather. A central air conditioner would be effective but usually not necessary. Reliance on good room units to allow comfortable sleeping may be sufficient. Also, a good attic fan and open lower floor windows can move the -7° to -10°C (20° to 30°F) cooler night air into the house in the evening (Fiugre 49). They may be thermostatically controlled. A well insulated, closed and shaded house will retain the cooler air for much of the next day. Heat pumps are seldom used in cold climates where cooling requirements are low due to the higher cost of the units.

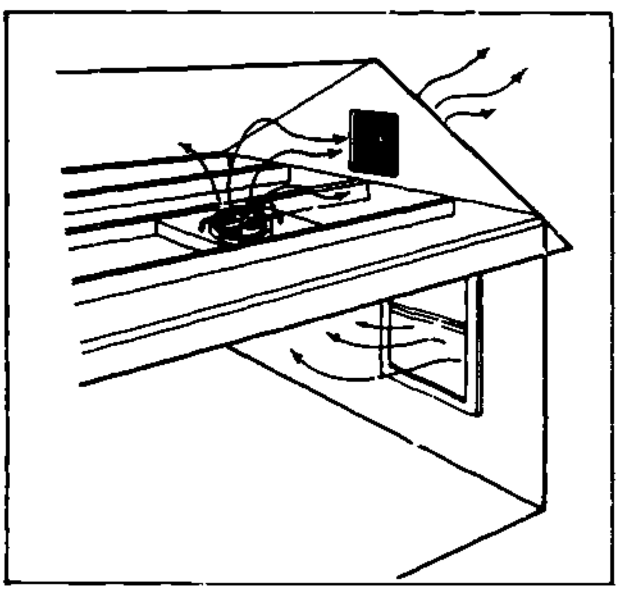


FIGURE 49. Attic [illegible] effective for cooling in [illegible].

b. Temperate Climates

In temperate climates, longer warm or hot periods may warrant a central air conditioning system. However, some of the methods suggested above will work well for buildings protected from direct solar exposure. Heat pumps can be economical because of their more continued use for either heating or cooling and where the average temperature is in the -1°C (30°F) range or higher.

c. Hot-Arid Climates

Hot-arid climates generally require several months of air conditioning along with humidity control. Central air conditioning systems are common as well as the use of individual room units in offices and apartments. Heat pumps are more efficient at these higher temperatures and useful because space heating is still needed for parts of each day over several months.

d. Hot-Humid Climates

Hot-humid climates also require fairly constant air conditioning for several months. Moisture must be removed from living and working spaces. Again, heat pumps will provide efficient heating and cooling in these areas.

3. EFFECT OF EFFICIENCY OF THE UNIT

Cooling equipment capacity, just like heating systems, is expressed in terms of Btu per hour. In air conditioning or refrigeration 12,000 Btu/hr is equivalent to a 908 kg (1 ton) cooling capacity. This means that a unit with a 12,000 Btu rating has the cooling effect of 908 kg (1 ton) of ice melting. Tonnage ratings are not too useful but simple specification conversion is possible. Also, horsepower ratings are not useful because units with the same horsepower can have very different cooling capacity.

A Btu rating is most meaningful since it refers to the amount of heat a given system can remove in a one hour period. Room units range in capacity from about 5,000 Btu/hr to 35,000 Btu/hr with the 12,000 Btu/hr size being most common. Central cooling systems range from 12,000 Btu/hr and up with the common residential size around a 30,000 Btu/hr capacity.

Usually it takes about 18 Btu/hr to cool one square foot. Since an 18,000-Btu unit can cool about 93 m^2 (1,000 ft^2) of space, a room unit will usually be smaller and most central systems will be larger.

After determining an approximate size, the important consideration is efficiency. Air conditioners vary considerably in efficiency. The efficiency rating of a unit is called its EER or Energy Efficiency Ratio. To find the EER of any unit, divide its cooling capacity Btu rating by its electrical input wattage:

$$\frac{\text{Btu Rating}}{\text{Wattage}} = \text{Energy Efficiency Ratio (EER)}$$

The higher the EER, the more efficient the equipment. You are saving money when you use less power (wattage) to accomplish a given cooling effect. For example, a 12,000 Btu air conditioner which uses 2,000 watts would have an EER of 6.0 while another 12,000 Btu air conditioner which uses 1,200 watts will have an EER of 10.0. Efficiency of air conditioners can range from less than 5.0 to over 12.0 Btu of cooling per-watt-hour of electricity consumed (Btu/watt-hr). The total kilowatt hours you would pay for over a cooling season could add up to quite a difference between air conditioners with the same Btu ratings. You should not purchase an air conditioner with less than 8 EER.

Installation and operating tips for maintaining efficient service from air conditioning equipment are included in the sections to follow.

4. EFFECT ON ENERGY USE

In the residential sector, air conditioning ranks third as a major energy-consuming function, behind space heating and water heating. In the commercial sector, air conditioning is second only to space heating. The average annual growth rate for residential air conditioning (primarily room units) is about 15 to 20% while commercial increases are in the 10 to 12% range. Air conditioning contributes heavily to the annual peak load that occurs in the summertime for many utility systems.

The use of optimum amounts of insulation in homes can reduce both the space heating requirements and the energy used for air conditioning. Reductions in electricity consumption for air conditioning in gas heated homes may be as high as 25% and in the all-electric homes as much as 18% when compared with houses insulated to FHA Minimum Property Standards.

5. EFFECT ON COST BENEFITS

Cost is proportional to energy use.

K. What Type of Ventilation to Use

Ventilation is the movement or exchange of fresh air to achieve proper temperature and comfort levels. Ventilation for specific living spaces is necessary for the removal of odors and stale air. Ventilation of an attic or other areas of a building is also necessary to avoid moisture or heat build-up which can result in structural damage and increased energy costs.

To help you gain an understanding of the importance of ventilation and the selection of ventilation systems, the following topics will be included:

1. Types of Ventilation.
2. Effect of Climate.
3. Effect of Efficiency.
4. Effect on Energy Use.
5. Effect on Cost Benefits.

1. TYPES OF VENTILATION

The two basic types of ventilation systems are natural or static ventilation and power ventilation. Window openings are a common method of using natural wind pressure and thermal effect to move fresh air into buildings and hot or stale air out. Static ventilation systems are a common way to provide air changes in attics. Power ventilators which operate electrically are often necessary in conjunction with static systems to achieve the desired results.

They are discussed as follows:

a. Attic Ventilation

Attic ventilation is by static or powered ventilation systems. They are as follows:

(1) STATIC ATTIC VENTILATORS. Static ventilators for attics usually consist of openings with grills, screens or louvered slats which allow air to flow into an attic under the eaves and out of the roof or gable-ends. The factors to consider when selecting ventilators for attic areas are as follows:

- The ratio of vent area to floor area.
- The placement of vents to fully utilize the wind pressure and the thermal effect of the building location.
- The placement of vents so elements of weather cannot penetrate the attic.

The suggested ratio of vent area to floor area is about 1 m^2 (1 ft^2) of net free venting to 150-250 m^2 (150-250 ft^2) of floor area. This ratio should increase as cooling degree days increase (Table XI).

TABLE XI. VENT AREA IN SQUARE INCHES REQUIRED FOR ATTIC FLOOR MEASUREMENTS

Length (ft)	Width (ft) 20	30	40	50
20	192	288	384	480
30	288	432	605	720
40	384	576	805	960
50	480	720	1008	1200
60	576	864	1210	1440
70	672	1008	1411	1580

When placing vents, wind pressure is a most important factor. Wind pressure against one side of a building or roof creates negative pressure areas on the other sides in patterns that draw air out of the building (Figure 50).

No one type of vent will work well alone for the various problems of natural ventilation. They are:

- Wind pressure.
- Thermal effect.
- Radiation heat.
- Wind direction.
- Weather conditions.

Combinations of vents provide for more complete air flow in attic spaces. Some combinations are better than others.

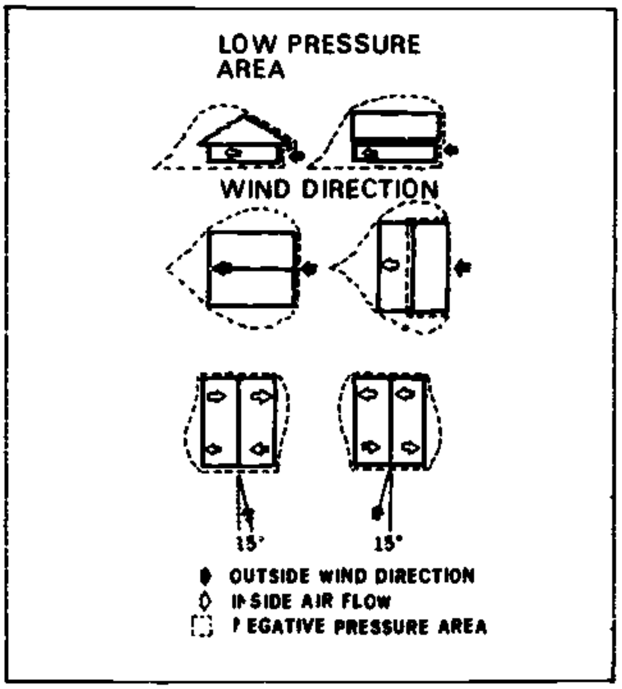


FIGURE 50. Wind creates low pressure areas around buildings that cause air flow.

The thermal effect of hot air rising suggests that high vents allow overheated air to escape while low vents provide cooler replacement air. To allow the net free area to be effective regardless of wind direction, vents are placed as "continuously" as possible.

The various types of static attic vents and useful combinations are described as follows:

(a) Roof Louvers (Figure 51). Usually several of these dome units are mounted near the ridge of the roof. They are made from aluminum, plastic, steel or wood. Aluminum is the least expensive. Screens or slits are used to keep out insects.

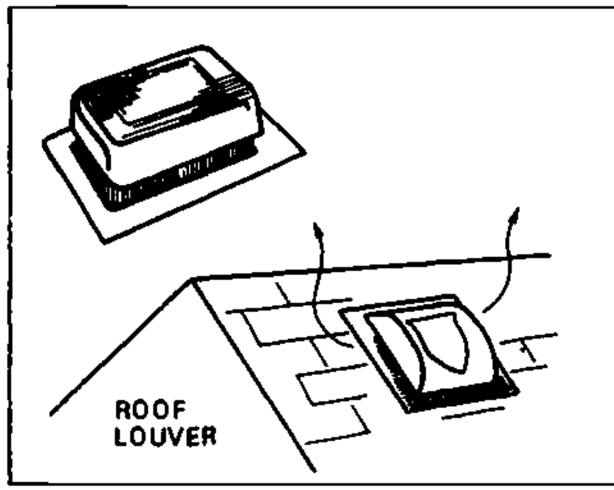


FIGURE 51. Roof louver for static attic ventilation.

(b) Turbine Wheel (Figure 52). This roof louver turns with the wind to more effectively remove attic air. Turbines are not frequently chosen due to the possibility of weather penetration.

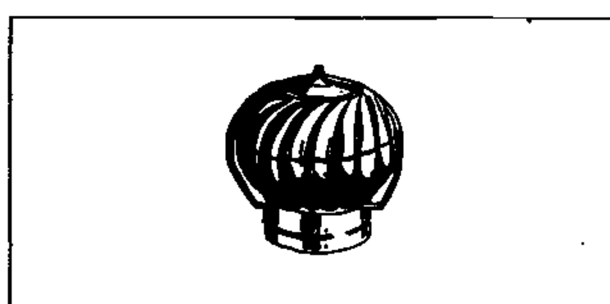


FIGURE 52. Turbine wheel for static attic ventilation.

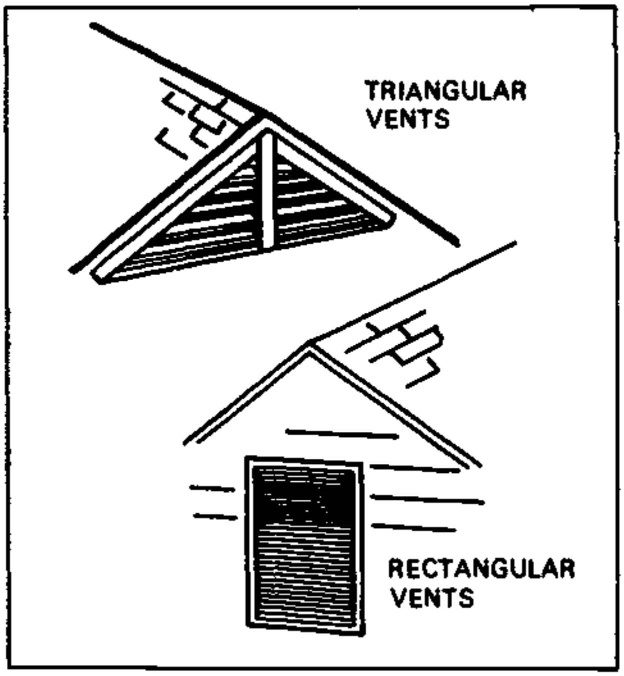


FIGURE 53. Gable-end louver for static attic ventilation.

(c) Gable-End Louvers (Figure 53). Available either in triangular or retangular shapes, they are mounted in or near the top point of the end gables. Air flow varies with the direction of the wind and when used alone they are only somewhat effective. Weather penetration can be a problem if severe. The illustrations show the shapes, placement and wind effects.

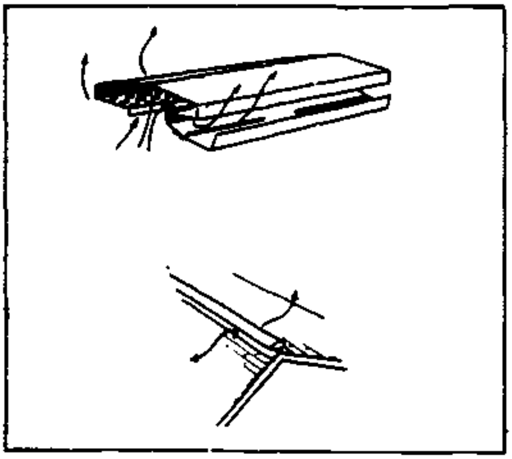


FIGURE 54. Ridge vents for static attic ventilation.

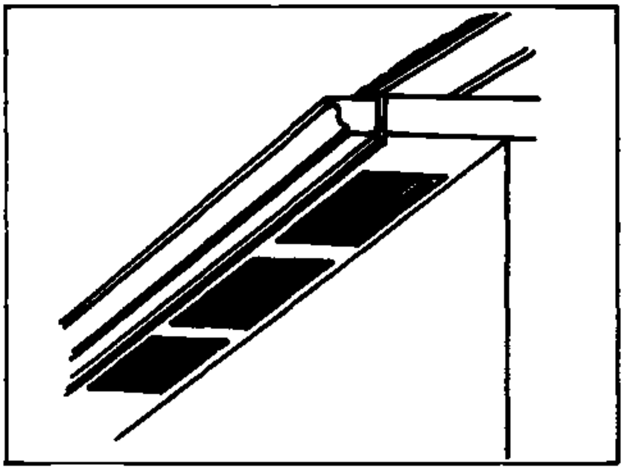


FIGURE 55. Soffit vents for static attic ventilation.

(d) Ridge Vents (Figure 54). This is a continuous opening along the full length of the roof ridge. Net free area is figured at 381 cm^2 (18 in^2) per lineal foot. In conjunction with vents under the eaves, it provides uniform continuous air flow under the roof surfaces.

(e) Soffit Vents (Figure 55). These vents offer effective air circulation no matter what the direction of the wind. They provide only partial ventilation unless combined with roof louvers or ridge vents.

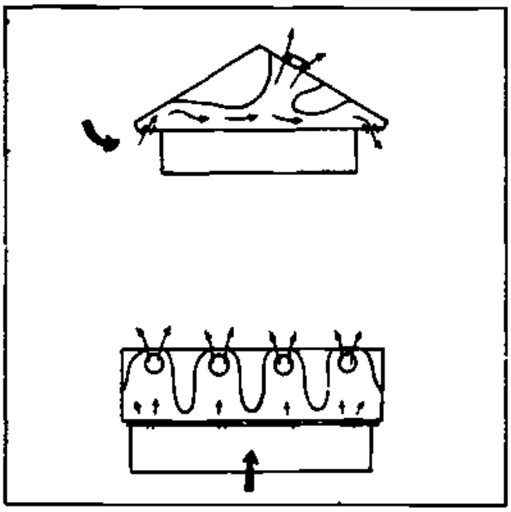


FIGURE 56. Air flow pattern with roof louvers and soffit vents.

(f) Roof Louvers and Soffit Vents (Figure 56). You will need to balance the air flow with a roof louver and soffit vent system.

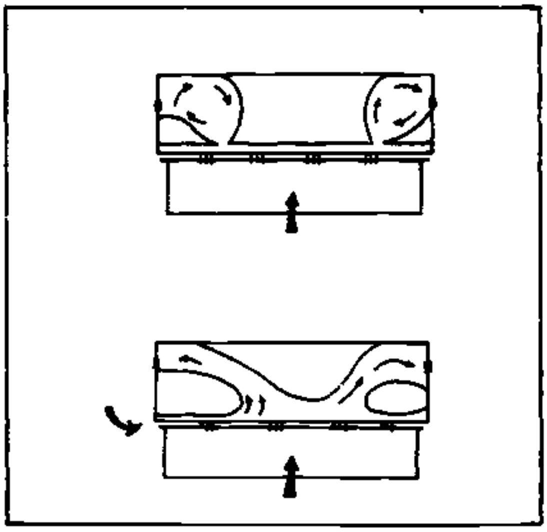


FIGURE 57. Good air flow patterns with gable-end louvers and soffit vents.

(g) Gable-End Louvers with Soffit Vents (Figure 57). Gable-end louver and soffit-vent system does not alter air flow patterns of each unit.

(h) Ridge Vents and Soffit Vents (Figure 58). The continuous ridge and soffit vent combination provides the most efficient system, making the most of the thermal effect, wind pressure and direction.

Given the attic floor measurement, Table XI will help you to estimate the net free-vent area in square inches required. A ratio of 1 to 150 is considered good; a ratio of 1 to 300 is considered an absolute minimum.

(2) POWER ATTIC VENTILATORS. Power ventilators run on electricity and provide effective ventilation with fewer venting holes. Often they are used when no natural ventilating system has been installed. A power ventilator can be controlled by a thermostat or a humidistat to shut off when the temperature is reduced to a desired level. The combination of static vents under the eaves with power vents on the rear slope of the roof near the top (or in the gable ends) can provide a very effective ventilation system.

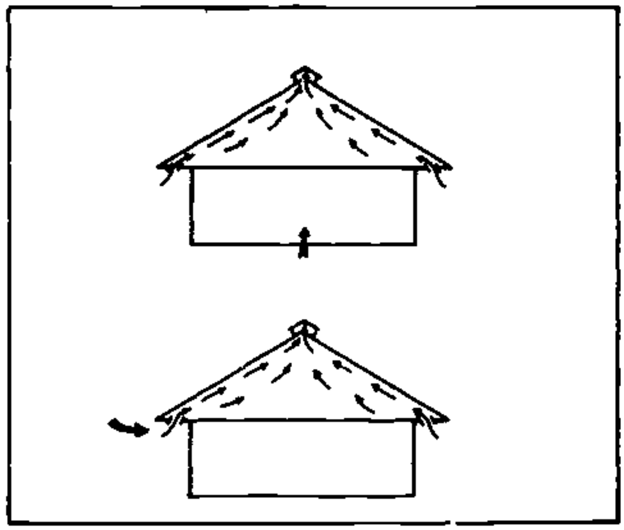


FIGURE 58. Air flow pattern with continuous ridge vents and soffit vents.

An estimate of the power vents is based on achieving at least 10 complete air changes per hour. Table XII can be used to determine the required CFM (cubic feet per minute) rating of a power ventilator for a given attic. Home Ventilating Institute (HVI) standards recommend a minimum of 0.21 m^3/min per m^2 (0.7 CFM per ft^2) of attic floor space, plus 15% for dark roofs.

