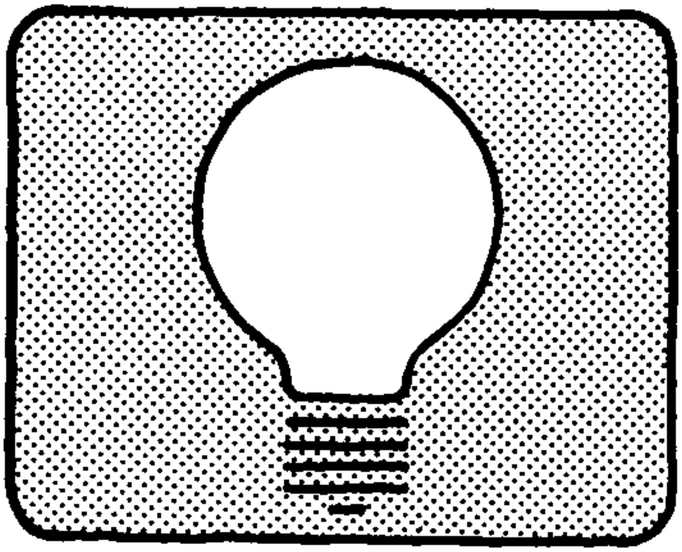
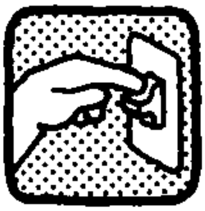
CHAPTER 2
DESIGN IDEAS

This chapter is an examination of the elements of comfort and a discussion of various design ideas that should be utilized in a passive solar home.



2.1 COMFORT

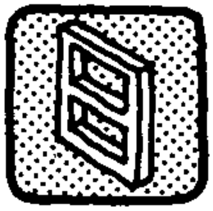
2.2 CONSERVATION



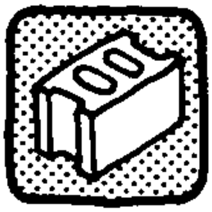
2.3 SITE PLANNING

2.4 INSULATION

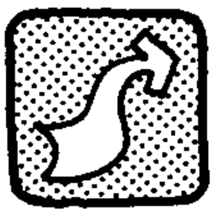
2.5 WINDOWS



2.6 MASS



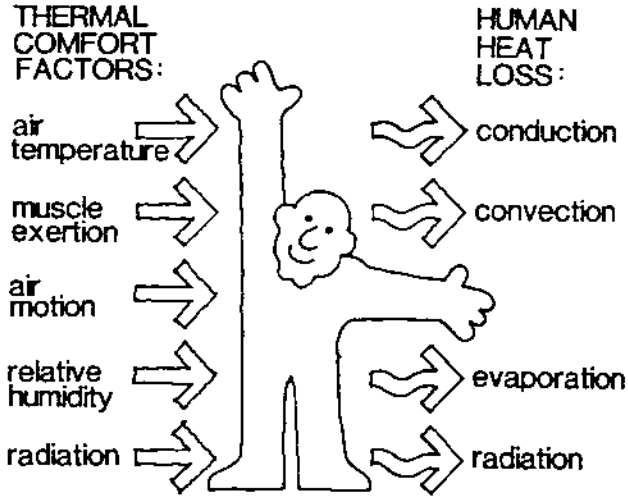
2.7 VENTILATION



2.8 MISCELLANEOUS

COMFORT

One of the primary functions of a well-designed house is to provide comfortable living space for its occupants and, therefore, it is important to look closely at the concept of comfort and some of the factors that influence how it is perceived. The focus of this section is on factors that affect feelings of warmth and coolness -- thermal comfort (FIG 2.1-1).



2.1-1 HUMAN COMFORT FACTORS

The human body is a heat generator that converts chemical energy from food that is eaten in a slow, controlled burning process. The rate of burning, and thus the amount of heat produced, depends on the level of physical activity, ranging from about 300 btus per hour for sleeping, to about 4000 btus per hour for heavy work. The human body is like any other system which produces heat -- if heat is removed from the system at a slower rate than it is produced, the temperature will rise. Conversely, if heat is removed faster than it is produced, the body will cool down. It is this rate of heat removal which is of obvious concern in the perception of thermal comfort.

The body loses heat in a number of ways. One of the most important is through convection. If the surrounding still air is cooler than skin temperature, the air is heated by the skin, and convects naturally, carrying away body heat. Moving air, such as a draft or breeze, enhances this effect by moving the air away more quickly.

Another major heat loss process of the body is radiation. Because skin is warm, it continually radiates energy. This effect can be partially or completely offset by the fact that the body is also absorbing radiation given off by all surrounding surfaces because, in general, warm surfaces radiate more energy than cool ones.

Finally, a significant amount of body heat is lost by the process of evaporation of skin surface moisture. When water evaporates, it absorbs heat in order to make the change from liquid to gas. The majority of this heat is taken from the skin, cooling it. One of the body's own automatic temperature regulating systems involves the production of skin moisture (perspiration) when extra cooling is needed.

A number of related factors that influence the heat loss rates by each of these mechanisms will be examined in more detail in the chapter (FIG 2.1-2). A good house design should try to maximize these factors when they are helpful and limit these factors when they are not helpful.