TABLE XII. RECOMMENDED RATING OF A POWER VENTILATOR FOR ATTIC DIMENSIONS

Length (ft)	Width (ft) 20	30	40	50
20	280	420	550	700
30	420	630	840	1050
40	560	840	1120	1400
50	700	1050	1400	1750
60	840	1250	1560	2100
70	980	1470	1950	2450

b. Other Ventilators

Other areas of a house besides the attic require ventilation. Basement crawl spaces underneath floors can be a major source of moisture. Ventilators should be installed in the foundation of masonry. Basementless crawl spaces should have net free area of 1/150 of the ground area except when the ground surface is covered with a vapor barrier. If a vapor barrier is used, the ratio can be reduced to 1/1500. The same previous FHA chart can be used to determine the net free area requirement.

Another source of moisture comes from inside a home or building. Often moisture which works its way into and through walls causes blisters and peeling of exterior paint. Paint breather vents or miniature circular louvered vents are used to correct this problem. This method for allowing the walls to "breathe" can also help insulation retain its insulating value and preserve the wall elements from deterioration.

In the laundry, a dryer vent to the outside and perhaps the use of an exhaust fan near the washer will remove excess humidity. Kitchen ventilation systems use either an over-the-stove hood unit or wall-mounted fan to remove odors and moisture from the area.

2. EFFECT OF CLIMATE

There are two basic climatic conditions that exist in every home, summer heat and winter moisture. Ventilation offers an effective means of correcting the problems caused by these two conditions. They are discussed as follows:

a. Summer Heat

Summer heat often builds up in attic spaces to 57°C (135°F), or even 66°C (150°F), when the sun beats down on the roof (Figure 59). This superheated air soon penetrates even insulated ceilings into the living area below. Proper ventilation will greatly increase comfort and substantially reduce air conditioning costs.

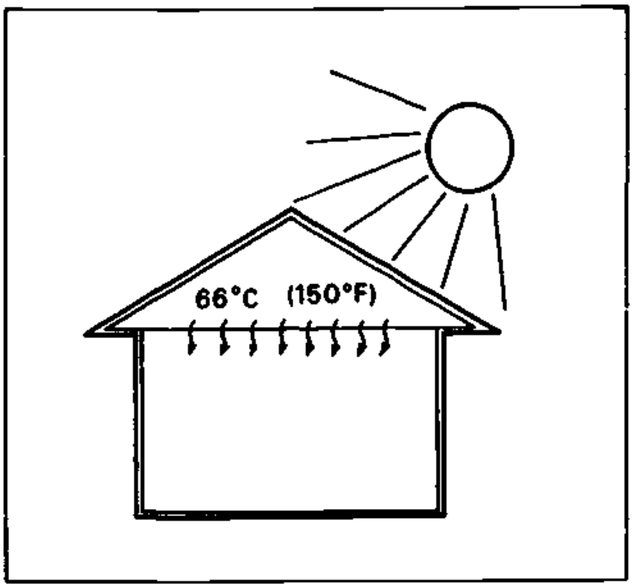


FIGURE 59. Summer heat builds up rapidly in an unvented attic.

b. Winter Moisture

Winter moisture is caused by the use of various household appliances, such as dishwashers, dryers and humidifiers. Daily use of the shower and tub, and cooking vapors all contribute to excessive moisture within your home. When moisture-laden air from the living area rises to the attic, problems will result. This condensed moisture can soak insulation, impairing its efficiency. It can stain or crumble ceilings, and blister exterior paint. Frozen and thawed, it can damage roof shingles. The most effective way to remove excess winter moisture is by proper ventilation.

3. EFFECT OF EFFICIENCY

Watch the EER ratings on your power ventilation. There is a vast difference in electric motor and fan efficiencies.

4. EFFECT ON ENERGY USE

Energy used in a well designed ventilation system is efficient.

5. EFFECT ON COST BENEFITS

The cost of installing and operating a well designed and efficient ventilating system carries a quick return.

L. What Type of Lighting to Use

Home lighting consumes 3% to 5% of the electricity used by a family. Excessive lighting or ineffective lighting is not difficult to spot. Lighting can be reduced and still provide visual comfort as well as save energy. The energy saving may seem small, however; lighting produces much more heat than light and can contribute to higher cooling costs when cooling systems are in operation.

The first factor in selecting a lighting system is effectiveness. Efficiency is next. From this section, you will be able to compare lighting methods and select the most efficient ones. They are discussed under the following headings:

1. Types of Lighting.
2. Effect on Energy Use.
3. Effect on Cost Benefits.

1. TYPES OF LIGHTING

There are two types of lights, natural and artificial. They are discussed as follows:

a. Natural Lighting

There are also two types of natural lighting which can be used to improve our visual comfort in a home or business. These are windows and skylights.

(1) WINDOWS, properly placed in close relationship to task areas and with careful consideration of heat loss and gain, will reduce artificial lighting needs.

(2) SKYLIGHTS, or "windows to the sky," often can provide natural light where windows in walls are not possible. These can provide ventilation and moisture removal as well as view.

b. Artificial Lighting

There are three types of artificial lighting. They are incandescent bulbs, fluorescent tubes and high intensity discharge (HID) bulbs.

They are discussed as follows:

(1) INCANDESCENT BULBS have been on the . arket for over 80 years. They now come in inside-frost, inside-white and clear. There are many shapes and sizes available. They are the most popular for home use but also the most expensive to operate. The use of three-way bulbs and dimmer switches can contribute a savings.

(2) FLUORESCENT TUBES will provide four times as much light as incandescent bulbs of the same wattage. Therefore, a 25-watt fluorescent light is equal in light value to a 100-watt incandescent bulb. Cooler operation is another advantage of fluorescent tubes over incandescent bulbs. They come in straight .30 to 1.2 m (1 to 4 ft) tubes, circular tubes or U-shaped tubes. Life expectancy is often 10 to 20 times that of the incandescent bulb (Figure 60).

The quality of light from fluorescent lighting has been peculiar in its effect on the appearance and color of objects and people. New color-corrected tones of white will help this problem. Until now, it was not possible to switch bulbs from one type to another without changing the whole fixture. A new fluorescent light is available which fits incandescent fixtures.

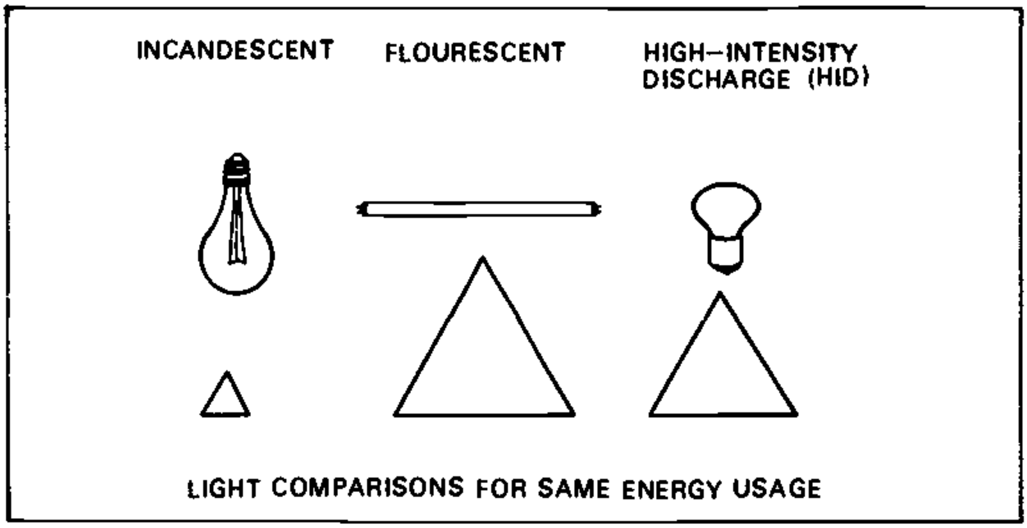


FIGURE 60. Incandescent bulbs are least efficient of the lighting sources.

(3) HIGH INTENSITY DISCHARGE (HID) BULBS are used to direct high intensity light on a small area. The HID bulb provides two to five times the light of an incandescent bulb of the same wattage and can last from 10 to 30 times longer. They come in colors and tones similar to incandescent bulbs. To date, they are more often used in buildings other than homes. Table XIII indicates the recommended amount of light in lumens for several specific visual tasks.

2. EFFECT ON ENERGY USE

An automatic reduction in bulb wattage or replacement of larger wattage bulbs with a number of smaller wattage bulbs is not the answer to energy conservation in lighting.

Bulb brightness is measured in lumens. Larger wattage bulbs are generally more efficient and produce more lumens per watt of power than smaller bulbs. Effectiveness of lighting, or the ability of the lighting system to help us see better, is not the most important criterion for a lighting system.

Excessive lighting means more light than is required for a particular task. Selecting the right amount of light for each task area will eliminate excess and save energy.

A comparison of energy consumption, bulb life and available light for incandescent bulbs and fluorescent tubes is given in Table XIV.

3. EFFECT ON COST BENEFITS

The benefits of purchasing one type or size of bulb over the other is illustrated in Table XV where standard incandescent bulbs are compared with long-life incandescent bulbs on the factors of size in watts, lumens of light and bulb life.

Long-life bulbs furnish only about 80 percent of the light of standard bulbs. The trade-off is between amount of light and bulb-life. Longer lasting bulbs are usually placed in hard-to-get-at places such as in stairwells.

TABLE XIII. LIGHT RECOMMENDED FOR SPECIFIC TASKS (ANSI, Standard for Industrial Lighting, A11.1-1965 [R 1970)]

Specific Visual Tank	Lumens
Reading and writing, handwriting, indistinct print, or poor copies	70
Books, magazines, newspapers	30
Music scores, advanced	70
Music scores, simple	30
Studying at desk	70
Recreation:	
Playing cards, billiards	30
Table tennis	20
Grooming: Shaving, combing hair, applying makeup	50
Kitchen work:	
At sink	70
At range	50
At work counters	50
Laundering jobs:	
At washer	50
At ironing board	50
At ironer	50
Sewing:	
Dark fabrics (fine detail, low contrast)	200
Prolonged periods (light to medium fabrics)	100
Occasional (light-colored fabrics)	50
Occasional (coarse thread, large stitched, high contrast of thread to fabric)	30
Handicraft:	
Close work (reading diagrams and blueprints, fine finishing)	100
Cabinet making, planing, sanding, glueing	50
Measuring, sawing, assembling, repairing	50
Any area involving a visual task	30
For safety in passage areas	10
Areas used mostly for relaxation, recreation and conversation	10

TABLE XIV. ENERGY COMPARISON FOR INCANDESCENT BULBS AND FLUORESCENT TUBES

	Incandescent Bulb	Deluxe Fluorescent Tube	Fluorescent Advantages
Watts	75	30 (44 total input watts)	31-watt (or 41 percent) energy savings
Bulb life	750 hrs.	15,000 hours	Lasts 14,240 hours more (or 20 times longer)
Light emitted	1180 lumens	1530 lumens	350 more lumens, or 30 percent more light

TABLE XV. LUMEN OUTPUTS OF STANDARD AND LONG-LIFE INCANDESCENT BULBS

	Watts	Lumens	Bulb Life (hrs)	Lumens/ Watts
Standard bulbs	100	1740	750	17.4
	75	1180	750	15.7
Long-life bulbs	100	1690	1150	16.9
	100	1490	2500	14.9
	100	1470	3000	14.7
	92	1490	2500	16.2
	90	1290	3500	14.3

M. What Type of Water Heater to Use

In most homes, water heaters are second only to heating systems in energy consumption. Hot water consumption for a family of four is about 28 L (75 gallons) per day, requiring 68 L (180 gallons) of oil or 6,000 kwh of electricity to do the heating per year. The cost for water heating would be about $100 per year for oil or gas and over $200 per year for electricity.

A water heater consists of a source of heat, a storage tank and a thermostat control. The most common types are electric, gas and oil. Hot water may also be supplied by a coil in a hot water furnace or partially through solar thermal collectors which are entering the market.

There is little difference in the purchase price between water heater units. From your study of this section, you will be able to discuss the following factors and to select the most efficient system. When purchasing and installing a new water heater, the following factors should be considered:

1. Sizes of Water Heaters.
2. Types of Water Heaters.
3. Water Temperature Requirements.
4. Compatibility with Alternate Systems.
5. Effect on Cost Benefits.

1. SIZES OF WATER HEATERS

Table XVI is helpful in selecting the size of water heater for a family.

TABLE XVI. SUGGESTED WATER HEATER SIZING GUIDE (GALLON STORAGE CAPACITY)

House Specification	No. in Family					
	1	2	3	4	5	6
One Bath	40	40	40	40	50	50
One bath with dishwasher	40	40	40	40	50	50
One bath with clothes washer	40	40	40	40	50	50
One bath with clothes washer & dishwasher	40	40	40	40	50	50
Two Baths	40	40	40	40	50	50
Two baths with dishwasher	40	40	40	40	50	50
Two baths with clothes washer	40	40	40	40	50	50
Two baths with clothes washer & dishwasher	40	40	50	50	50	60
Three Baths	40	40	40	40	50	50
Three baths with dishwasher	40	40	40	40	50	50
Three baths with clothes washer	40	40	50	50	50	60
Three baths with clothes washer & dishwasher	40	40	50	60	60	80
clothes washer & dishwasher	40	40	50	60	60	80

2. TYPES OF WATER HEATERS

Select a water heater for which you have good information on its construction, installation, use and maintenance (Figure 61). Quality insulation and ease of temperature control are two main items to check before buying. Obtain a guarantee and a service contract when possible.

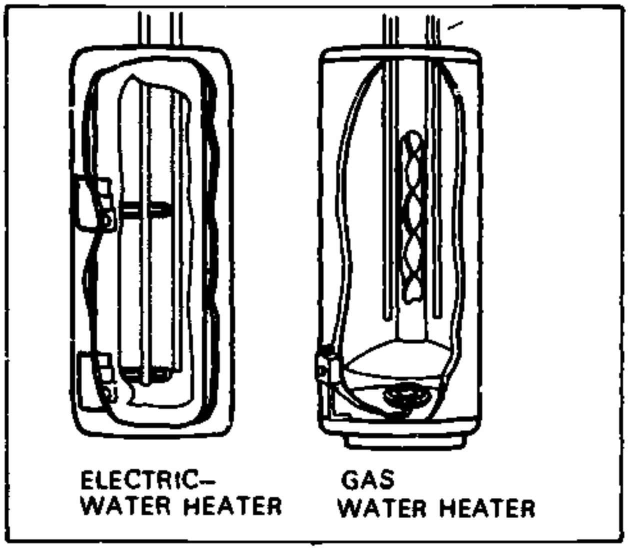


FIGURE 61. Typical water heater construction.

3. WATER TEMPERATURE REQUIREMENTS

The higher temperature setting is usually in the 76°-82°C (168°-180°F) range and is not necessary for most household tasks. A middle range of 60°-71°C (140°-160°F) is even too hot for all but perhaps dishwashing. A lower 49°-60°C (120°-140°F) setting is satisfactory for most situations, but will even need tempering with cold water to be comfortable for baths and showers. The addition of a small hot water heater near a dishwasher may be the solution to obtaining a higher temperature 66°C (150°F) for a small task.

4. COMPATIBILITY WITH ALTERNATE SYSTEMS

Solar thermal systems and gas systems using methane or hydrogen as alternatives to traditional hookups are coming on the market. These may have some influence on your choice of a new water heating system.

5. EFFECT ON COST BENEFITS

Since electric water heaters generally cost more to operate, you should compare overall efficiency of electric heaters with gas heaters. Electric rates vary from 2¢ to 8¢ per kWh across the country. Availability of gas also varies considerably. Insulate your water heater. Turn the thermostat down. Consider adding a solar unit.

Water conservation is a matter of conscious use and the selection of water-saving equipment. Many communities are becoming very active in water conservation and are amending plumbing codes to require water-conserving plumbing fixtures.

N. What Type of Plumbing to Use

From your study of this section, you will be able to discuss the factors which influence the wise selection of plumbing. They are discussed under the following headings:

1. Water Consumption.
2. Type of Plumbing Equipment.

1. WATER CONSUMPTION

A typical four-member family consumes about 1136 ℓ (300 gallons) each day or about 110,000 gallons per year for indoor uses alone. Water is used for toilets, lavatories, bathing, laundry, utility sinks, and kitchen dishwashing and food preparation. Additional water is used outdoors for car washing and lawn sprinkling, but it seldom drains into a sewer system. Swimming pools are now becoming another major water consumer in some locations.

Table XVII shows a breakdown of daily water consumption for a typical home with a family of four.

TABLE XVII. DAILY WATER NEEDED FOR A FAMILY OF FOUR

Use	Gallons/Day	Percent of Total
Toilets	120	40
Lavatories	10	3
Bathing	100	33
Laundry	35	12
Utility Sink	5	2
Kitchen	30	10
TOTAL	300	100

The actual water consumption for a home varies widely, depending on the living habits of the users as well as the efficiency of the fixtures and appliances. Since about one-fourth of the water consumed is hot water, lower water consumption is a double saving.

2. TYPE OF PLUMBING EQUIPMENT

Let's look at several ways in which we can decrease water consumption by selection of plumbing fixtures with water saving features. They are discussed as follows:

a. Toilets

Most tank-type toilets consume 19 ℓ (5 gallons) per flush. Water-saving toilets can be purchased from most of the major manufacturers which consume about 1 ℓ (3 gallons) per flush (Figure 62). Brick and dam-like inserts can be used to save water in existing toilets, provided the toilet will still work properly and not require two flushes.

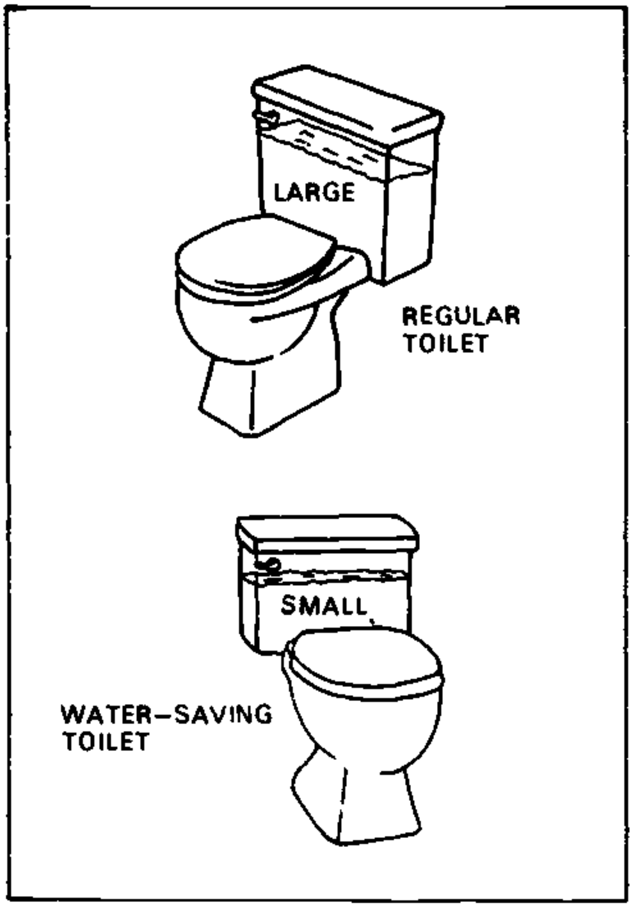


FIGURE 62. Water-saving toilet.

A number of waterless toilets are now available (Figure 63). These units compost toilet wastes as well as kitchen scraps. Where allowed by Code, they can be a good substitute for a septic system if drainage is poor or sewer systems are expensive to hook up or not available. Unless properly installed and maintained, these units can become a problem.

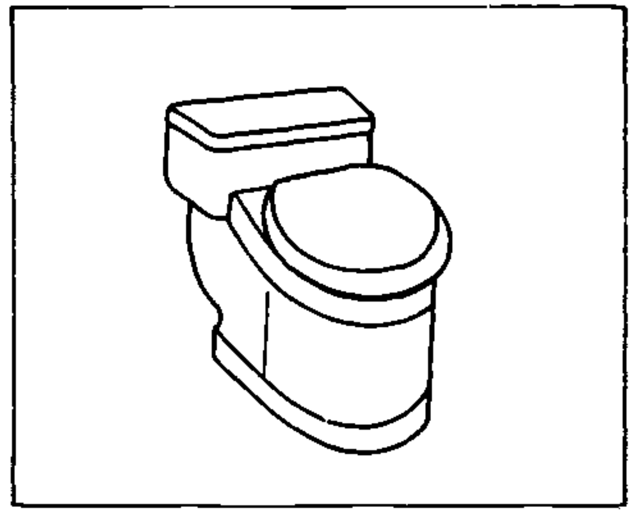


FIGURE 63. Waterless toilet.

For larger buildings, methods involving chemical treatment, incineration and water cycling systems are coming into use. The installation of a water reuse system which recycles water from sinks, tubs, and washers for use in toilets can save between 40 and 50% of the total household consumption (NASA).

b. Lavatory Faucets

Water-conserving faucets have a flow rate of about 3.8 ℓ (1 gal) per minute compared to normal flow rates of 8 to 11 ℓ (2 to 3 gallons) per minute. Existing faucets can be modified to save water by installing flow control valves in both supply lines or by adding an adjustable spray head (Figure 64).

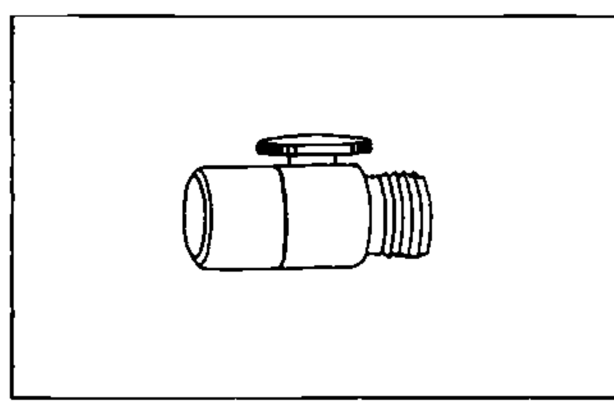


FIGURE 64. Adjustable spray head valve for inserting in faucets to reduce water flow.

c. Showers

A 114-liter (30-gallon) per shower usage is based on a 10-minute shower with a conventional 11 ℓ (3-gallon) per minute flow-rate head. Some shower head flow rates run as high as 23 ℓ (6 gallons) per minute. A water-conserving shower head should have a flow rate of only 10 ℓ (2.75 gallons) per minute (Figure 65). An adjustable head will allow individuals to select desired spray patterns. Shutting off the spray head for soaping along with shorter showers will cut water consumption by half, and could save $20.00 or more per year.

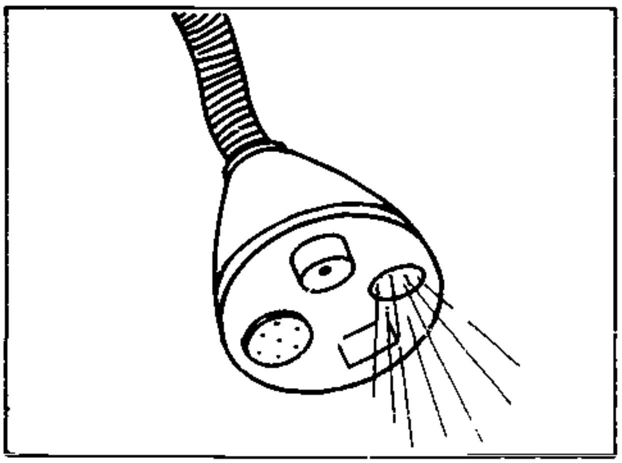


FIGURE 65. Adjustable shower head can be used to save energy.

d. Kitchen Faucets

It is common practice to let kitchen faucets run full force when cleaning vegetables or rinsing dishes. Lower flow rate faucets with spray heads will not be a difficult adjustment to make. In-line flow control valves can be placed in existing supply lines (Figure 66). A good flow rate for these faucets is 8 ℓ (2 gallons) per minute.

e. Dishwashers

A dishwasher should not have a flow control valve placed in the water supply line as it will prevent proper cleaning action.

Most dishwasher manufacturers now have "energy saver" models which allow the selection of a "short wash" cycle which can be used for all but the very dirty dishes. This cycle uses about 38 ℓ (10 gallons) as opposed to about 57 ℓ (15 gallons) per regular wash cycle. The cost saving here is mainly the energy for heating the water, which can be considerable.

f. Clothes Washers

The major saving here again is the energy used to heat the water. Temperature controls and variable water levels, "sud-saver" features, and more cold water washing will produce significant savings in this area.

g. Outdoor Water Uses

The greatest water consumption outdoors is lawn sprinkling systems. These should be regulated for minimum moisture requirements and perhaps eliminated in favor of "ground covers" for many areas.

Car washing requires over a hundred gallons per wash. A self-closing nozzle is helpful. A better solution is the "no-hose" system. Use a few buckets of water and save energy with energy.

In summary, selecting water saving plumbing fixtures and using some common sense may save as much as $30.00 for water and $50.00 for heating costs in one year.

II. Installing Energy-Saving Materials

After one understands the need to conserve energy in buildings, how energy is used, how its loss and gain is measured, and what components of a building can be designed or modified to be made more energy-efficient, it is very important to put this knowledge into practice. Many steps can be taken by individuals, some in a rather short period of time, that can save significant amounts of energy. It is important, however, to follow the proper procedures or the materials may not function properly, and actual damage to the structure may result.

The procedures are given under the following major headings:

A. Installing Insulation in the Structure.
B. Installing Vapor Barriers.
C. Installing Weatherstripping and Caulking.
D. Installing Storm Windows and Doors.

A. Installing Insulation in the Structure

Before installing insulation in new construction or remodeling work, all carpentry required to frame the structure, as well as all electrical, plumbing, and heating-cooling rough-in procedures must be completed, to allow only a minimum of disturbance to the insulating material after it has been installed.

Insulation should be installed on all surfaces where the flow of heat will be detrimental to the efficient heating and/or cooling of a building. The methods of installing insulation differ somewhat depending upon the part of the structure to be insulated. From your study of this section, you will be able to install insulation properly. Procedures are given under the following headings:

1. Installing Insulation in the Ceiling.
2. Installing Insulation in the Floor.
3. Installing Insulation in the Walls.
4. Installing Insulation in the Basement and Crawl Space.

1. INSTALLING INSULATION IN THE CEILING

Only those ceilings exposed to unheated attics or directly covered by roofs need to be insulated. However, because the heat loss is greatest through ceilings and proper ventilation of attics is essential, it is very important that insulating is done properly. Figure 66 shows where insulation should be placed

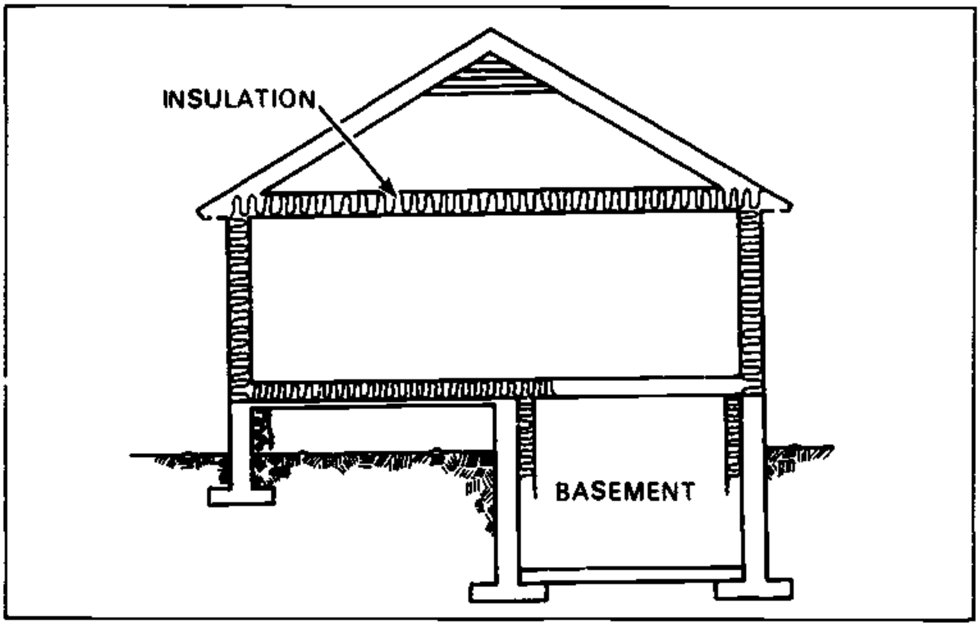


FIGURE 66. Insulation for a one story building with attic.

in a one story house with an attic. If the house has access to the attic by way of a stairway, Figure 67 shows how the stairwell should be insulated. Buildings which have no attic, as in Figure 68, must have insulation in the roof-ceiling area, making certain to allow enough space above the insulation for air circulation. Figure 69 shows where insulation must be placed in houses

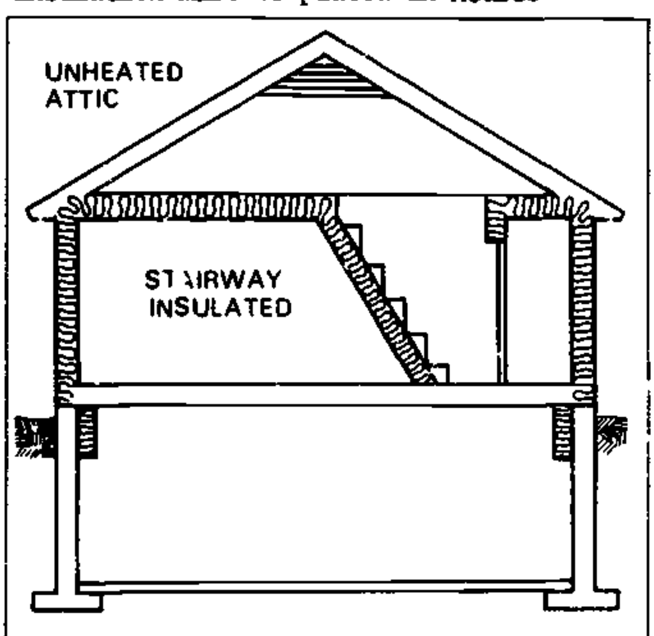


FIGURE 67. Stairway to unheated attic should be insulated.

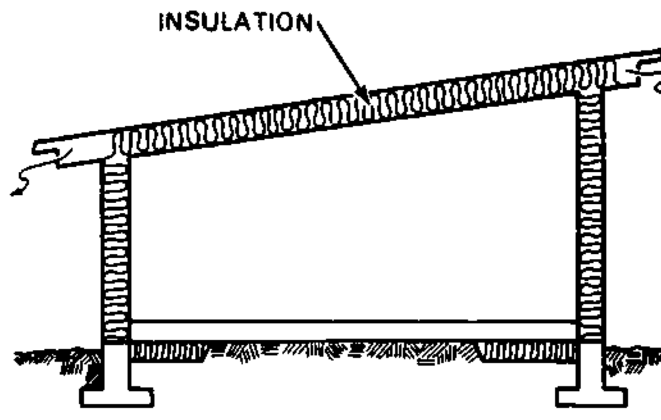


FIGURE 68. Building with no attic space must have insulation under the roof.

where some of the attic area has been finished for living purposes, or dormers have been added for more living space, light, and ventilation. Again, it is important that space be left between the insulation in the drop ceiling and the roof boards to allow air circulation from the attic area behind the knee wall to the upper attic area for proper ventilation.

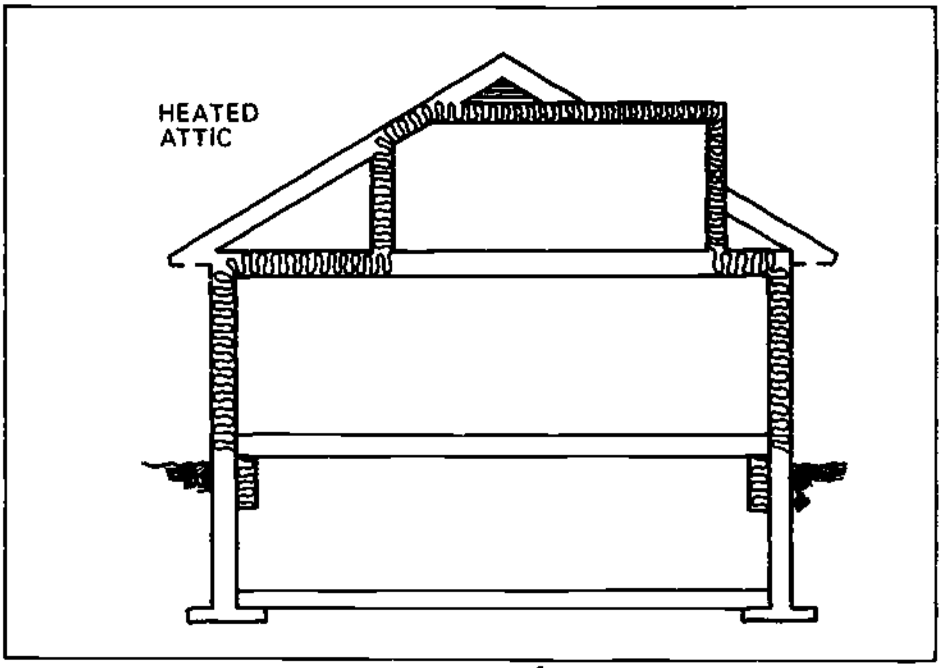


FIGURE 69. Heated attic insulation.

Insulation in ceilings of the following categories of insulation are described:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

The majority of flexible insulation is manufactured with kraft paper or asphaltic, plastic, or aluminum vapor barriers adhered to at least one side. If the insulation has a vapor barrier, it is very important that the vapor barrier be placed toward the heated side of the ceiling (facing downward). It is also essential that the vapor barrier not be torn, as it then becomes less effective.

Batt or blanket insulation with a paper or vapor barrier backing is usually fastened to ceiling joists or studs in one of two ways. It is simplest to staple the flanges of the insulation to the edge of the stud or joist (Figure 70). This procedure makes for the best seal for the vapor barrier, but it sometimes leaves an uneven surface upon

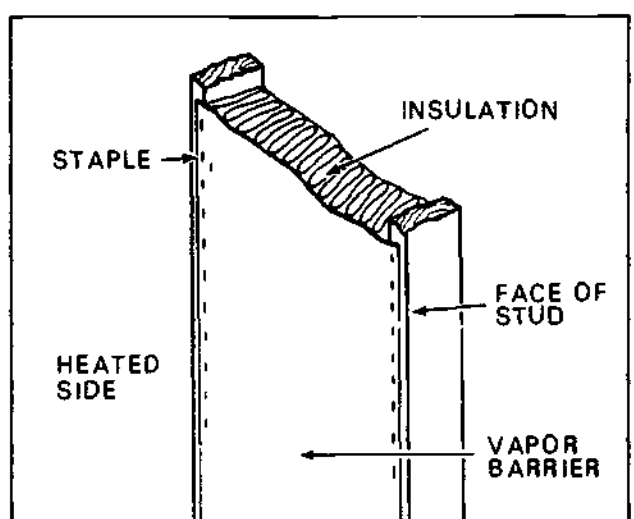
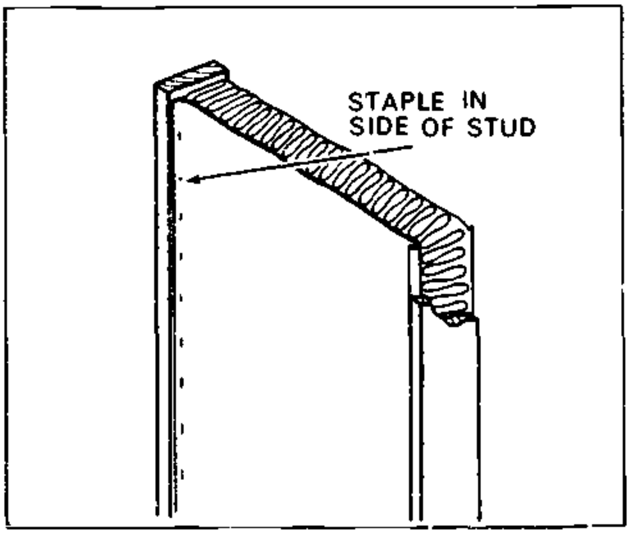


FIGURE 70. Batt Insulation is stapled to the face of the stud. Vapor barrier to the heated side.

which to place wall covering and does not allow for the use of adhesives to hold wall coverings in place. Otherwise, the flange can be stapled along the side of the stud to form an air space between the insulation and the wall covering (Figure 71). The latter is the procedure required if the insulation has a reflective foil surface on it.

Blanket insulation comes in rolls and is usually available in thicknesses up to 3 1/2 inches. The thicker the insulation, the less area a roll will cover. Batts are available in thicknesses up to 5 inches and come in a series of shorter pieces packaged together. Both are made in widths for installation in 16-inch or 24-inch on-center spacing of framing members.



Batts or blankets may also be purchased without any backer or vapor barrier. These are made to fit in spaces between joists or studs by friction. Many spaces will require several batts to cover their length. Care should be taken that joints between batts are pushed tightly together. In ceilings, especially with 61 cm (24 in) o.c. framing, these are most successfully installed by laying them in after the ceiling covering has been installed. The measuring and cutting of such insulation is accomplished in the manner previously described. A separate vapor barrier will be needed.

If flexible insulation is to be used to add thickness to existing batt or blanket insulation, it is best to use the type that has no vapor barrier. If batt or blanket insulation with a vapor barrier is used, the vapor barrier should be slashed and again placed to the warm side but not fastened. If the space between ceiling joists is not filled with the first layer, the second layer is merely laid between the joists on top of the first. If the space has already been filled, the batts or blankets can be run at right angles to the direction in which the joists run, to give total coverage.

For protection, the installer should wear safety goggles and clothes that fit tightly about the neck and wrists.

To install blanket insulation, proceed as follows:

1. Measure the length of the space to be insulated.

2. Add to this length another 10.2 cm (4 in) or 15.2 cm (6 in) if one end is to start at outside wall.

3. If several pieces of the same length are needed, measure this distance from a wall and make a mark on the floor (Figure 72).

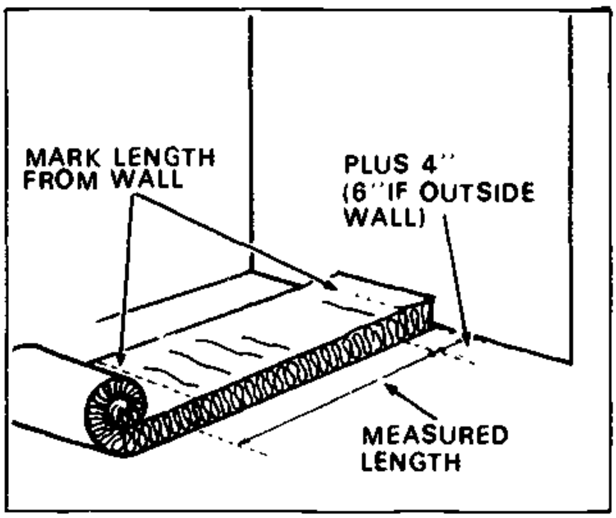


FIGURE 72. Cut sections to proper length.

4. Place end of blanket against wall and unroll to mark.

5. Compress the material with a straight edge and cut with a sharp knife (Figure 73).

6. Peel the insulation away from the paper or vapor barrier for about 5.1 cm (2 in) at each end--10.2 cm (4 in) if end is to start at outside wall (Figure 74).

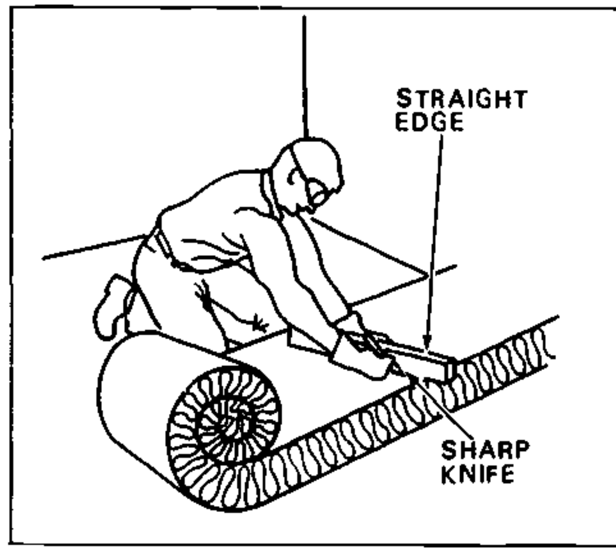


FIGURE 73. Compress the insulation with a straight edge and cut with a sharp knife.