COMFORT

AIR TEMPERATURE

The most obvious factor which influences thermal comfort is surrounding air temperature. Lower air temperatures increase the driving force for convective losses, since the body/air temperature difference is greater. Convective losses diminish and decrease as the air temperature rises to and exceeds the skin temperature.

BODY HEAT GENERATION

The amount of heat that the human body can or must lose in order to maintain a comfortable skin temperature depends heavily on the amount of heat produced. This heat production is mainly determined by physical activity; the air temperature required for comfort is much lower when a significant amount of activity is involved.

AIR MOTION

Convective heat loss from the skin surface can be enhanced by "helping" the natural convection. Moving air picks up heat as it contacts the skin and removes it faster than natural convection, creating a perception of cooler surrounding temperatures. This forced convection effect is desirable in warm weather, when the moving air is called a "breeze", and undesirable in the winter, when it is called a "draft".

Moving air also affects the amount of evaporative cooling. Air which has already picked up moisture is removed and replaced by drier air more rapidly than with still air. Studies have shown that a significant cooling effect can be gained from air that is moving even at an imperceptible rate -- 10' to 50' per minute (about 0.1-0.5 MPH). The optimal direction seems to be from the front and above the subject.

HUMIDITY

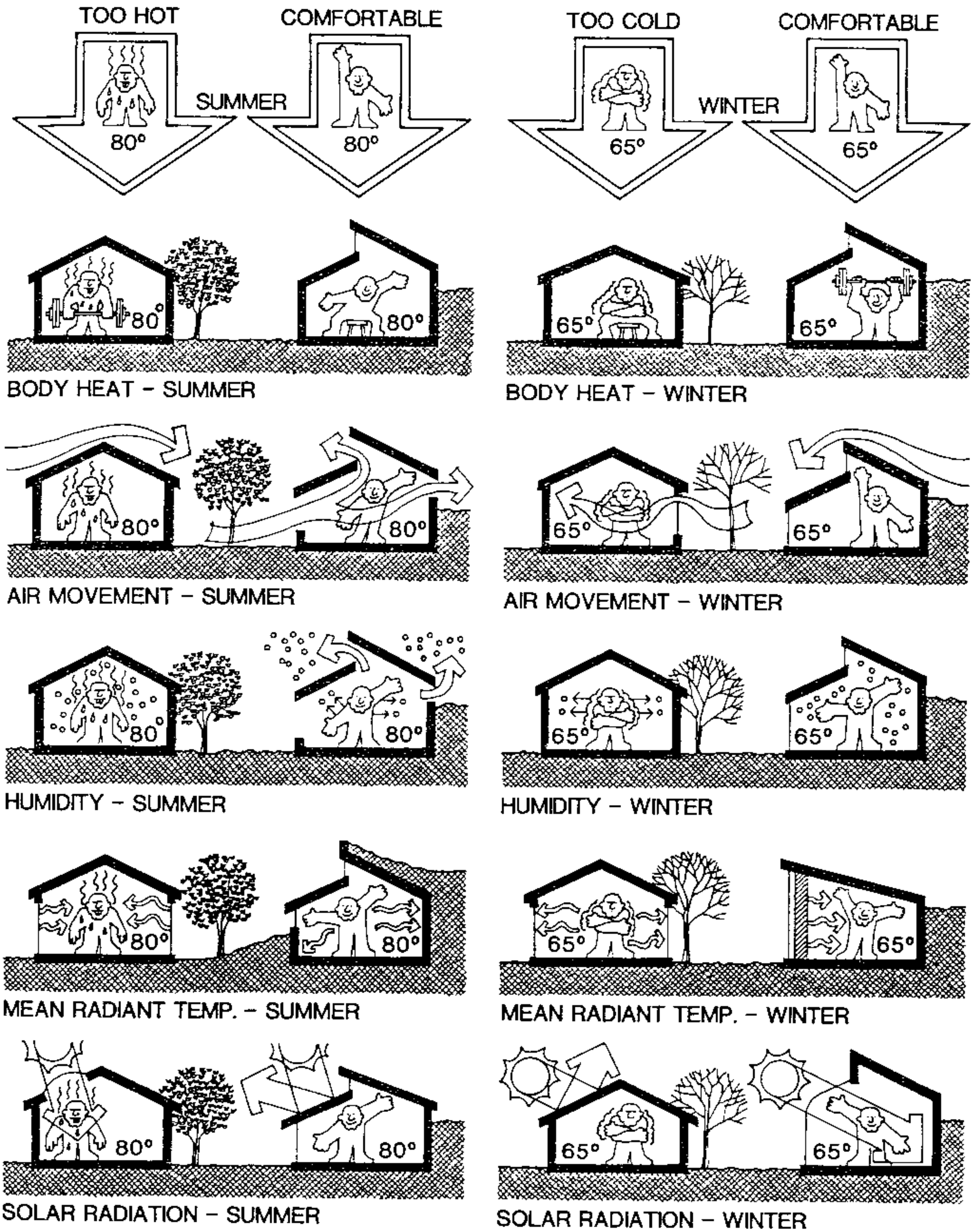
Humidity is a measure of the moisture content of air. The maximum amount of water vapor that air can hold depends on the temperature: the warmer the air, the more moisture it can hold. The relative humidity of air is the description, expressed in percentage, of the amount of water in the air compared to this maximum. For example, a relative humidity of 50% indicates that the air contains one-half the moisture that it can hold at this temperature.