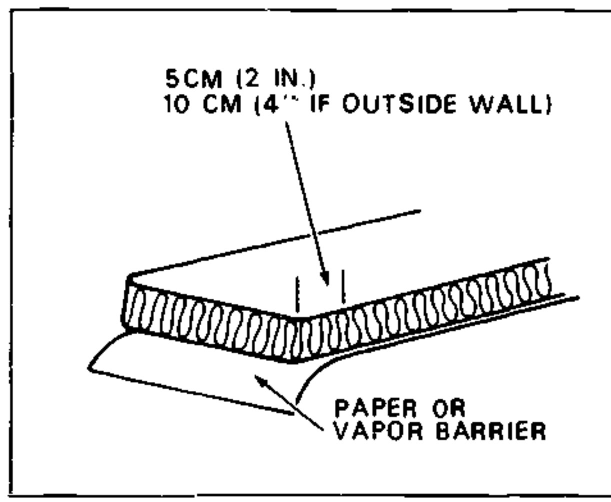


FIGURE 74. Peel insulation away from vapor barrier on end.

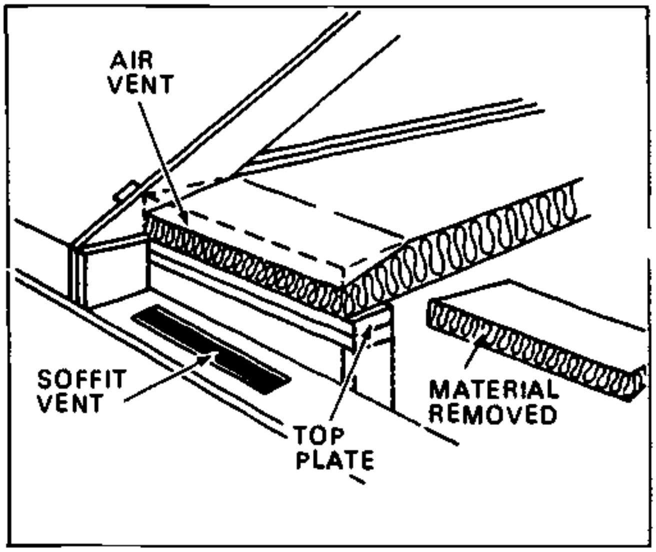


FIGURE 75. Provide air space for attic ventilation.

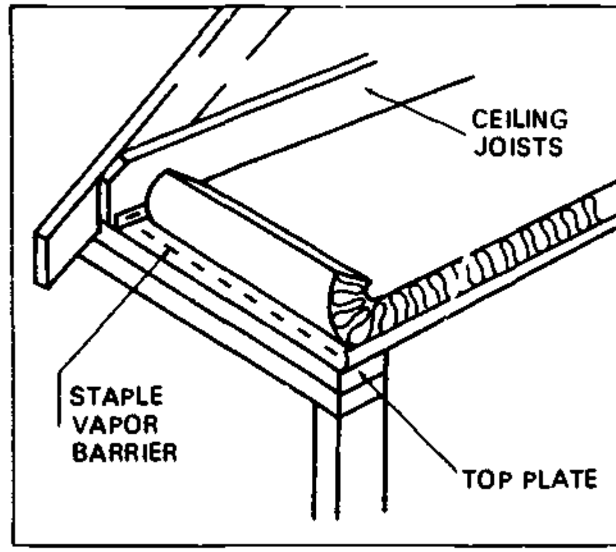


FIGURE 76. Staple vapor barrier or paper.

7. If one end is to start at outside wall and end of insulation over wall plate will block space between rafters to the underside of the roof boards, remove enough insulation from the top cover of the blanket to allow for at least 2.5 cm (1 in) of clearance for ventilation from cornice (Figure 75).

8. Place end of insulation on top of double top plate and staple paper or vapor barrier to edge of double top plate (Figure 76).

9. Staple to edge or side of ceiling joist or truss chord. Staples 6 mm (1/4 in) long should be no more than 15.2 cm (6 in) apart and care must be taken to have vapor barrier fit tight to joist (Figure 76).

10. Where there are electrical boxes in the ceiling, place the insulation above them and cut the insulation so that it can be fitted around the wires or conduit.

CAUTION! Do not place insulation within 7.6 cm (3 inches) of recessed fixtures. They are designed to dissipate the heat generated by the light bulbs into the air above them; covering them with insulation can cause them to overheat and possibly cause a fire to start. Also, do not cover non-ducted exhaust vents.

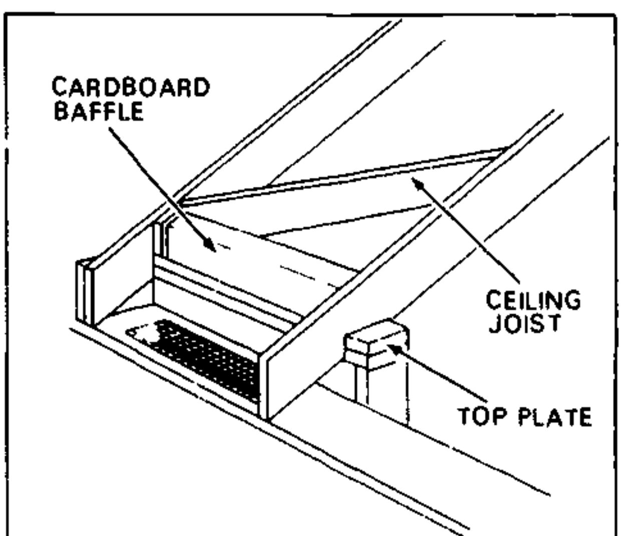
11. Use longer lengths first and the shorter pieces to do the shorter areas.

If joints are made in an area, be sure to butt the ends of the pieces of insulation tightly together.

b. Loose-Fill Insulation

A very popular type of insulation to use in ceilings is loose-fill insulation. Some of these insulations, such as mica pellets, are easily placed by pouring and leveling while others such as glass or rock wool and cellulose fiber are best installed with a blower.

Certain preparations may be made so that the installation will be done most effectively. One of these preparations is the installing of cardboard baffles where the joist space meets the outside wall (Figure 77). The purpose of the baffles is to keep the insulation from being shoved or blown into the soffit area and to keep the insulation from blocking the flow of air from the soffit vents to the attic. The cardboard baffles may be purchased pre-cut and creased for bending, or they can be made of surplus cardboard by the installer. The baffles may be stapled or nailed into place with large headed nails. They are much easier to install in new construction before the roof boards have been put in.



If a vapor barrier is desired in the ceiling, it must be installed at this time. Installation of vapor barriers will be discussed in Part B.

Anyone who works with loose-fill insulation in closed spaces should wear a respirator in addition to safety goggles and clothing that fits tightly at the neck and wrists.

Loose-fill insulation may be installed by (1) pouring or (2) blowing. Either method may be used equally as well for installing additional insulation over existing insulation to increase the R-Value of the ceiling structure. Procedures are given as follows:

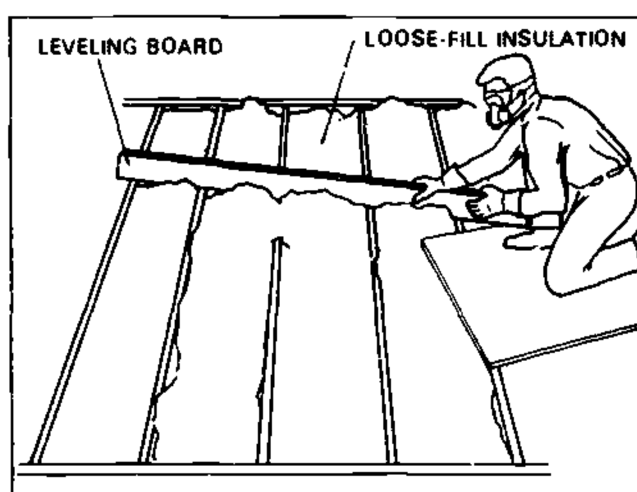
(1) POURING METHOD. If your insulation is the type that does not pack when bagged, following the pouring method:

1. Carry bags of insulation into attic.

2. Open bags and pour insulation in spaces between joists.

3. Level off insulation to desired thickness with leveling board (Figure 78).

   If depth desired is greater than joist, level by installing screeds perpendicular to the joists.



4. Be sure that all areas are properly covered and that recessed lights are uncovered.

   To keep insulation from recessed fixtures or exhaust vents, use a non-combustible material such as sheetrock scraps to hold insulation back.

5. Remove empty bags from attic as they constitute a fire hazard.

(2) BLOWING METHOD. Glass and rock wools and cellulose fibers are best blown in place, because the process of blowing tends to restore the material to its natural fluffy state. This procedure enhances its insulating value. While a single individual can install insulation by the pouring method, it takes two people to blow in insulation. One person must feed insulation into the blower while the other directs the hose in the attic.

With the recent emphasis upon insulation, more insulation suppliers have blowers that they rent to individuals to enable them to do the insulating themselves. These blowers are usually equipped with an electric control which enables the person directing the hose to control the flow of insulation. A person who has not used a blower before should follow very closely the directions that are given when it is rented.

It is best to select an area easily accessible to make a trial application and complete coverage. Once this skill has been acquired, the most inaccessible spaces are filled first while the applicator works gradually toward the exit to the attic. The same precautions regarding recessed lights and unducted vents must be followed when insulation is blown in place.

c. Rigid Insulation

Rigid insulations are used primarily in ceilings where the roof and ceiling structure is one, such as plank and beam or bar joist and steel deck construction; therefore, it is usually installed when the building is constructed. Rigid cellulose fiber planks of 5.1 or 7.6 cm (2 or 3-inch) thickness may replace solid wood decking in plank and beam construction. It is laid on top of the beams and nailed in place with long spikes. Roofing is then applied over it. This method is more energy efficient than solid wood decking, but neither is adequate in view of the rising cost of energy. Therefore, it is now recommended that enough rigid insulation, probably one of the foam plastics, be placed over the decking to bring the R-Value up to the desired level (Figure 79). This method of insulation can be used to upgrade the R-Value of existing plank and beam ceilings as well.

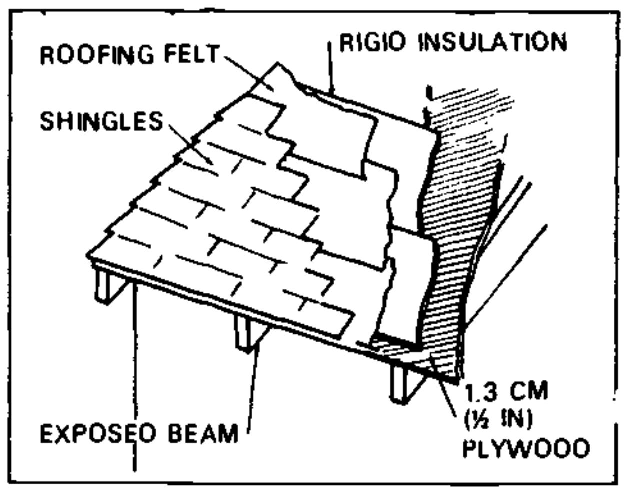


FIGURE 79. Rigid insulation placed over plywood ceiling with exposed beam.

In sloped ceilings that are framed with rafters, the rafter is sometimes made deeper than necessary for structural strength, in order to accommodate the proper thickness of insulation and still provide an air space for ventilation. Lumber may be saved by sizing the rafters for strength and placing rigid insulation on the underside of the rafters in addition to the batts between the rafters. This method may also be used to upgrade the insulating value of existing structures (Figure 80).

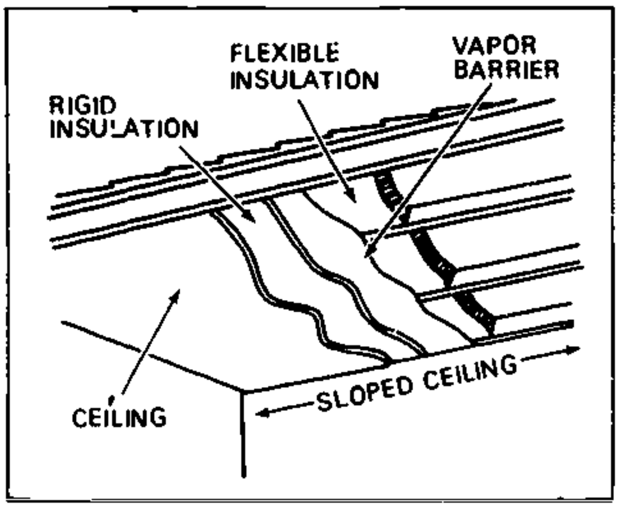


FIGURE 80. Use of both flexible and rigid insulation in sloping ceiling.

Some companies who manufacture materials for suspended ceilings are now trying to make the public aware of the insulating value of such ceilings. If information on the U-value of suspended ceilings is given, be sure to ascertain whether this refers to the U-Value of the panels or of the total suspended ceiling. The panels may be good insulators but the metal grid that supports the panels conducts heat readily. Such a ceiling installed for insulation purposes will be installed in a manner similar to any other suspended ceiling.

d. Reflective Insulation

Reflective insulations are seldom used in ceilings as the only form of insulation. They are most effective in climates where protection from summer heat is the major concern. The aluminum foil backing found on some batt and blanket insulations acts as a reflective insulation as well as a vapor barrier. In order to be effective, this insulation must be installed with an air space of at least 1.9 cm (3/4 in) between the reflective surface and any surface opposite it. The same holds true for reflective insulations made of a single sheet of material. Otherwise, the procedure followed in its installation is the same as for any other type of flexible insulation. Although stapling is the most popular method of fastening reflective insulation, it may also be nailed. It must, however, be fastened often enough to be held against the framing material without gaping.

Reflective insulations that unfold to form multiple air spaces, each surrounded with reflective surfaces, are provided with tabs for fastening them to the structure. Again, care must be exercised to keep the insulation at least 1.9 cm (3/4 in) away from the back side of the ceiling covering. This insulation is best installed in new constructions, or when remodeling rather than when used as a measure to upgrade the insulating value of an existing structure.

2. INSTALLING INSULATION IN THE FLOOR

Insulation in floors is installed only over unheated areas. Most insulation that is installed in floors has the heated area above it. Many times this insulation is not installed during the proper phase of construction or is installed later to make the floors warmer. These factors tend to make proper installation more difficult and lead to its being installed improperly.

Procedures vary for flexible, rigid and loose-fill insulation. They are given under the following headings:

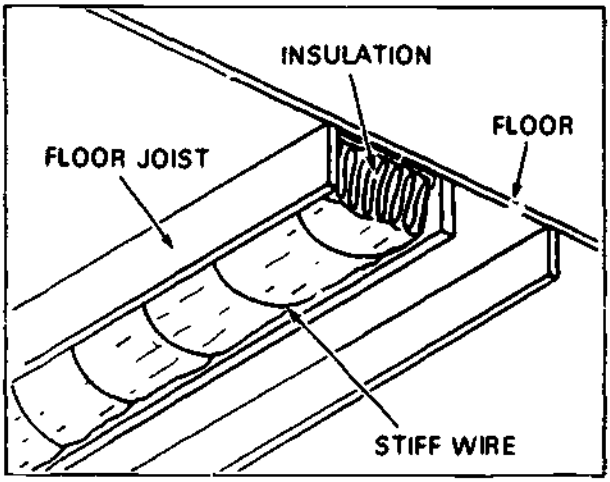


FIGURE 81. Stiff wire may be used to support flexible insulation between flow joists.

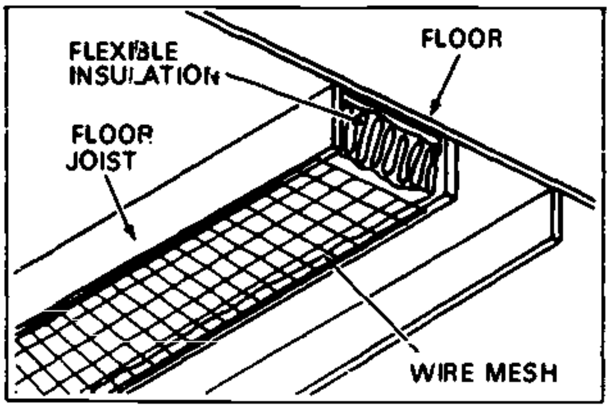


FIGURE 82. Mesh wire used to support insulation between floor joists.

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

Most flexible insulation has the vapor barrier on the side from which it is fastened, requiring that one of the following things be done.

The insulation should be installed from above by stapling it in place before the subfloor is put down.

Some insulation is made completely enclosed by kraft paper with the vapor barrier to be placed up and the stapling to be done from beneath.

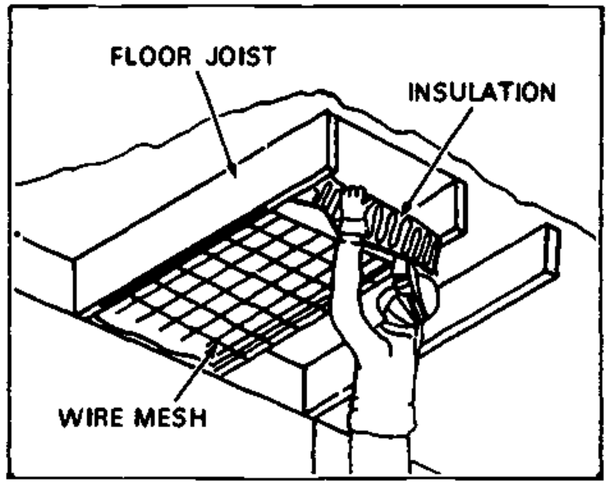


FIGURE 83. Installing flexible insulation under floor.

A vapor barrier can be installed above or beneath the subfloor and insulation without a vapor barrier can be installed from beneath. This is supported by wire. Use either pieces of heavy gage wire which are pointed on each end or wire mesh. Place the vapor barrier up (Figures 81 and 82).

(1) HEAVY GAGE WIRE. Proceed as follows:

1. Cut insulation proper length.

2. Slide batts of insulation between the joists on top of the wire (Figure 83).

3. Repeat steps 1 and 2, working on areas that are small enough to get the insulation in place easily.

4. End at obstructions such as walls or cross bridging.

Otherwise, the methods of cutting and installing the flexible insulation in floors is similar to that described in section "1. Installing Insulation in the Ceiling."

b. Loose-Fill Insulation

The only way loose-fill can be used to insulate floors is if a covering has been installed on the under sides of the floor joists. Unless the subfloor has not yet been installed, loose-fill is seldom used for insulating floors.

c. Rigid Insulation

Rigid insulation may be used for the following conditions:

(1) EXISTING SLAB FLOORS that are cold may be made warmer by installing wood sleepers on the concrete, insulation between the sleepers, a vapor barrier over the sleepers and insulation and/or a wood floor with appropriate floor coverings over that (Figure 84).

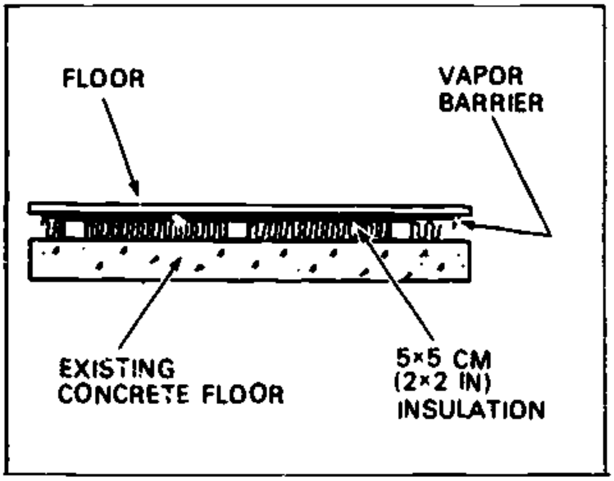


FIGURE 84. Install rigid insulation between vapor barrier and slab.

(2) FRAME FLOORS. In frame floor construction, rigid insulation can be nailed on the underside of the joists. If the insulation does not provide a vapor barrier, one should be installed between the joists and the insulation first.