Humidity affects the rate of evaporative cooling. Moisture-laden air does not readily absorb additional water vapor. Dry air, however, readily absorbs skin moisture, cooling the skin (FIG 2.1-3).

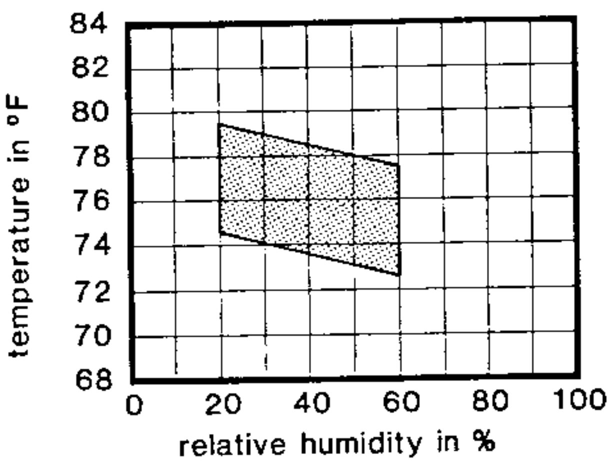
Although it would seem that a 0% relative humidity is desirable in summer, and 100% relative humidity is desirable in winter, this is not the case. Humidity values below 20% produce such problems as dry skin and hair, drying and cracking of furniture, and excessive static electricity. Very high humidity values give a "dank" or "muggy" feeling to the air. Humidity levels above 50-60%, even though comfortable, can cause winter moisture problems in the home, due to excessive condensation on windows and within walls.

In the winter months, particularly during very cold weather, indoor humidity levels can drop to a very low level, even when the outdoor relative humidity is high. This is because as outside air is heated, its total moisture capacity increases, while the actual moisture content remains the same. From the definition of relative humidity, it should be clear that the final humidity value must be lower than the outdoor value. For this reason, some sort of air humidification is a valid energy saver in the winter, as it can reduce body heat loss and thus allow a lower air temperature.

The summer months present the opposite problem in some areas of eastern Nebraska because of relatively humid summer conditions. Conventional refrigeration-type air conditioners and



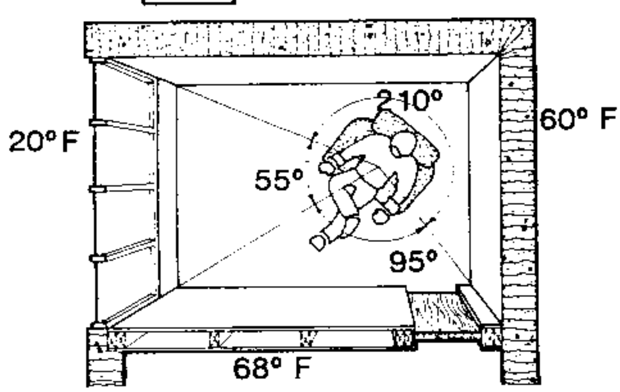
2.1-2 SEASONAL COMFORT FACTORS



2.1-3 COMFORT ZONE: TEMPERATURE VS. HUMIDITY

$$MRT = \frac{210 \times 60 + 95 \times 68 + 55 \times 20}{360}$$

MRT = 56° F



2.1-4 MEAN RADIANT TEMPERATURE

heat pumps usually alleviate the humidity problem by cooling the outside air to well below room temperature, so that much of the water vapor condenses on the cooling coils. This cold, low moisture air is then mixed and warmed with warmer room air, so that the final relative humidity is usually within comfortable limits.

MEAN RADIANT TEMPERATURE

As discussed earlier in this chapter, the human body loses significant amounts of heat by radiation. At the same time, it receives and absorbs heat energy radiated by all surfaces around it. If most or all of the surrounding surfaces are warmer than the skin, the body may have a net heat gain due to radiation. Conversely, if the body is surrounded by cold surfaces, it will experience a net heat loss due to radiation.

This concept is quantitatively described by the mean radiant temperature (MRT). The MRT is an expression of the average temperature of the surfaces surrounding a certain point (FIG 2.1-4). The temperature of each surface which is in direct view of the location of interest is multiplied by the angle covered by the surface from that viewpoint. These products are added and divided by 360 to give the average surface temperature, weighted for the extent of exposure. In these calculations, the ceiling and floor are normally ignored, a simplification which does not significantly compromise the value of the MRT as a prediction tool.

If a room has one wall at a temperature different than the other walls, the MRT will vary according to location in the room. In a room with one cold window, for example, points close to the window will show lower MRTs due to the larger angle of exposure to the window. A similar but opposite effect would be noticed if there were a hot radiator or stove in the room.

In a passive solar house, the MRT may be raised significantly by a warm thermal mass wall on one side of the room. A mass floor or ceiling would have the same effect, although this would not affect the simplified MRT calculation.

A drape or curtain hung over a cold window will moderate the MRT effect of the cold window, as the winter covering replaces the window as the radiating surface. The window covering will normally be closer to room temperature than the glass surface.

A better treatment of the cold window surface would be some type of inside insulating device, which not only raises the MRT, but also reduces conduction losses through the glass. These insulating devices work best if they fit tightly all around the window frames. (More about this kind of window treatment later in Chapter 2).

The advantage of a high MRT in the winter is that lower air temperatures can be used. In the summer, a low MRT can allow comfortable conditions with higher air temperatures (FIG 2.1-5).

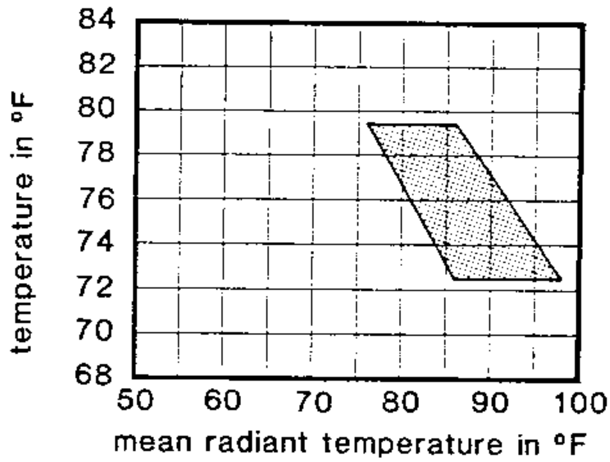
DIRECT SOLAR RADIATION

The effect of direct solar radiation on the body is, in reality, the effect of an extremely high MRT. Air temperatures of 40°F and below can feel comfortable in direct sunshine if other conditions are favorable.

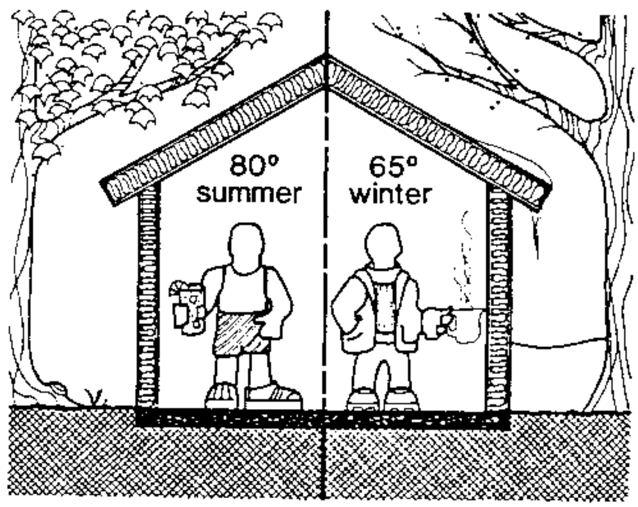
CLOTHING

Insulation helps to retain heat. Similarly, body heat can be conserved with clothes that are good insulators (FIG 2.1-6).

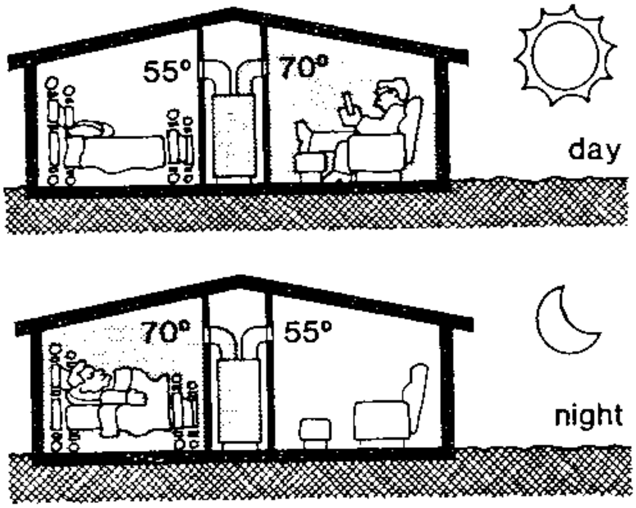
An extra sweater or jacket prevents body heat loss in several ways. First, it prevents significant convection losses by controlling air flow. Also, it drastically cuts radiation losses on parts of the body that are covered. Finally, it reduces evaporative cooling by controlling air movement next to the skin.



2.1-5 COMFORT ZONE: TEMPERATURE VS. MRT



2.1-6 DRESS FOR COMFORT



2.1-7 ZONED HEATING

TEMPERATURE ZONING

For all of the foregoing reasons, and because different areas of the home inherently are associated with different levels of activity, it seems reasonable that various areas of the home would have different temperature requirements. Kitchens, for example, are areas of relatively high activity which could benefit from a somewhat lower air temperature than a family room, where the main activity may be reading or watching television. Bedroom temperatures are subject to personal preference, but often can be lower than other living spaces (FIG 2.1-7).

Some kinds of heating systems, such as electric baseboard units, lend themselves well to room-by-room temperature control if individual room thermostats are installed. For this reason, and because they are very easy and inexpensive to install, baseboard units are a popular source of back-up auxiliary heat for solar homes. Such a system, with time-controlled thermostats, offers the most flexible programming of indoor space temperatures. Even without this type of automatic control, manual operation of thermostats and dampers in a forced air system can yield similar results.

Before investigating some of the methods used to optimize the solar performance of a house, it is important to discuss those techniques which make a house more energy efficient. All these techniques reduce the winter heating requirements of a home so that the smallest possible heating system -- whether solar, conventional, or a combination -- can be used effectively. Most of these conservation tips are equally applicable to existing homes (FIG 2.2-1).