Less severe problems with cold floors can be helped by using a foam backed carpet as a finish floor covering, or by cementing 3 or 6 mm (1/8 or 1/4 in) felt board to the concrete with a mastic. Finish floor covering then is placed over the felt board.

(3) SLAB FLOORS. Rigid insulations are used primarily to insulate concrete slab floors. Insulations used for such purposes must have strength to resist compression by the weight of the concrete and those objects placed on the floor.

Proceed as follows:

1. Place insulation before concrete is poured (Figure 85).

2. It must extend down inside foundation wall to frost line, or extend horizontally under slab floor for 61 to 91 cm (2 to 3 ft)

3. Rigid insulation may extend under the entire floor.

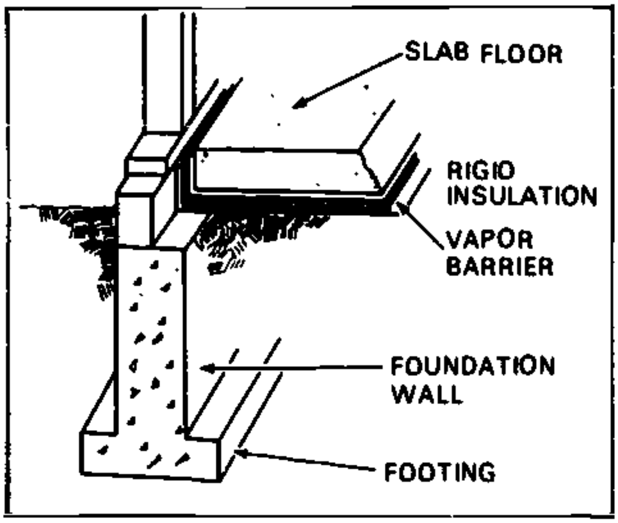


FIGURE 85. Rigid insulation must extend down to the frost line or 61 to 91 cm (2 to 3 ft) under the slab floor.

d. Reflective Insulation

Reflective insulation would be installed in joist spaces in the same manner as it is in ceilings.

3. INSTALLING INSULATION IN THE WALLS

Any wall which will be exposed to the outside or an unheated area of the building should be insulated. After installing the insulation in the ceilings and floors of a new house, one finds that work on the walls is quite easy. However, extreme care must be exercised in the installation process. There are many more openings around which to work. Electrical wires, electrical boxes and sometimes plumbing must be worked around also.

Installing insulation in walls is discussed under the following headings:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.
e. Foam Insulation.

a. Flexible Insulation

Batt and blanket insulation is a very popular type of insulation to be used in the walls of houses and additions under construction. The method of cutting and installing batts and blankets in walls is the same as the procedure described in "1. Installing Insulation in the Ceiling." Add the following procedures:

1. Work insulation behind all water and drain pipes (Figure 86).

   Do not pack.

2. Work insulation behind electrical boxes and take care to seal cuts in wall insulation around electrical wires and conduit (Figure 86).

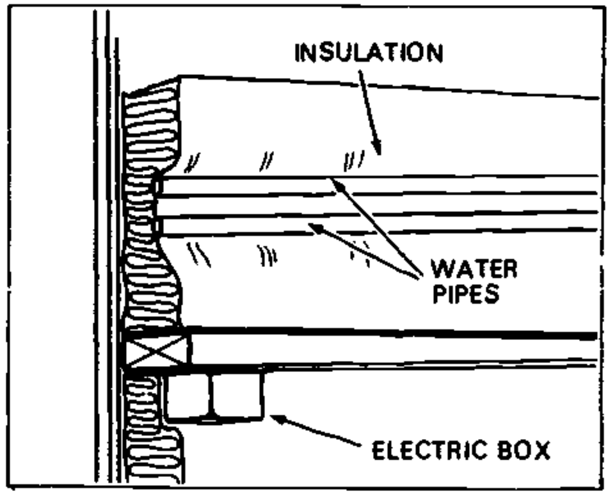


FIGURE 86. Work insulation around pipes and wires.

3. Cut and install insulation in all odd-sized stud spaces no matter how small they are.

4. Completely fill the stud space and staple vapor barrier all around the top, bottom and sides.

5. Stuff cracks between window and door frames and rough openings full of insulation and cover with a vapor barrier (Figure 87).

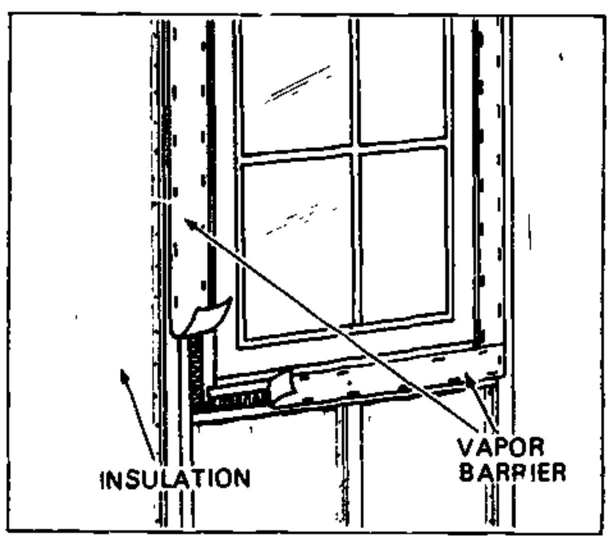


FIGURE 87. Fill all cracks with insulation and cover with vapor barrier.

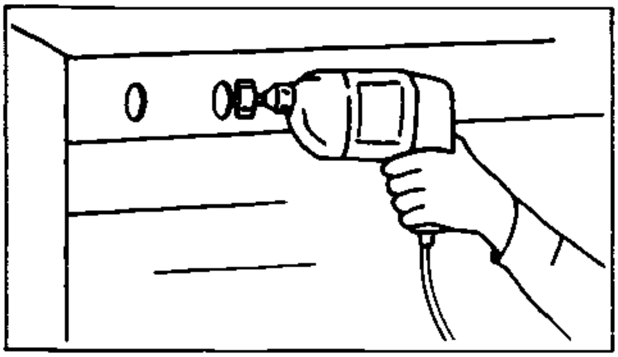


FIGURE 88. Drill hole at top of sheathing.

b. Loose-Fill Insulation

Proceed as follows:

1. Install both ceiling and sheathing and vapor barriers on new construction.

2. Drill hole in sheathing at top of wall (Figure 88).

   On old construction, check for fire stops (horizontal bracing between studs). If they are installed, you will have to fill below them also.

3. Blow in insulation (Figure 89).

   If you are filling the cores in concrete blocks, fill after every 3 or 4 courses rather than wait until wall is completed.

c. Rigid Insulation

The primary use of rigid insulation on frame walls is as a combination sheathing and insulation. In this application, it is usually used together with another type of insulation. The two categories of rigid insulations are insulation boards and foam plastic sheets.

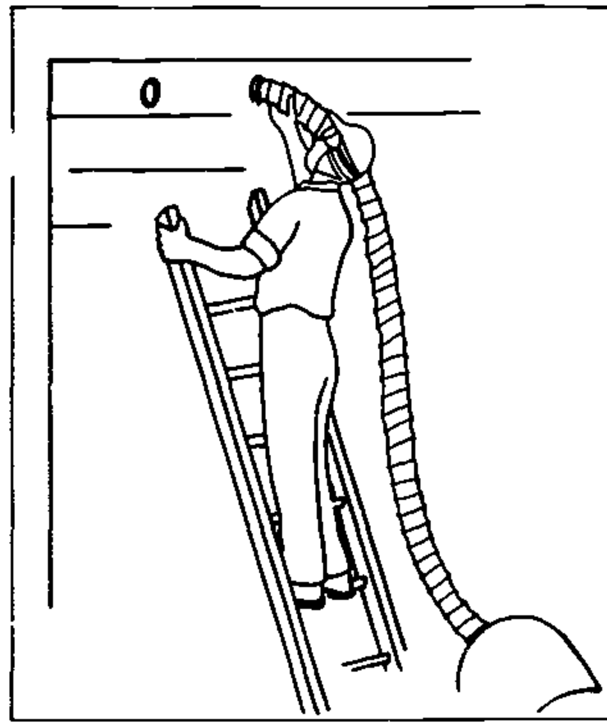


FIGURE 89. Blowing in insulation.

Proceed as follows:

1. Install wind bracing if needed.

   Foam plastic sheets are non-structural so they require that some type of wind bracing be installed in the wall. Some insulation boards have been approved by model codes for use without any other wind bracing, however.

2. Cut insulation boards and fasten to studs in place of sheathing.

   The foam plastic sheets are best cut by scoring the sheet with a utility knife and snapping the sheet in two.

   Nails with 1.1 or 2.5 cm (7/16 or 1 in) heads are required to fasten the sheathing. The following nailing schedule is recommended:

Fasteners	Crown or Head		Centers	
	cm	in	cm	in
Staples	1.1	7/16	20	8
Staples	1.9	3/4	31	12
Nails	1.1	7/16	31	12
Nails	2.5	1	61	24

If you have masonry walls, glue the insulation boards to the wall. Be sure to use the mastic recommended for the job.

d. Reflective Insulation

Reflective insulations in walls are used primarily to stop the transfer of radiant heat.

Three types are discussed here. They are as follows:

(1) Accordion Type.
(2) Rigid, Reflective One Side.
(3) Rigid, Reflective Two Sides.

(1) ACCORDION TYPE. Accordion-type reflective insulation is pre-made to unfold and staple in a stud space. It must be kept 1.9 cm (3/4 in) away from the inside surface of either wall covering to be effective.

(2) RIGID, REFLECTIVE ONE SIDE. Wallboards, such as gypsum board, and sheathing, such as insulating boards, are available with one reflective side. The reflective side is to be placed toward the inside of the wall. There must be a 1.9 cm (3/4 in) air space between any insulation in the wall cavity and the reflective insulation. Otherwise, they are installed in the same manner as regular wallboards and sheathings.

(3) RIGID, REFLECTIVE TWO SIDES. Insulation, made of a single sheet of material reflective on both surfaces that is installed alone in a stud space should be stapled in place midway between the sheathing and the interior wall covering.

e. Foam Insulation

Two types of foam insulation are the urethane foams and the urea-formaldehyde insulations. Neither of them can be applied without special equipment, as they are made by mixing two components together in an application gun.

They are discussed as follows:

(1) Urethane Foams.
(2) Urea-Formaldehyde Foam.

(1) URETHANE FOAMS. Urethane foam is sprayed on the surface to be insulated. A gas is formed which causes the material to foam and set in a short time. It can be sprayed in the stud spaces to a thickness of an inch or two and does a great deal to give the wall rigidity as well as insulating value. It also can be sprayed on the underside of roofs, etc.

Its application in a closed stud space has been unsuccessful, however, because it is difficult to get the exact amount of mixture between the walls. Too little will leave voids and cause heat loss and too much will expand and push the wall coverings away from the studs.

The material must be protected from light because ultraviolet light causes it to break down. The surface is also extremely flammable and when the material burns the smoke is highly toxic. It is also more expensive than most insulating materials, but it is a better insulator per inch of thickness than most. If the urethane foams are to be used, precautions must be taken to guard against the problems mentioned above.

(2) UREA-FORMALDEHYDE FOAM. The urea-formaldehyde foams are foamed into the wall cavity about as aeresol shaving cream would be. They do a good job of sealing around electrical boxes and other obstructions in the stud space. The material is very light and easily crushed. It also has the disadvantage of shrinking somewhat, causing gaps between surfaces in the stud space through which heat can escape. Two holes are drilled into the sheathing in each stud space and the material is foamed into the bottom hole while the upper hole lets out the air.

4. INSTALLING INSULATION IN THE BASEMENT AND CRAWL SPACE

If a building has a crawl space, the floor above the crawl space can be insulated and the crawl space ventilated or the crawl space itself can be insulated. Good insulation is especially necessary in a crawl space or basement if the crawl space contains heating ducts for the furnace.

Insulating basements and crawl spaces is discussed under the following headings:

a. Flexible Insulation.
b. Loose-Fill Insulation.
c. Rigid Insulation.
d. Reflective Insulation.

a. Flexible Insulation

Basements and crawl spaces in wood framed houses have one part of the structure that is often not insulated. This area is the band joist. Normally at this point there will be only 3.8 cm (1 1/2 in) of lumber plus whatever is used as a siding on the outside. This is usually corrected by stapling flexible insulation in the space between the floor joists (Figure 90).

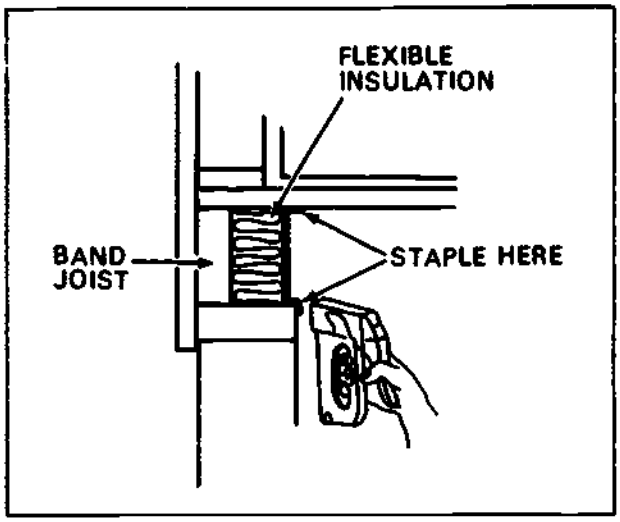


FIGURE 90. Insulate the band joist.

In addition to using flexible insulation at the band joist, it may also be used between furring strips if the basement is finished (Figure 91). In a crawl space, the batt can be stapled to the foundation wall and brought down to the vapor barrier on the ground (Figure 92).

In wood foundations, insulation is installed exactly as it is in any other stud wall.

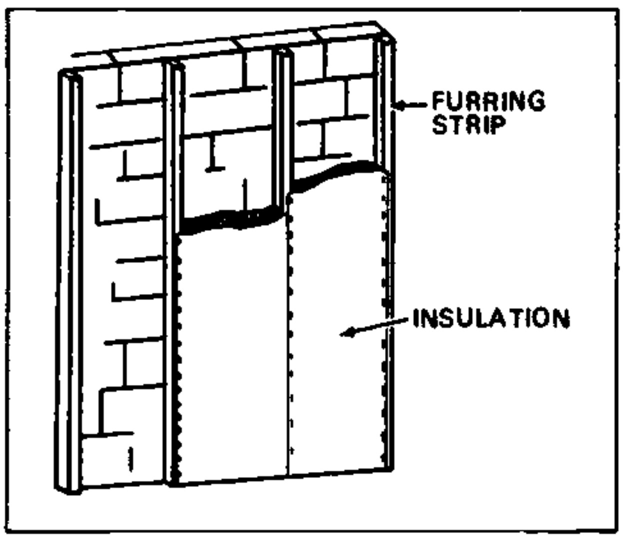


FIGURE 91. Furring strips may be added to a masonry wall to provide for flexible insulation.

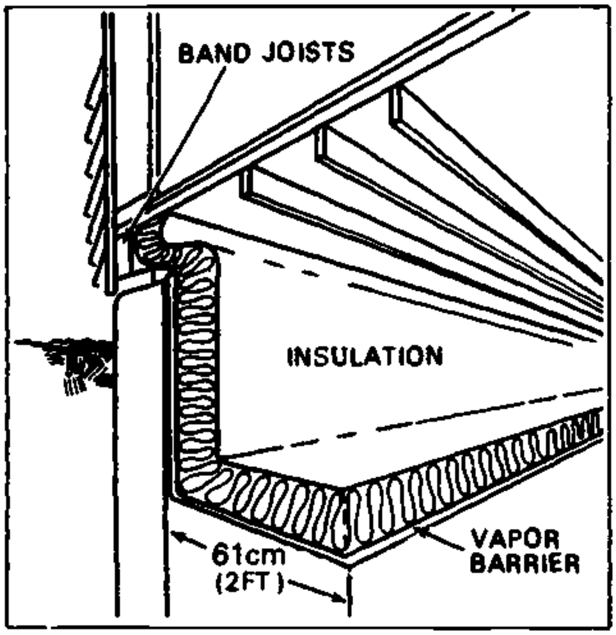


FIGURE 92. Insulation of band joist and crawl space.

b. Loose-Fill Insulation

Except for use as a poor insulation in the cores of concrete blocks, loose-fill insulation has little use in this area of the building.

c. Rigid Insulation

Basements may be insulated by using mastic to glue foam plastic board either to the inside or outside of the wall. If the foam board is glued to the outside, it must be protected from the effects of weather by painting it with a latex texture paint or by applying some other material that is compatible with the foam.

Other types of rigid insulation may be used between furring in basements and on the inside walls of crawl spaces.

Walk out basements must have the exposed part of the basement treated in the same manner as the slab floor described in "A. 2." for rigid insulation.

d. Reflective Insulation

Reflective insulations are seldom used in basements and crawl spaces.

B. Installing Vapor Barriers

In Section I, the effect of moisture upon the building and the necessity for vapor barriers are discussed. Remember that to turn liquid water into water vapor takes heat, so when we keep water vapor from escaping we are saving heat. In addition, we are keeping the insulation dry, which also saves heat; we are also keeping the structure of the building dry to make it last longer. Care must be taken that the vapor barrier is on the warm side so that moisture will not condense on it.

Another precaution that must be taken is to have no more than one vapor barrier on any surface. If there are two vapor barriers of equal effectiveness or two vapor barriers with the most effective one closest to the outside, there will be a tendency for moisture to be trapped between them. In this instance, as many problems can arise as would if no vapor barrier were present. Therefore, if it is necessary to have two vapor barriers present, take a knife or other sharp object and cut slits in the one nearest the outside which will render it useless as a vapor barrier.

The vapor barrier should also be free from holes and other openings which will cause water vapor to leak into the structure. Just as the air will sooner or later cause water vapor to leak from one hole in a tire, so will a significant amount of water vapor leak through one hole in the vapor barrier. Vapor barriers should cover the warm side of all insulated surfaces.

From your study of this section, you will be able to install vapor barriers properly.

Installing vapor barriers is discussed under the following headings:

1. Installing Vapor Barriers in New Construction.

2. Installing Vapor Barriers in Existing Buildings.

1. INSTALLING VAPOR BARRIERS IN NEW CONSTRUCTION

In new construction, the vapor barrier can either be an integral part of the insulation or it can be a separate layer. If the vapor barrier is part of the insulation, it will be installed with the insulation. The above mentioned precautions are to be followed in this instance, too.

If the vapor barrier is separate, proceed as follows:

1. Use .10 mm (4 mil) polyethylene.

2. Staple it to edges of framing across windows and doors.

   Install on heated side of studs.

3. Tape joints with duct tape.

4. Cut cross-wise and seal around electrical boxes with sealing compound.

5. Seal any tears or holes.

6. Cut out plastic from doors and windows after construction is completed.

2. INSTALLING VAPOR BARRIERS IN EXISTING BUILDINGS

If the building is an existing one and has no vapor barrier, consider the following options:

(1) Interior Walls Good.
(2) Interior Walls Not Good.

(1) INTERIOR WALLS GOOD. Proceed as follows:

1. Add decorative wall covering, or

2. Apply two coats of aluminum primer paint, or

3. Add new wall, or

   Install a vapor barrier on old wall before applying new wall.

4. Provide for ventilation of interior walls.

   Drill holes at top and bottom of each stud space and install miniature vents (Figure 93).

5. Add soffit and attic ridge vents for ventilating the attic.

6. Lay a vapor barrier on the ground in the crawl space.

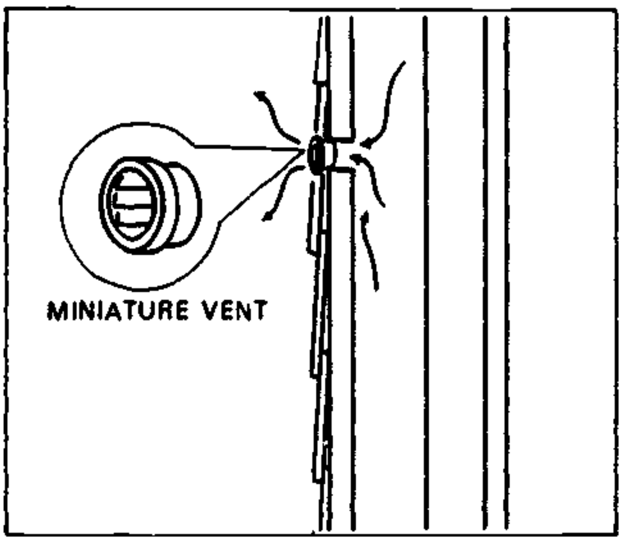


FIGURE 93. Miniature wall vents.

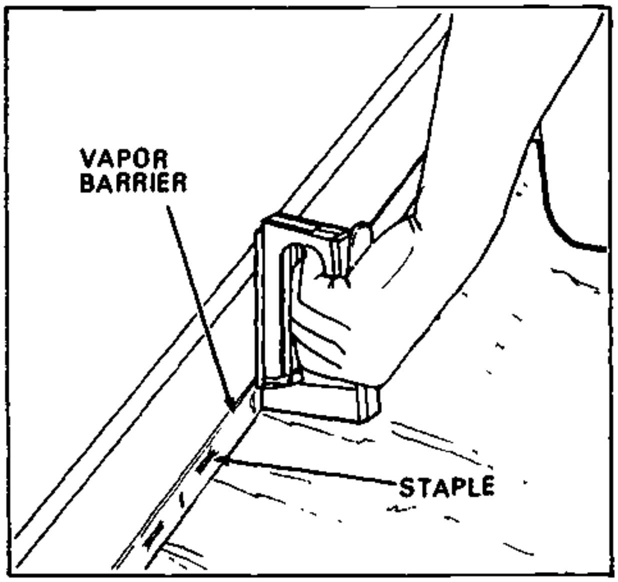


FIGURE 94. Installing vapor barrier in attic.

7. Add ventilation to crawl space.

   Should be equal to 1/1600 of the crawl space area.

8. Install vapor barrier in attic (Figure 94).

9. Install vapor barrier under floor.

   Staple to flow joist on bottom of floor.

(2) INTERIOR WALLS NOT GOOD. Proceed as follows:

1. Remove wall coverings.

2. Install vapor barrier.

   If you need insulation, add insulation. Then attach polyethylene sheets to studs as in new construction.

3. Follow steps 4-9 in previous section.

C. Installing Weatherstripping and Caulking

If a new building is being constructed, select windows and doors for their energy efficiency as well as their appearance and price. If descriptive literature on doors and windows does not give information on the U-value of various glazing methods and the infiltration rate per unit length of crack area, ask your salesman or dealer to provide this information.

On completion of this section, you will be able to install weatherstripping and caulking properly.

There are two basic steps that can be taken to stop or slow infiltration into a building. They are discussed under the following headings:

1. Installing Weatherstripping.
2. Installing Caulking.

1. INSTALLING WEATHERSTRIPPING

Weatherstripping is installed primarily on doors and windows. There are many kinds of weatherstripping. Some of the most popular ones are shown in Figure 95. Weatherstripping is sold by the running foot, or in the case of some weatherstripping for doors, by the set. Those made of foams or plastic such as vinyl should be checked yearly, as the materials tend to lose their resiliency and become less effective. All weatherstrips should also be checked for signs of wear and breakage, and metal ones should be checked to make sure that they are not bent out of shape.

Installing weatherstripping is discussed under the following headings:

a. Weatherstripping Doors.
b. Weatherstripping Windows.

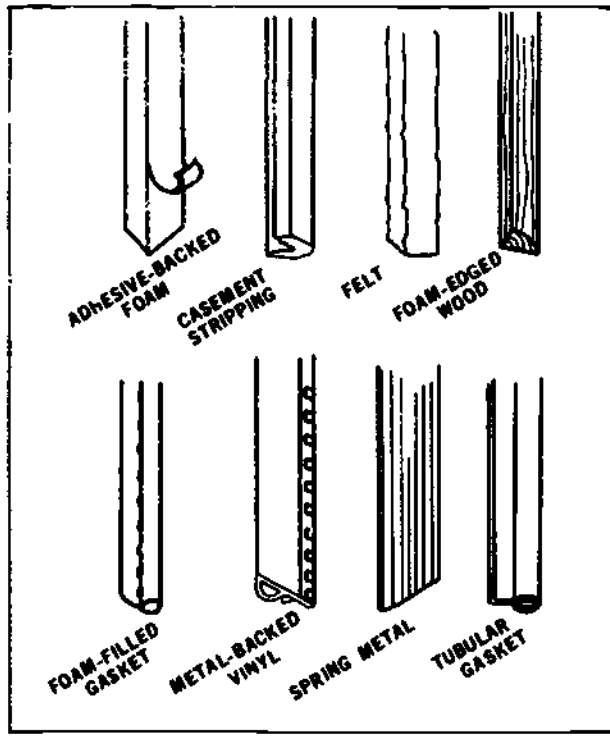


FIGURE 95. Types of weatherstripping.

a. Weatherstripping Doors

Garages are usually not heated, but homeowners like to keep them as warm as possible. Swinging doors may be treated the same as exterior doors in the rest of the house. Overhead doors should have a rubber astragals fastened to the bottom of the door with roofing nails spaced 2-3 inches apart. If the overhead door needs to be very airtight, weatherstripping may be nailed on the door stop so that it fits tightly against the exterior of the door.

(1) AROUND DOORS. The following procedure is used to install weatherstripping around a door:

1. Check door for air leakage.

2. Cut weatherstripping to proper length.

Use saw, hacksaw, or tin snips, whatever is appropriate for the given material.

3. Close door and install weatherstrip on latch side first.

   Press weatherstrip against door and fasten with nails, screws or staples.

4. Install on hinge side of door and then install piece over top of door.

5. Check door.

   If it closes too hard, weatherstrip may be pressed too tightly to door. If door closes easily, check with hair dryer for further air leakage.

(2) THRESHOLD. Because of the motion of the door, possible unevenness of the floor, and wear from traffic, the bottom of the door is usually more difficult to make airtight. If weatherstripping is attached to the door along the bottom, it should be adjusted periodically (Figure 96). One variety is attached to the door at the bottom on the outside and is made to swing down into place as the door closes, helping to eliminate drag on the weatherstripping.

An aluminum threshold with a vinyl insert is frequently used (Figure 97). The following procedure is used in installing one:

1. Shut door and use a scribe to mark a line on the inside of the door 1.6 cm (5/8 in) up from the surface upon which the threshold is to be mounted.

2. Pull the hinge pins on the door and cut the door off, following the line, and level it 3 mm (1/8 in) to the outside to slide over the threshold first and compress the vinyl insert as the door is closed.

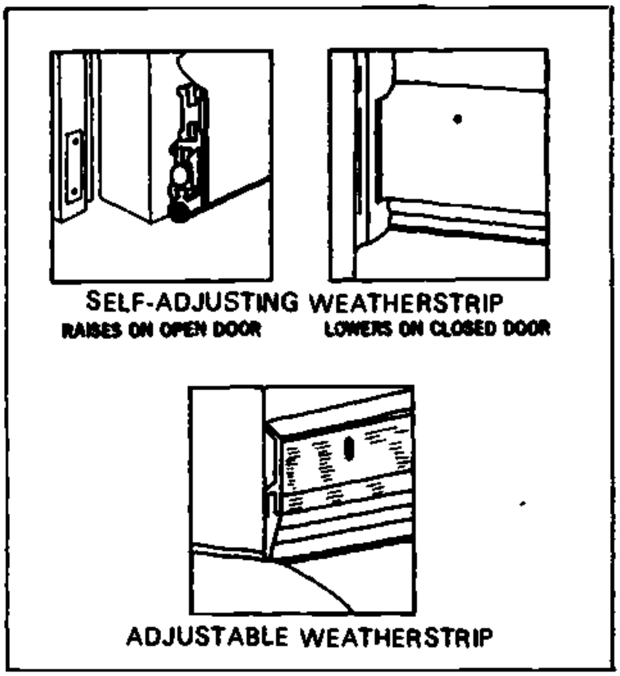


FIGURE 96. Adjustable threshold.

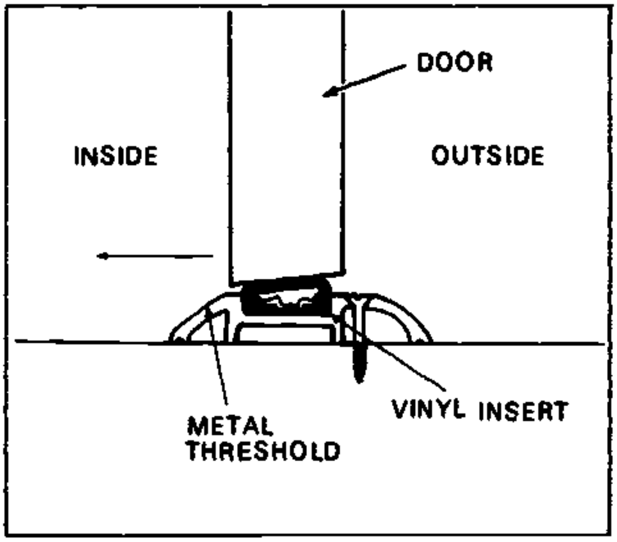


FIGURE 97. Aluminum threshold with compression seal.

3. Measure between the door and mark the threshold.

   Try to leave screw holes near the ends of the threshold if possible.

4. Use hacksaw to cut off threshold to length.

5. Install threshold with screws to floor.

6. Cut and install vinyl insert.

7. Check door for ease of closing and threshold for seal.

b. Weatherstripping Windows

Casement, awning, hopper, and fixed windows are easy to apply weatherstripping to because all weatherstripping can be applied from the same side. Casement and awning windows could have weatherstripping applied on the inside. Hopper and fixed windows would have it applied on the outside. Other openings that have removable covers such as attic access doors and disappearing stair units may also have to be weatherstripped.

For double-hung and sliding windows, proceed as follows:

1. Nail spring metal inserts into the sash channels and spring metal flashing to the bottom of the lower sash and inside edge of upper meeting rail (Figure 98).

2. Stick adhesive-backed foam to the bottom rail of the lower sash, the exterior of the meeting rail of the upper sash, and to the parting bead (Figure 99).

3. Vinyl weatherstripping may be nailed to the same surfaces. Apply it to the bottom rail of both the lower and upper sash (Figure 100).

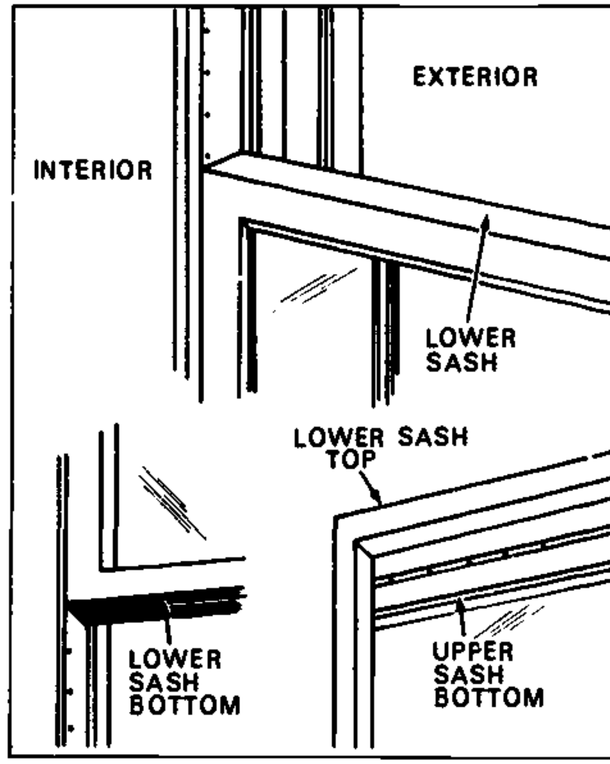


FIGURE 98. Spring metal inserts for double-hung windows.

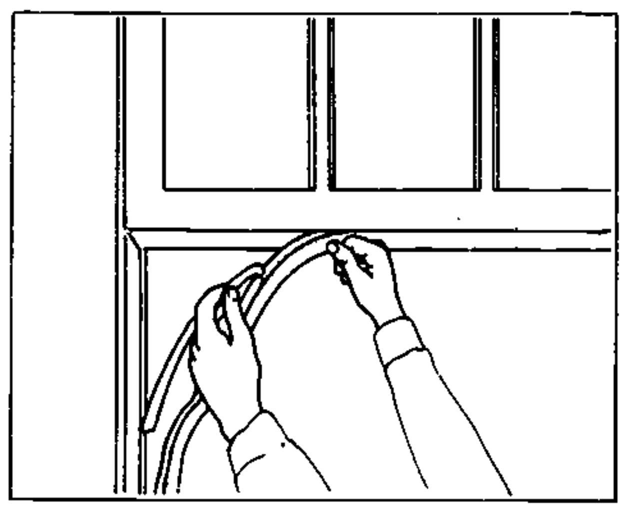


FIGURE 99. Adhesive-backed foam applied to bottom of window sash.

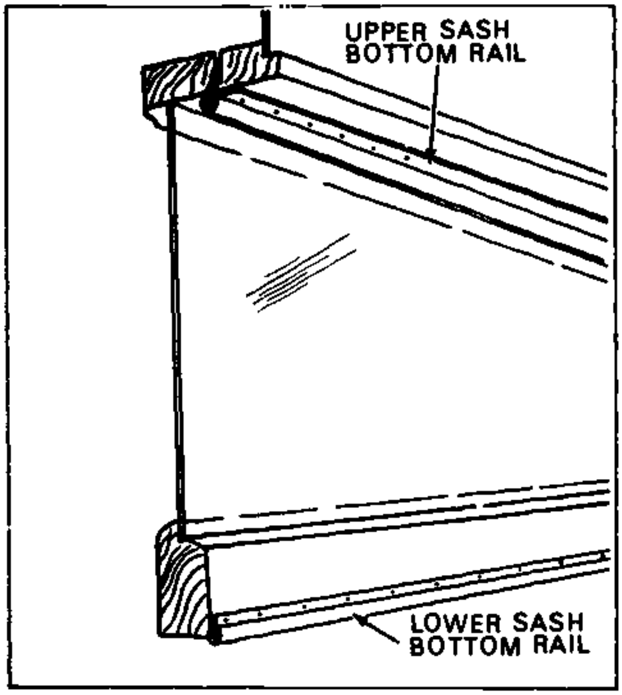


FIGURE 100. Vinyl weatherstripping.

2. INSTALLING CAULKING

Caulking can protect against infiltration and retard heat loss through cracks in the house as well as protect the structure from insects and moisture.

Any time there is a crack between two different parts of a house, it should be caulked. Figure 101 shows some of the places where a house should be caulked.

The following steps should be carried out when applying caulking:

1. Use a wire brush, scraper, or chisel to clean out old caulking.

2. Large cracks may have to be packed with oakum.

3. Use solvent to clean area.

   Also be sure that area is not wet.

4. Cut tip off nozzle of caulking tube at 45-degree angle.

   The farther up the tip that the cut is made, the larger the bead of caulking will be. Caulking should lap both sides of the crack.

5. Insert rear of tube into gun first and drop nozzle into slot in front of gun.

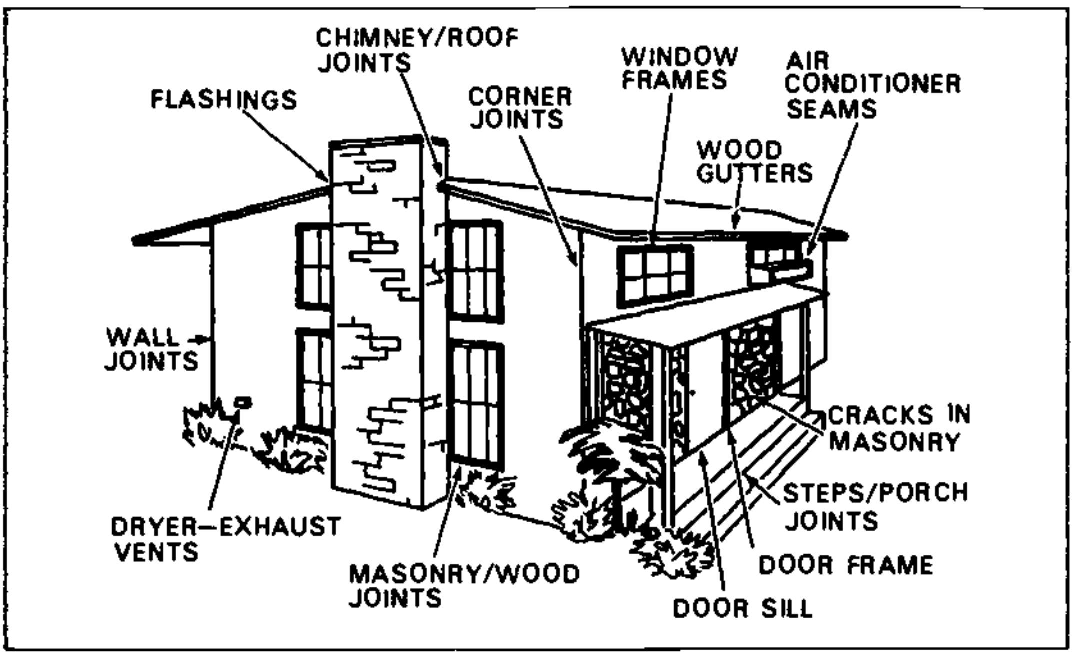


FIGURE 101. Places where caulking may be needed.

6. Push a sharp object into the nozzle to break the plastic seal at the base of the cartridge.

7. Hold caulking gun at a 45-degree angle to the surface to be caulked (Figure 102).

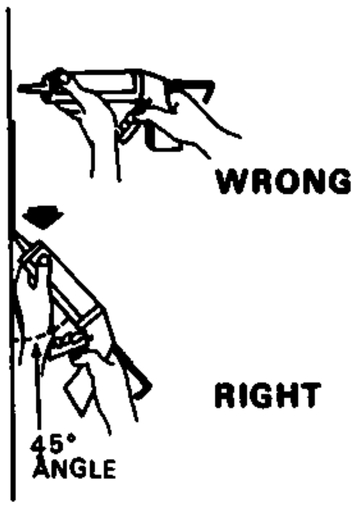


FIGURE 102. Proper use of caulking gun.

8. Squeeze trigger of caulking gun with slow, even pressure until caulking begins to come out of end of nozzle.

9. Move nozzle slowly and steadily along the crack, allowing the tip to form the bead of caulking.

   Do not let the tip of the nozzle smear the caulking. Your goal is an even and neat-looking job. Move the gun from top to bottom, and for right-handed people, from left to right.

   It will take practice to get proficient with a caulking gun but do not get discouraged. The best bead is made in one steady, continuous pass. Start in an inconspicuous place and do not be afraid to clean up a few of the first tries and start again.

10. When a crack is finished, remove the gun and release the pressure on the caulking tube by twisting the plunger rod to disengage it from the trigger ratchet.

D. Installing Storm Windows and Doors

The heat loss through a single thickness of window glass is about five times as great as the heat loss through an ordinary wall structure without any insulation. Therefore, rather large amounts of energy can be saved by reducing heat loss through the windows and doors. On completion of this section, you will be able to install storm windows and doors properly.

Procedures are given under the following headings:

1. Installing Storm Windows.
2. Installing Storm Doors.

1. INSTALLING STORM WINDOWS

Procedures are given under the following headings:

a. Glass With Wood Frames.
b. Glass With Aluminum Frames.
c. Rigid Plastic.
d. Flexible Plastic.

a. Glass with Wood Frames

Proceed as follows (Figure 103):

1. Measure old window frames.

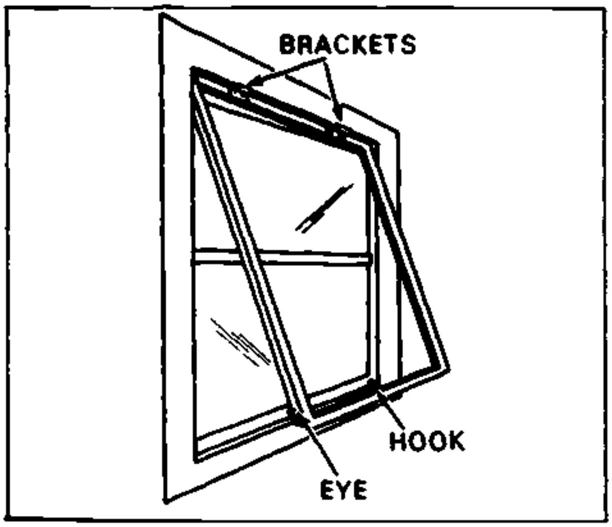


FIGURE 103. Installing glass storm window with wood frame.