1) Sill sealer. A sill sealer reduces heat loss between the foundation and the wood sill.

2) Weatherstripping. Air leaks around doors and windows -- even if they cannot be felt -- contribute significantly to infiltration heat losses. Replacement of damaged, worn, or missing weatherstripping can often make a noticeable difference in heating bills.

3) Airlock entry. As much as 10% of a home's total winter heat loss is due to warm air that exits every time an outside door is opened. These losses can be greatly reduced by using an airlock, or double door entry, properly designed so that only one door will be opened at a time.

4) Wall insulation. Insulation is a home's prime defense against heat loss. It is not uncommon to find older homes in Nebraska that have no wall insulation at all. This may have been a prudent and sensible way to build a home at a time when fuel was cheap and insulation was relatively expensive, but it makes no sense now.

5) Windows. Assuming reasonably well-insulated walls and ceilings, windows typically account for the largest heat-loss in a typical home. Window insulating devices are useful, particularly at night. These insulating window coverings should fit tightly all around to perform well.

6) Storm windows. Although not the optimum kind of double glazing that should be used in our climate, tight-fitting, sealed storm windows in good condition are of definite benefit.

7) Maintenance. A home cannot operate efficiently for long by itself. It is somewhat like a machine, with many parts that must work together to perform its task. Weatherstripping, caulking, siding, roofs, etc., all need periodic inspection and maintenance.

8) Caulking. Air leaking around door and window frames will bypass even the best weatherstripping -- even in brand new windows. Caulking around frames will drastically cut infiltration losses. Other areas, such as small foundation cracks, wall-piercing vents, etc. can benefit as well. A good quality exterior grade of caulking is recommended for outside work, as cheaper types will not last more than a season or two.

9) Exterior wall outlets. If codes permit, electrical outlets can be eliminated on exterior walls as outlet boxes eliminate needed insulation and also provide an easy path to the inside for infiltration drafts. An alternate measure is to provide foam outlet seals behind wall plates.

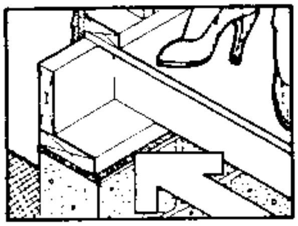
10) Special thermostats. Thermostats with a clock or timer can be set to lower the indoor temperature automatically during times when the house is empty, or during sleeping hours.

11) Tankless water heaters. Much of the energy provided to heat water in a conventional water heater is lost through the walls of the tank, from the surface of the hot water pipes, and up the flue of gas or oil models. Water heaters are available which heat the water at each point of use as it is needed. No hot water is stored, nor are long hot water pipes necessary.

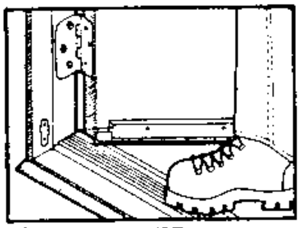
12) Duct insulation. Hot air heating ducts passing through unheated areas lose heat by conduction through the duct material, or through leaks. Sealing and insulating these ducts will ensure that more hot air flows to its intended destination.

13) Attic insulation. Heat loss through the ceiling of a home is a major factor in total building loss. Many

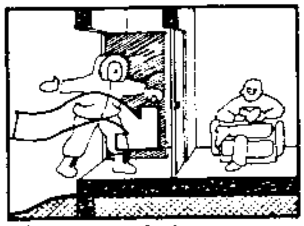
CONSERVATION



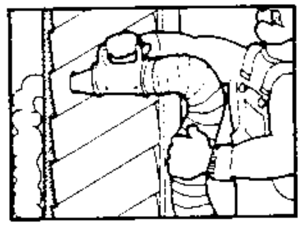
1) SILL SEALER



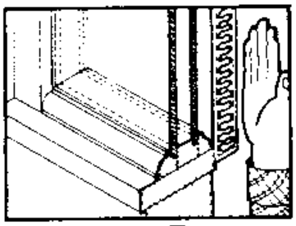
2) WEATHER-STRIPPING



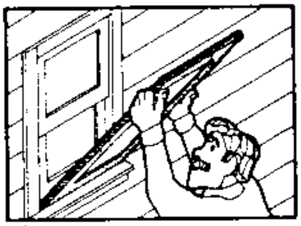
3) AIRLOCK



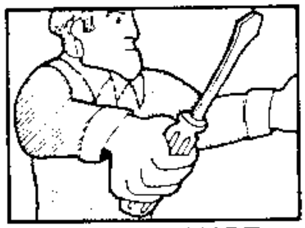
4) WALL INSULATION



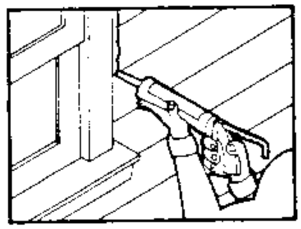
5) MOVABLE INSULATION



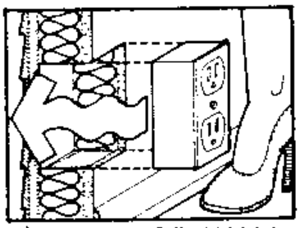
6) STORM WINDOWS



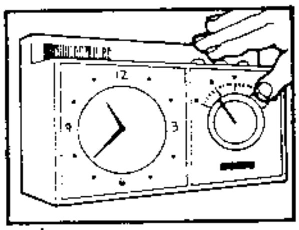
7) MAINTENANCE



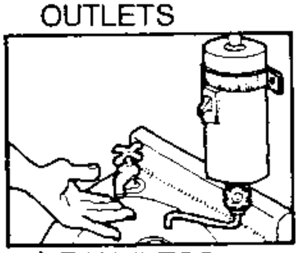
8) CAULKING



9) EXTERIOR WALL OUTLETS

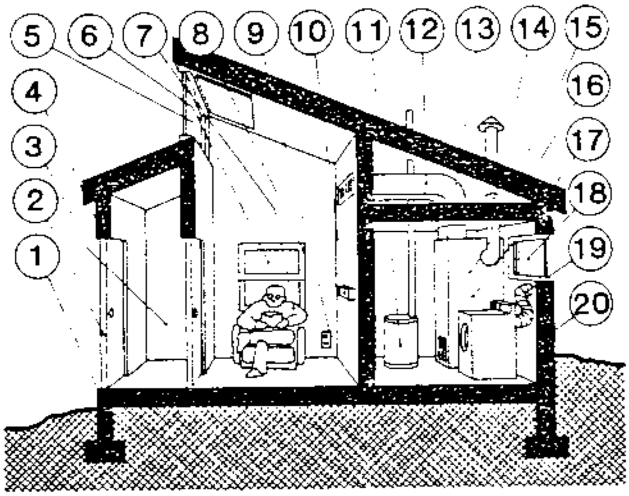


10) SPECIAL THERMOSTAT



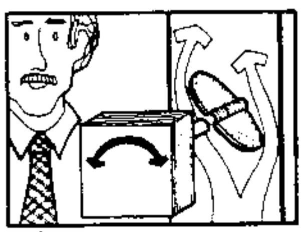
11) TANKLESS WATER HEATER

12) DUCT INSULATION

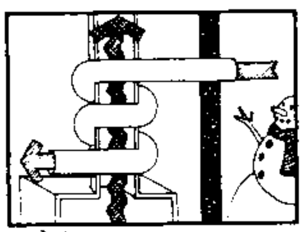


2.2-1 CONSERVATION IDEAS

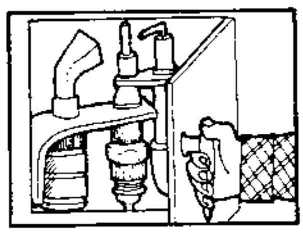
13) ATTIC INSULATION



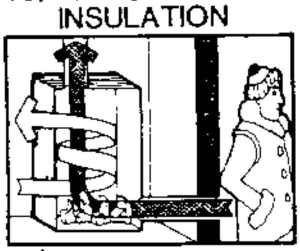
14) FURNACE DAMPER



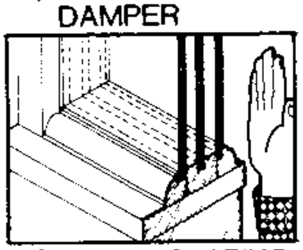
15) HEAT EXCHANGER



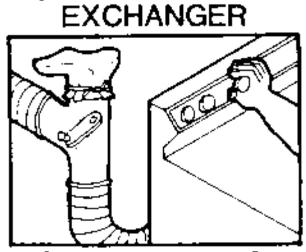
16) ELECTRIC IGNITION



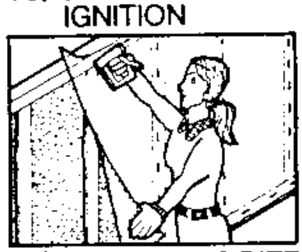
17) OUTSIDE COMBUSTION AIR



18) TRIPLE GLAZING



19) DRYER HEAT RECOVERY



20) VAPOR BARRIER

Nebraska homes have grossly inadequate attic insulation. Many insulation contractors currently recommend a minimum R value of 40 for attic insulation. Attention to detail around the edges of the attic can also be beneficial.

14) Furnace dampers. When a gas or oil furnace is not running, warm air continues to escape through the flue. Automatic dampers which prevent this effect are relatively cheap, easy to install, and are approved in most areas.

15) Air-to-air heat exchanger. Some of the heat from hot gas or oil furnace flue gasses can be recaptured by an air-to-air heat exchanger. The same technique can be used on gas or oil water heaters.

16) Electronic ignition. Gas or oil furnaces and water heaters typically use a small continuous flame called a pilot light to ignite the main burners. This continuous use of fuel can become expensive over several months. Many newer appliances use a pilotless ignition system which lights the main burners with a small, quick electric spark.

17) Outside combustion air. The air that a gas or oil furnace, water heater, or fireplace use to supply oxygen for fuel combustion is lost up the chimney. It makes more sense to use unheated outside air instead of heated indoor air, to supply oxygen for the fire.