2. Have new frame made at your builder supply company.

3. Trim to fit.

   Use old window to mark new one. Note that each window in an old building may be of different dimensions.

4. Paint new frames.

5. Install in same manner as old windows.

b. Glass with Aluminum Frames

Storm windows for casement, awning, and hopper windows are purchased as a piece of glass with an aluminum frame around the edge. They are fastened to the inside or outside of the sash. In some brands of windows, they merely snap into place and are called RDG's or removable double glazings.

It is possible to use combination storm windows or RDG's in combination with insulating glass to form a triple glazing. While double glazing will cut the heat loss almost in half, the triple glazing will cut it down to nearly a third of what a single layer of glass will lose.

Aluminum combination storm windows include two storm sashes and one screen. They come as double-track units that have an upper storm sash and lower screen in the outside track and a lower storm sash that raises for ventilation in the inside track. Triple track units have separate tracks for each sash and the screens. They have the advantage of allowing ventilation from the top of the window as well as from the bottom. Aluminum combination storm windows can be used only on double hung and horizontal slider windows because they do not open out. To install them, the following procedure is used (Figure 104):

1. Measure the windows according to the instructions of the dealer.

2. Trim to fit if needed.

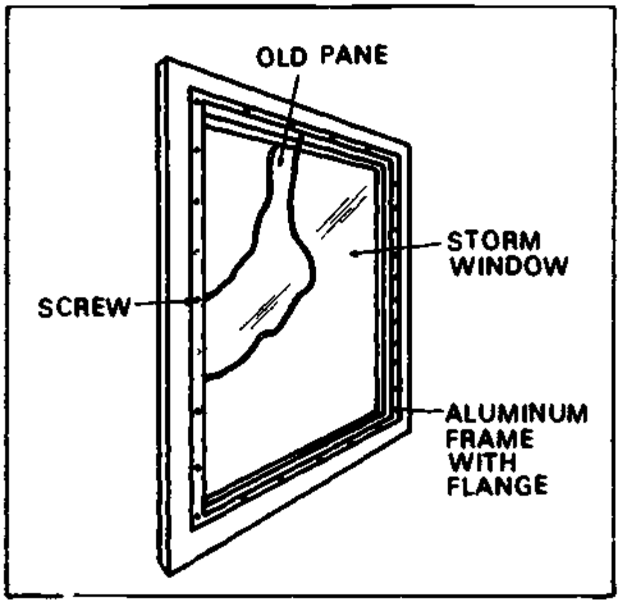


FIGURE 104. Installing aluminum framed storm window.

Windows should come trimmed to size and pre-drilled for screwing them into place. If part of the frame must be trimmed to fit, most aluminum storm windows have a series of grooves along each edge to help you. Use a tin snips to start a cut at one of these grooves, grasp the cut end with pliers, and pull. The metal will rip off along the groove.

3. Place the storm against the window frame and adjust it so that the exposure is even on both edges and the storm is level and square.

4. Mark the location of two holes on opposite sides of the frame.

5. Unless you have help to hold the storm, take it down and make lead holes for the screws.

   This job can be done with a drill, an awl, or a nail and hammer.

6. Caulk the window frame where the storm will fit.

7. Put the storm back up and put the two screws in to hold the storm in place.

8. Put in the rest of the screws.

9. Clean away the excess caulking.

10. Check to see that the vent holes or notches in the storm window frame at the sill are clear of caulking.

    These are present to allow condensation that collects on the sill to run out. If the condensation cannot get away, it will cause the sill to rot.

c. Rigid Plastic

One brand of single pane storm windows of rigid plastic is installed in the following manner (Figure 105).

1. Measure windows.

2. Cut frame moldings.

   For windows with stools, cut two frame moldings to the height dimension and one frame and one sill molding 2.9 cm (1 1/8 in) shorter than the width measurement.

3. For windows without stools, cut two frame moldings to the height measurement and two frame moldings to the width measurement.

4. Score and snap plastic.

   For windows with stools score and snap the rigid plastic 1.3 cm (1/2 in) shorter than the width measurement and 1.0 cm (3/8 in) shorter than the height measurement. For windows without stools, the rigid plastic is scored and snapped 1.3 cm (1/2 in) shorter than each measurement.

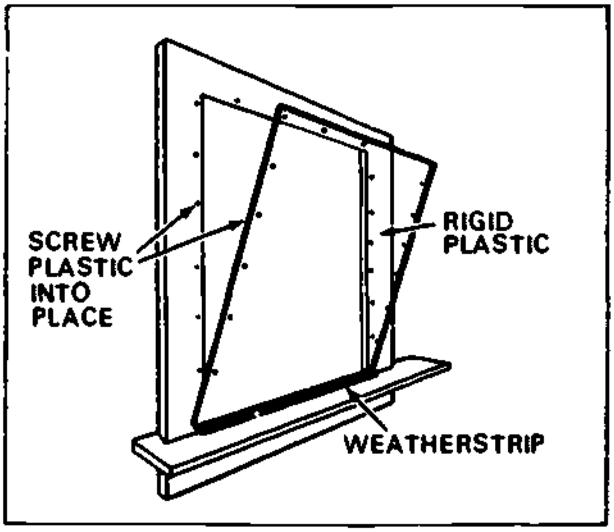


FIGURE 105. Installing rigid plastic storm window.

5. Remove protective film from rigid plastic and slip frame members onto its edge.

   Be sure that both the inside of the window and the inside of the rigid plastic are clean.

6. Clean the assembled storm window for fit.

7. Remove the protective cover from the adhesive and press the window into place on the inside of the window casing.

   Some frames are made to screw into place instead and can be fastened to the outside of the window as well.

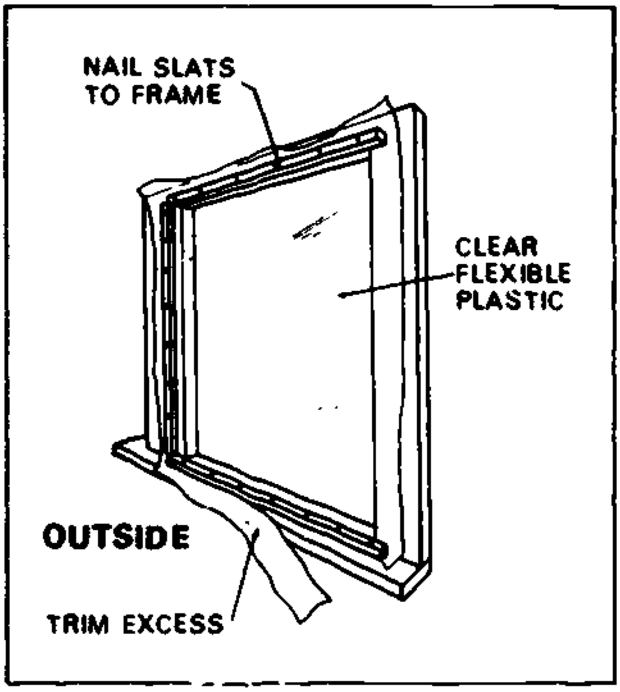


FIGURE 106. Installing flexible plastic on outside of window.

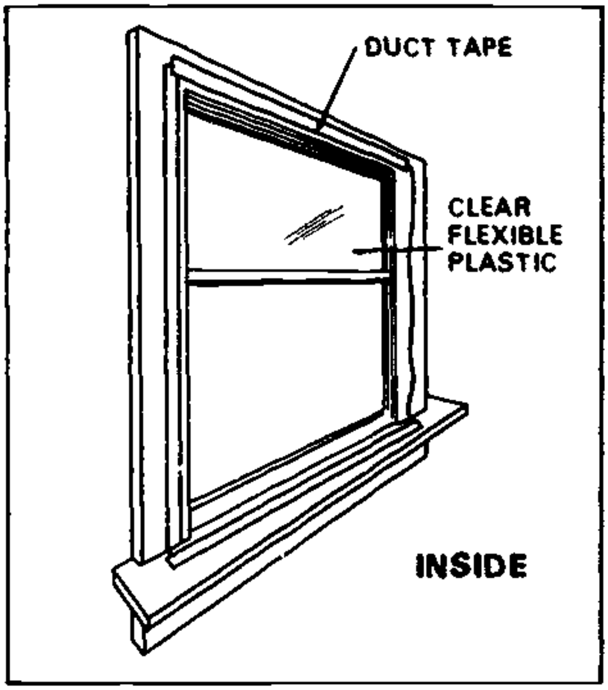


FIGURE 107. Installing flexible plastic on inside of window.

d. Flexible Plastic

Flexible plastic may be installed on either the outside or inside of the window. Procedures are given under the following headings:

(1) Outside Installation.
(2) Inside Installation.

(1) OUTSIDE INSTALLATION. Proceed as follows (Figure 106):

1. Purchase 2.5 cm (1 in) wood slats.

2. Measure width of widest window and total length of all windows and purchase the number of linear meters (feet) of .15 mm (6 mil) polyethylene film that is needed.

3. Cut plastic 10.2 cm (4 in) oversize.

4. Nail the slat across the top of the window frame with the plastic beneath.

5. Nail the slat to the sill with the plastic pulled tightly beneath the slat.

6. Nail the slats to the side window frames, trying to get the wrinkles out of the plastic as you do.

7. Trim the excess plastic off with a utility knife.

(2) INSIDE INSTALLATION. Proceed as follows (Figure 107):

1. Measure windows and purchase plastic.

2. Purchase duct tape.

3. Cut plastic 5.2 cm (2 in) oversize.

4. Put tape along the top edge of the plastic with 1.3 cm (1/2 in) of tape beyond the edge.

5. Fasten tape to the top casing.

6. Put tape along bottom edge of plastic, bend bottom 1.3 cm (1/2 in) of plastic and stick tape to sill.

7. Put tape along both sides of the window to hold plastic firmly in place.

2. INSTALLING STORM DOORS

The R-Value can almost be doubled by placing a wood storm door over a wood exterior door. The aluminum storm door will perform only half as well, but if it has good weatherstripping, it will cut down greatly on infiltration. Procedures are given under the following headings:

a. Installing Wood Storm Doors.
b. Installing Aluminum Storm Doors.

a. Installing Wood Storm Doors

Wood storm doors are hung to the brick mold or the outside casing of the door. Briefly, these are the steps (Figure 108):

1. Trim the storm door to fit the opening, making it 3 to 5 mm (1/8 to 3/16 in) narrower and shorter than the opening.

   If the opening is not square, be sure to make the door fit any variations.

2. Mark the location and outline of the hinges on the edge of the door and inside edge of the brick mold or the outside casing.

3. With a chisel, cut the gains for the hinges into the edge of the door and inside edge of the brick mold or the outside casing.

4. Slip the pins out of the hinges and screw each half of the hinge into place.

5. Put the door up and put the pins back into the hinges to hold the door into place.

6. Install the latch according to the instructions.

7. Install and adjust the door closer and wind check according to the instructions.

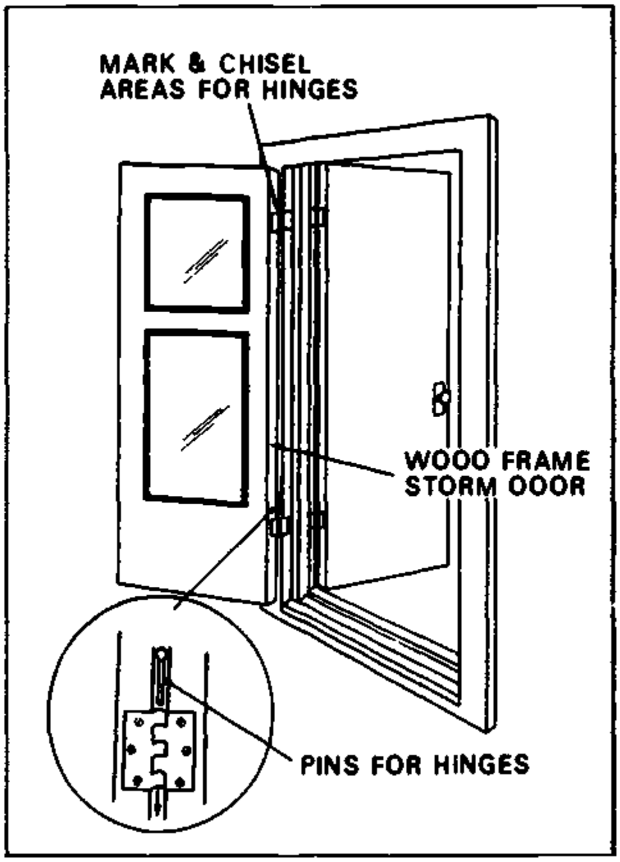


FIGURE 108. Installing wood storm door.

b. Installing Aluminum Storm Doors

Aluminum storm doors are usually purchased pre-hung, meaning that the aluminum door is already hung to a frame around both sides and the top. The frame pieces are called Z bars. There will be spaces between the frame and the door. Leave them there until the door is set in place. The following steps are taken when hanging an aluminum storm door (Figure 109):

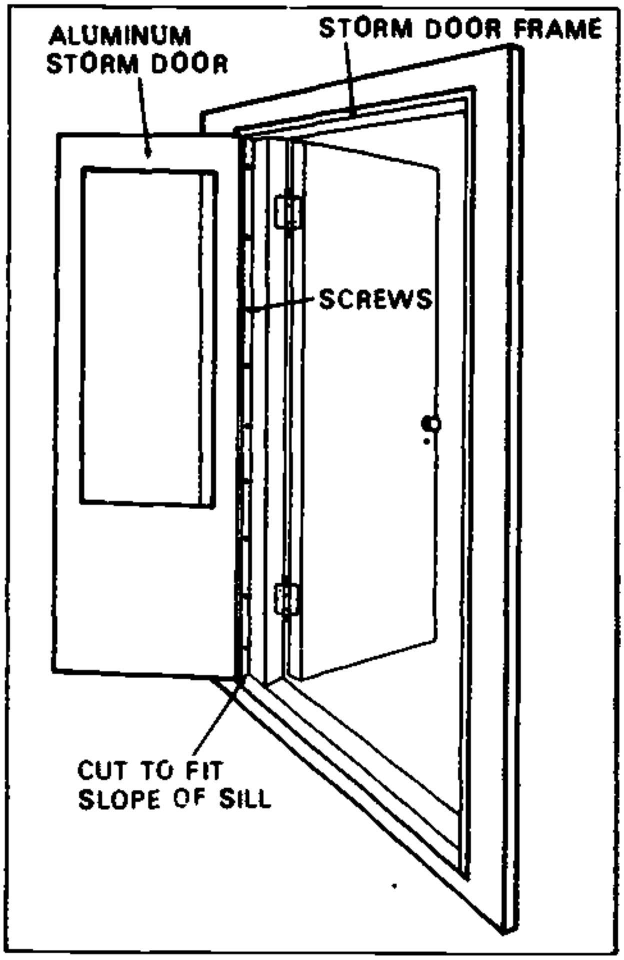


FIGURE 109. Installing aluminum storm door.

1. Measure the opening between the inside edges of the brick mold or outside casing for the width and between the inside edge of the head trim and the door sill for the height.

   Check the frame for squareness also.

2. Check the width and length of the storm door frame to see if it will fit the opening.

3. Measure along the side frames and mark them to the proper length.

4. Cut the bottom ends off the side frames (Z-bars), square across the front and about 3 mm (1/8 in) shorter in the back.

   This type of cut will give them an angle that will correspond with the slope of the door sill.

5. Put the door and frame assembly into the opening, center it and screw it into place with 4 screws.

6. Remove the spacers from between the door and frame into the trim.

   Also drive three screws through the edge of the frame on the hinge side into the trim.

7. Install the door latch according to the instructions.

8. Install the automatic door closer according to the instructions.

9. Install the wind check unit according to the instructions.

10. Adjust the automatic door closer and make sure the door closes freely, latches, but does not hang.

III. Improving Efficiency of Equipment

Because the emphasis upon consuming energy is rather recent, many of the energy consuming systems that we have are not as efficient as they could be.

There are two basic things that can be done to all heating systems using fossil fuels:

- The flue from the furnace to the chimney may have a heat recovery unit installed so that less heat will be lost up the chimney. Be careful, however, not to cool the gases so much that the proper draft is not maintained in the chimney.

- Have an automatic ignition system installed on a gas or oil furnace to replace the pilot light. Over the period of a year, the pilot light consumes rather large amounts of energy.

Some of the improvements mentioned here are simple and inexpensive; others will be quite costly and time consuming. In this section, suggestions are given as to how some systems can be made more efficient. The areas to be covered are discussed under the following headings:

A. Improving Efficiency of Heating Systems.
B. Improving Efficiency of Cooling Systems.
C. Improving Efficiency of Ventilating Systems.
D. Improving Efficiency of Lighting Systems.
E. Improving Efficiency of Plumbing Systems.
F. Improving Efficiency of Appliances and Equipment.

A. Improving Efficiency of Heating Systems

Anything that can be done to improve the efficiency of heating systems will make the energy dollar go farther. From your study of this section, you will be able to describe methods of improving efficiency of equipment. The following topics will be discussed in this section:

1. Fireplaces.
2. Stoves.
3. Forced Air Systems.
4. Hot-Water Systems.
5. Heat Pumps.

1. FIREPLACES

The majority of fireplaces are very inefficient sources of heat. Considering the amount of heat lost through leaky dampers when the fireplace is not being used, they may waste more heat than they produce, even if they are used frequently.

Fireplaces are discussed under the following headings:

a. Existing Fireplaces.
b. New Fireplaces.

a. Existing Fireplaces

Most existing fireplaces are either of complete masonry construction (sometimes called natural fireplaces) or of masonry with a prefabricated fire chamber. Within the last few years, the totally prefabricated fireplace and chimney have been gaining in popularity. Each of these categories will be discussed separately.

The existing natural fireplace is the most difficult to modify in any way. There are large amounts of masonry surrounding the fire chamber and a great deal of weight being supported by the structure. One thing, however, that can be done is to install a tempered glass screen with doors across the fireplace opening (Figure 110). To lessen the amount of heat loss up the chimney when the fireplace is not in use, keep the doors closed. The damper must be kept closed when not in use and the chimney should be checked periodically to make sure that it is not obstructed or partially blocked.

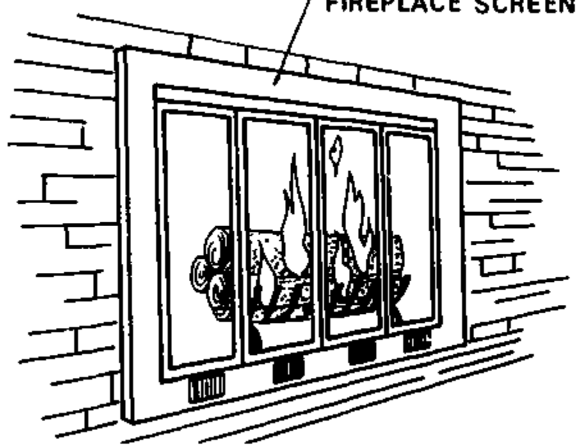


FIGURE 110. Tempered glass screen helps control heat in a fireplace.

b. New Fireplaces

In new construction, the placement of the fireplace will help determine the amount of heat gained from it. Fireplaces that are completely within the structure of the building will tend to radiate heat from the masonry to the house for long periods of time after the fire has gone out. Fireplaces on outside walls will radiate a great deal of this heat to the outside and also create insulating and caulking problems.

Any fireplace will be much more efficient if combustion air (called make-up air) can be provided directly from the outside (Figure 111). This air keeps the fireplace from drawing heated air from the building to provide air for combustion and to carry the smoke and other products of combustion up the chimney. When make-up air is drawn from the building, infiltration is increased and more outside air must be heated in order to keep the house warm. If an older house has had vapor barriers applied, has been weatherstripped, and has been caulked, the fireplace may start to smoke. The sources of make-up air through infiltration have been stopped and adequate draft can no longer be provided. The same will be true of new houses that have been made as energy-efficient as possible.