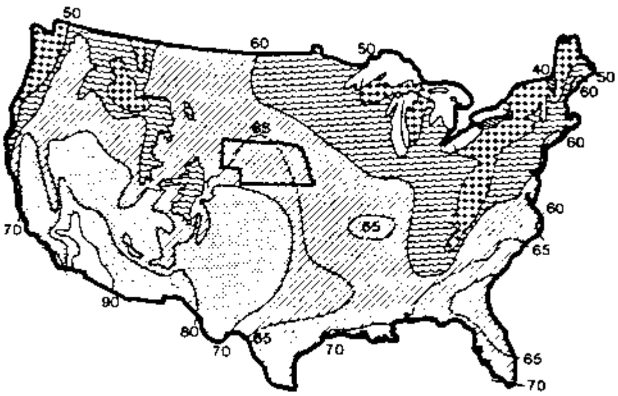
18) Triple glazing. Triple glazed windows are an effective measure to prevent heat loss, particularly on the north side of a house or where night insulation is impractical.

19) Clothes dryer heat recovery. Inexpensive two-way valves are available which allow the release of hot, moist air from a clothes dryer vent into the house. A lint trap should be part of the system (a fine screen or nylon stocking is often used).

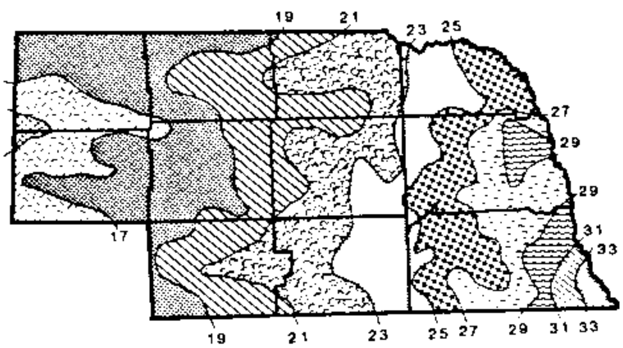
20) Vapor barrier. In the winter months, the air inside a home has more moisture than outside air, due to cooking, bathing, respiration, etc. If this moist inside air gets inside an exterior wall and gets to a point near the outside where the temperature drops far enough, the moisture will condense inside the wall. Wet insulation loses much of its insulating ability, and can cause water damage to wood and other materials. A vapor barrier applied just under the inside wall covering will prevent this and will aid in infiltration control. For the vapor barrier to be most effective, all rips and other penetrations must be minimized.

Although this is not an exhaustive list of conservation techniques, it serves to illustrate what can be done to new or existing homes to maximize the use of every heating dollar.

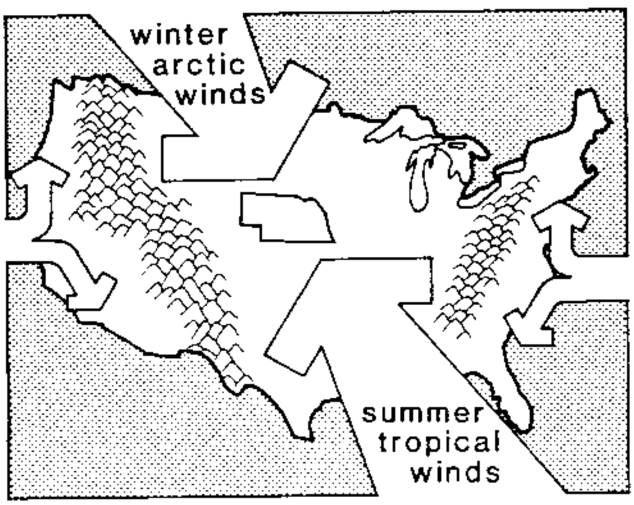
SITE PLANNING



2.3-1 MEAN PERCENTAGE OF POSSIBLE SUN



2.3-2 NEBRASKA MEAN ANNUAL PRECIPITATION



2.3-3 PREVAILING WIND DIRECTIONS

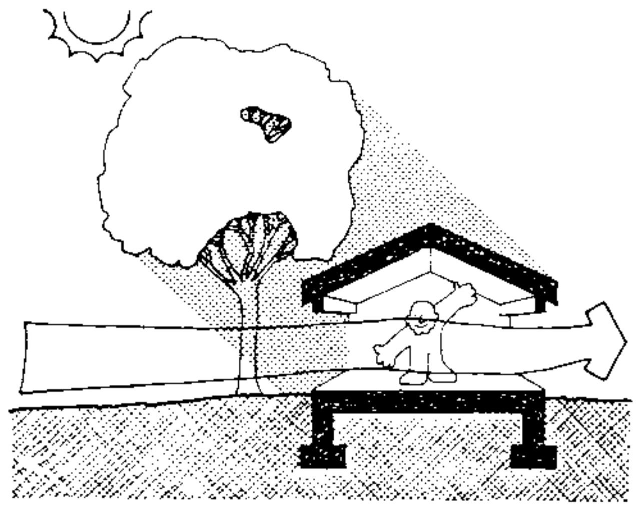
Intelligent planning of the home site can have a dramatic effect on the thermal performance of a house, both in the heating and cooling sesons. On the large scale, the geographical location of the site dictates several important factors affecting day to day weather, e.g., mean annual cloudiness (FIG 2.3-1) and rainfall (FIG 2.3-2). On the small scale, local land contours and vegetation affect natural wind patterns and velocities, which also affect the heating and cooling of the house.

Seasonal winds in Nebraska are influenced by many factors, including the geographical layout of mountains, and tend to be either from the southeast or northwest (FIG 2.3-3).