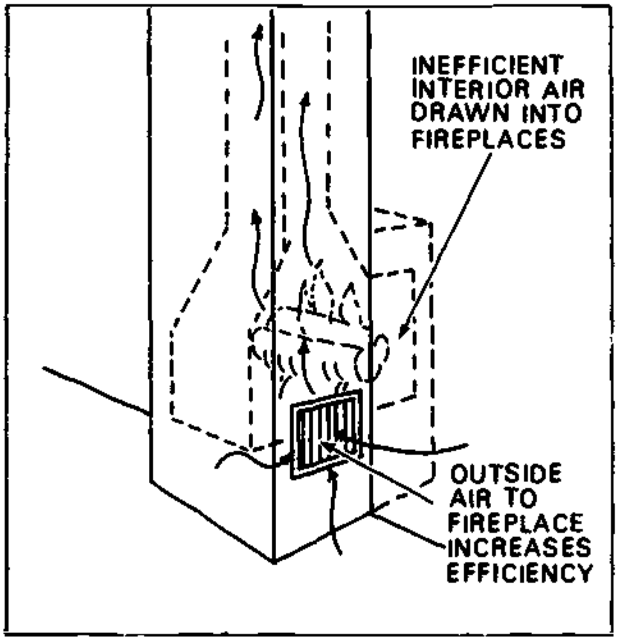


FIGURE 111. Make-up (outside) air should be provided for fireplaces.

The make-up air duct size will vary according to the flue size of the chimney. Care must be taken that the duct not be placed where it will be overheated by the fire in the fireplace and cause a fire in the structure of the house. A damper in the make-up air line will enable it to be closed when the fireplace is not in use.

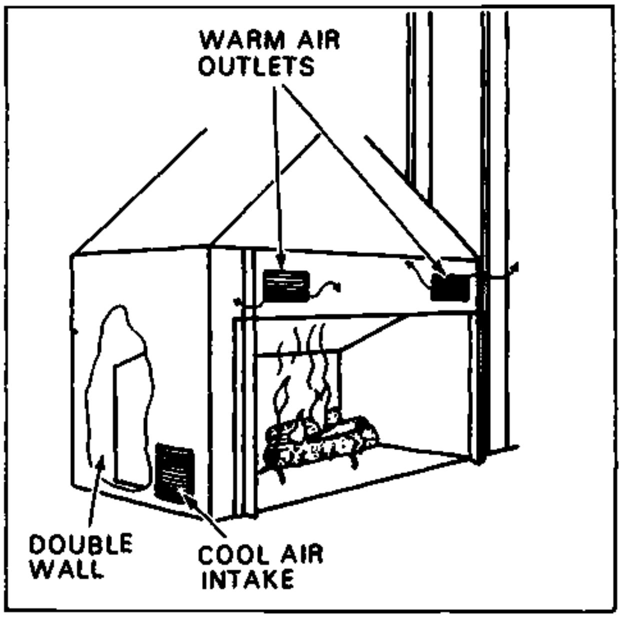


FIGURE 112. Prefabricated fire chamber for fireplace.

Prefabricated fire chambers have double steel walls (Figure 112). The air between is heated and moved into the room by convection or with a blower. Usually, there will be four openings in the front or sides of the face of the fireplace. The lower ones take cool air from the room into the double wall area and the heated air comes out of the upper ones. Air can even be moved to other rooms or levels of the building by using ducts and blowers.

Prefabricated fireplaces and chimneys are much easier to install, cost less, and are now engineered so that provisions have been made for make-up air, extra tight dampers and the heating of air in a double-walled fire chamber. They are constructed so that they can be placed right against the wood framing (Figure 113). This is the zero clearance feature. In many brands, this is accomplished by circulating cool outside air in two spaces between the outside wall of the fireplace or chimney and the inside one. The framing of the area in which the fireplace sits must be well insulated to prevent fire.

FIGURE 113. Prefabricated fireplace.

If you are going to install your own prefabricated fireplace, be sure to follow the instructions from the manufacturer to the letter so that you will have a safe and efficient fireplace that will last for many years.

2. STOVES

There are three basic things that can be done to improve the efficiency of stoves and space heaters. They are as follows (Figure 114):

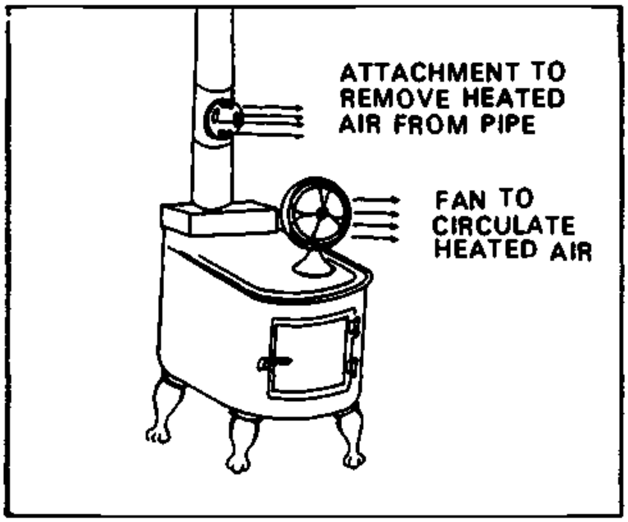


FIGURE 114. Attachment for improving the efficiency of a space heater or stove.

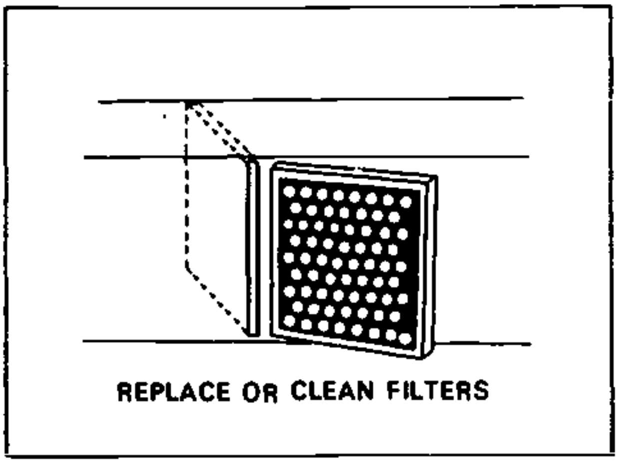


FIGURE 115. Keep furnace filters clean.

1. Make sure that the stove has enough make-up air for proper combustion.

2. Purchase an attachment to replace part of the stove pipe that will remove more heat from the stove pipe before the gases pass up the chimney.

CAUTION: Excessive cooling of the fire gases may cause improper venting of the flue gases.

3. Place a low speed fan near the stove to circulate the heat to other parts of the room.

3. FORCED AIR SYSTEMS

Forced air systems can be improved in efficiency by several methods. They are as follows (Figure 115):

1. Keep the furnace filters clean.

   When the filters become clogged or even partially clogged, the furnace cannot circulate the air through the furnace fast enough to carry away the heat produced, causing more heat to be lost up the chimney and thus making the furnace less efficient.

2. Have the furnace checked and adjusted periodically to be sure that the burner, if it is an oil or gas fired furnace, is operating at peak efficiency.

3. Duct make-up air directly from the outside to the fire chamber of the furnace.

4. Check the efficiency rating of your furnace.

   When installing a new furnace, shop for the most efficient for your area.

4. HOT-WATER SYSTEMS

Hot-water systems may be of two kinds: The gravity fed system and the forced hot-water heating system.

The reason that gravity hot-water systems are not being installed today is that the pipes and radiation units required are so large and the system contains so much water. Therefore, the temperature fluctuates greatly in the spring and fall. In the early morning hours, heat is called for and the system is heated up; as the morning progresses and heat is no longer needed, the system has not cooled sufficiently so the house is overheated. Heat is wasted because doors and windows must be opened to cool the house for comfort. Many times the system can be up-graded by replacing the old style radiators with baseboard radiation tube units or convector cabinets on the same piping system and including zone pumps at the boiler.

The forced hot-water system will probably be a rather efficient system as it is. It sometimes may be improved by placing insulation on pipes where the heat lost from the pipes is not needed.

In either of these systems, it is very important that all air be bled from the system to keep from having air locks in the pipes.

5. HEAT PUMPS

Heat pumps are merely refrigeration units that gather heat from the outside air or a source of water by having the cooling coils (evaporator) in one of those mediums. The condenser coils (like those usually seen beneath or on the back of a refrigerator) are placed in a fan cabinet through which air is circulated.

The main thing that can be done to improve their efficiency is to keep both the evaporator and condenser coils clean and free of dust and dirt (Figure 116), in order to allow for a free exchange of heat at both locations.

When purchasing a new heat pump, compare the efficiencies of different systems.

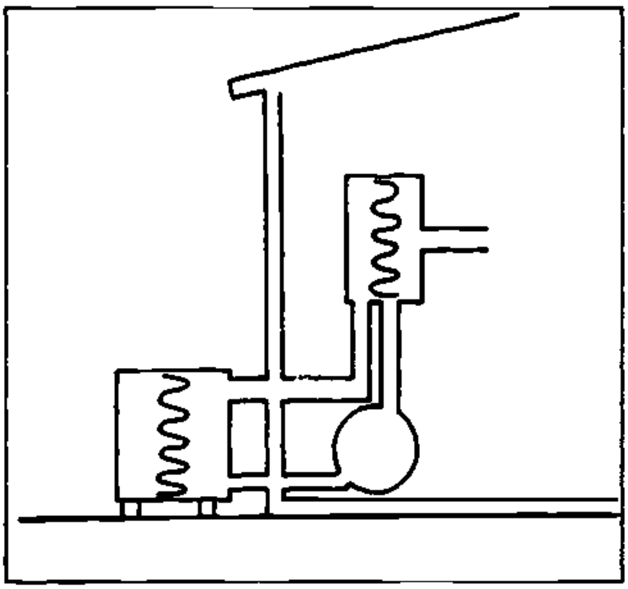


FIGURE 116. Keep heat pump coils clean.

B. Improving Efficiency of Cooling Systems

Air conditioning or cooling systems work the reverse of the heat pump mentioned in the preceding section. The evaporator coils are in the fan cabinet and the compressor and condenser unit are outside. Again, it is very necessary that the evaporator and condenser be kept clean and free of dust and dirt. The condenser unit must also be in a location where a free flow of air is possible and where it will not be subjected to long periods of direct sunlight.

All ducts from the fan cabinet to the register should be well insulated to cut down on condensation and heat gain. Keep filters clean.

C. Improving Efficiency of Ventilating Systems

Ventilating systems will consist of a fan, duct work and usually some type of air filter. The fan should be checked to see that the belt, connecting it with the electric motor that drives it, is in good condition and is not slipping. If the fan has a variable speed pulley system, the fan should be checked and/or adjusted for the proper speed. Intake and exhaust grills on the duct system should be cleaned and checked for obstructions. Finally, the air filters should be kept clean and free from dust.

D. Improving Efficiency of Lighting Systems

Wherever possible, use fluorescent lighting for general lighting because much more light is produced by the same voltage.

The use of light colors that reflect rather than absorb light will increase the efficiency of the lighting system. The strategic placement of windows will also help.

The efficiency of lighting systems can be improved by planning the lighting in each room so that any area of the room will be lighted separately as it is needed. This plan is called task lighting. Less light is required for lighting a small area than is required to light a whole room, so that a person can see well in any part of the room.

E. Improving Efficiency of Plumbing Systems

Plumbing systems consume energy in two ways: by requiring energy to pump the water, either from a private well or in a public system, and by using energy to heat water for the many activities in the home. The following items will be discussed:

1. Installing Insulation Around Hot Water Pipes.
2. Installing Insulation Around Hot Water Heaters.
3. Installing Pressure Reducer and Other Water-Saving Devices.
4. Checking for Leaks.

By taking some time and spending a rather small amount of money, a significant amount of energy may be saved in this area.

1. INSTALLING INSULATION AROUND HOT WATER PIPES

Uninsulated hot water pipes waste energy in two ways. First, water that is heated cools in the pipes and in summer the heat adds to the cooling load. Secondly, the cool water must be drawn from the pipes and this water is usually wasted. Therefore, it is best that all hot water pipes be insulated to where the pipes come through the wall.

The pipes may be insulated by purchasing a kit containing a roll of narrow fiberglass insulation and tape that wraps around the outside to protect the fiberglass. First the fiberglass is wound around the pipe and then the tape is wound the opposite direction to hold the fiberglass in place (Figure 117).

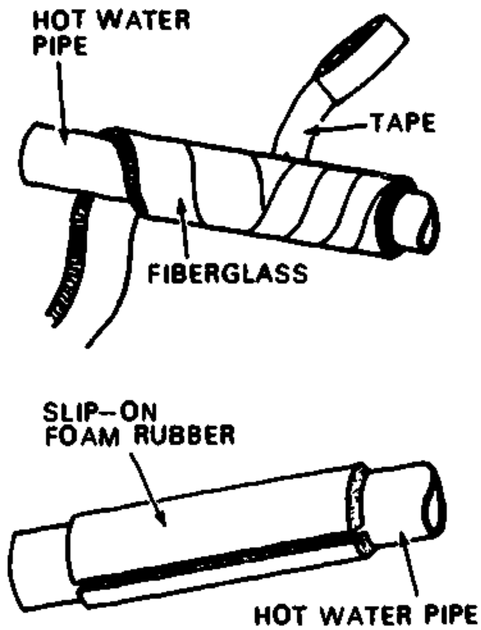


FIGURE 117. Insulating water pipe.

Another kind that is more easily installed is the pre-formed slip-on foam insulation (Figure 117). It comes formed in a tube shape and is split lengthwise so that it can be slipped over the pipe. Merely slip it over the pipe, press it together and tape it unless it happens to be the self-sealing type. Fittings and valves may still require the use of the wrap-around insulation.

2. INSTALLING INSULATION AROUND HOT WATER HEATERS

Although hot water heaters are insulated, they can be made to keep the water they hold hot longer by adding extra insulation to the outside.

Use duct tape to tape 7.6 cm (3 in) batts or blankets of insulation with a paper or foil facing to the outside of the water heater. It is possible to purchase insulation kits for this purpose or to purchase duct insulating blankets which look neater than regular blanket or batt insulation (Figure 118). Caution: On gas or oil water heaters, do not insulate the top of the heater as it may interfere with the draft's going to the flue. Also, do not insulate the bottom as it could cut off the air needed for combustion.

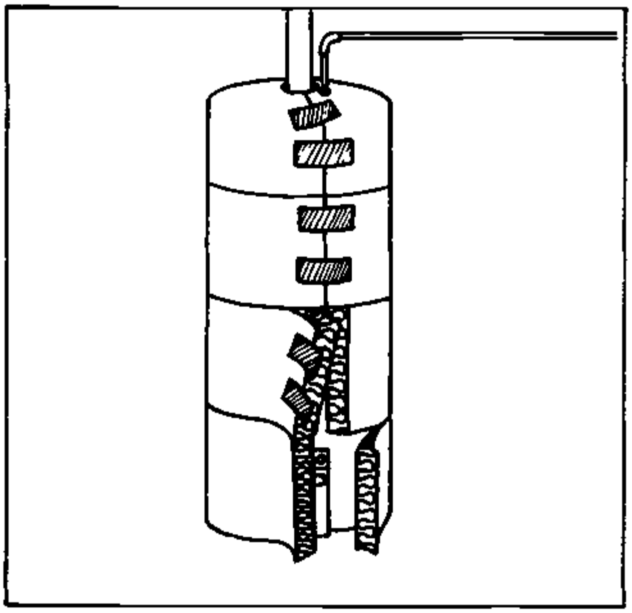


FIGURE 118. Insulate hot water heater.

3. INSTALLING PRESSURE REDUCER AND OTHER WATER-SAVING DEVICES

The conservation of water is another way to save energy.

For most purposes, no more than 276 kPa (40 psi) of water pressure is needed in a building. Greater pressure merely wastes water. If there is a private water system, the pressure control switch at the pump can be adjusted to control this problem. If a building is on a public water supply system and main pressures go above this point, a pressure reducing valve should be installed. This valve should be installed in the building supply line near the meter before any other pipes branch off (Figure 119). A strainer should be installed in conjunction with it to keep dirt out of the mechanism of the pressure reducing valve.

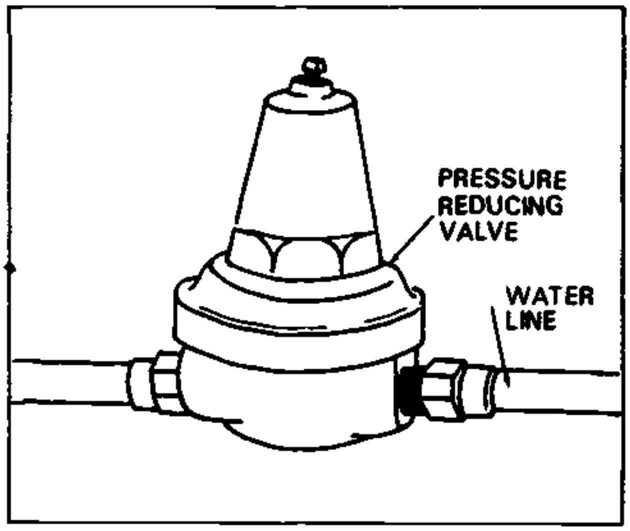


FIGURE 119. Pressure reducing valve.

Shower heads can also be purchased that are constructed so that the flow of water can be controlled and water conserved. To install one, merely remove the old shower head and screw the new one in place.

Toilets which use less water can be installed and many existing toilets will work just as well if a brick is placed in the tank to displace that volume of water.

4. CHECKING FOR LEAKS

Both hot and cold water pipes should be checked for leaks (Figure 120). Most leaks become readily evident due to dampness showing in the structure. In crawl spaces, however, a leak might continue undetected for long periods of time. Because of this fact, it is a good idea to check crawl spaces periodically.

The main sources of leaks that are ignored are dripping faucets at fixtures and toilet tanks that may have defective or improperly adjusted flushing and filling mechanisms.

A hot water faucet that drips may waste many Btu of heat as well as many gallons of water. Shut off the water supply to the faucet and change the faucet washer or O-rings depending upon the type of faucet it is. If the faucet can not be repaired in this way, then it must have the valve seal ground or be replaced. Most plumbing books give instructions for these operations.

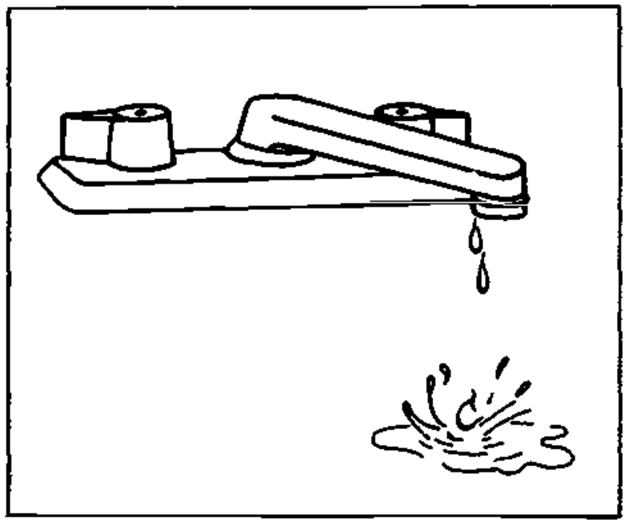


FIGURE 120. Stop dripping faucets.

Toilets that run continuously usually do so because of a defective or improperly seating tank ball or because the float is not adjusted to shut off the valve before the water reaches the top of the overflow tube. Again, refer to a plumbing book for the procedures to correct these problems.

F. Improving Efficiency of Appliances and Equipment

The first thing each person can do is to stop and think about whether every appliance on the market is necessary to own. Then decide what size is best. As an example, why buy a four slice toaster if most of the time no more than two slices are toasted at once. Electric refrigeration and food freezers that are frost-free consume much more energy, so think twice before purchasing them.

Gas cooking stoves with pilot lights may consume up to 1/2 of the total gas used. New gas appliances are avaiable with automatic igniters instead.

A microwave oven is more efficient than a regular one.

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