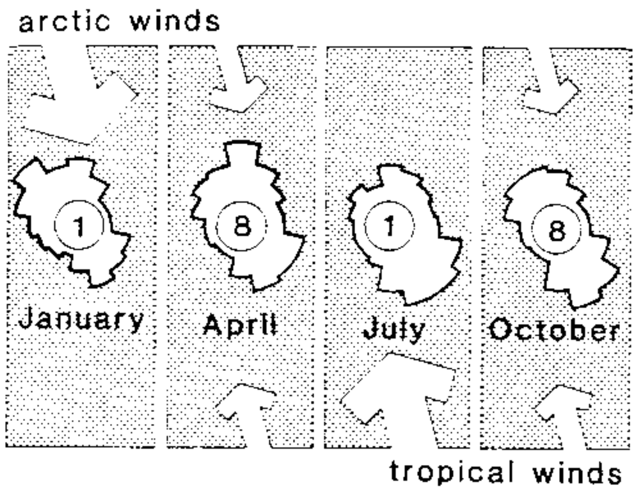
Wind characteristics at a particular location are often described by a "wind rose". A wind rose is actually a circular graph with the various wind directions distributed around the center, with north at the top, and east to the right. The distances from the center of the graph represent average wind velocity and frequency for each direction. It can be seen that in our state, summer breezes are often from the south or southeast, while winter winds are more commonly from the north or northwest (FIG 2.3-4 and 2.3-5).

Homes in much of Nebraska, particularly in the west, can make good use of summer breezes for cooling (FIG 2.3-6). In the winter season, protection from cold north winds can reduce heating requirements, largely by cutting infiltration losses. To accomplish this, local wind patterns can be influenced by terrain features and by vegetation such as large bushes or trees.

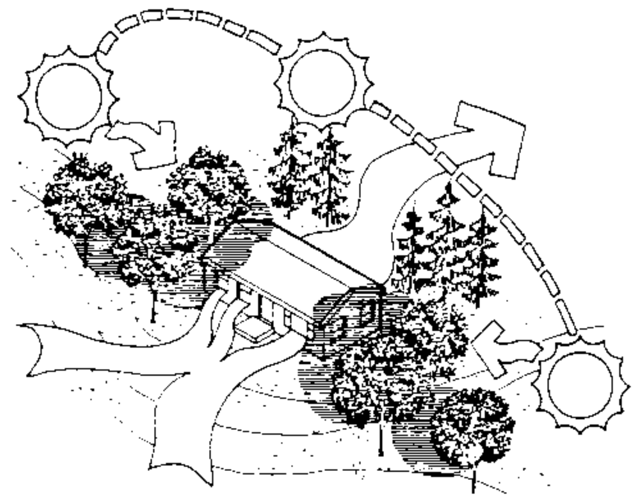
In addition to channeling and blocking wind, trees and other vegetation can be used as solar control devices. The roof and east and west sides of a building receive the most unwanted solar energy in the summer months. Summer shading of these surfaces will cut gains (FIG 2.3-7). Broadleaf (deciduous) trees should be used for this purpose since some winter gains can still be realizd through the bare branches. Note, though, that all trees are not created equal in this regard. Bare-branch densities vary widely among species, and transmit differing amounts of direct solar energy (FIG 2.3-8).



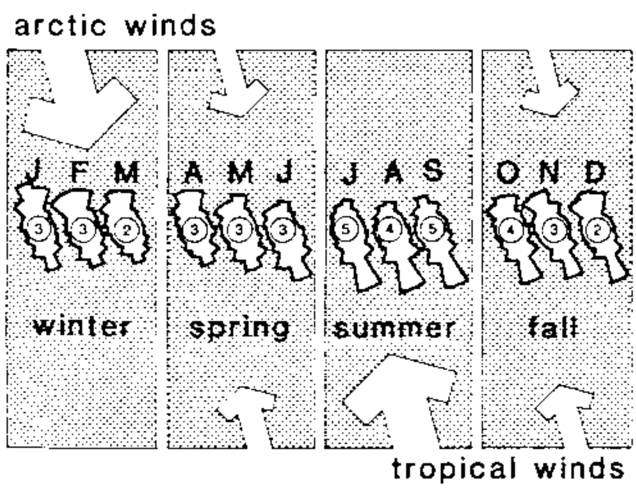
2.3-6 SUMMER SHADING AND VENTILATION



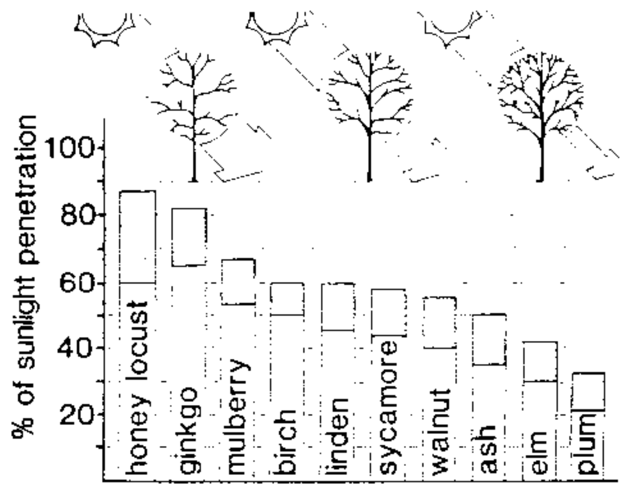
2.3-4 WIND ROSES: NORTH PLATTE



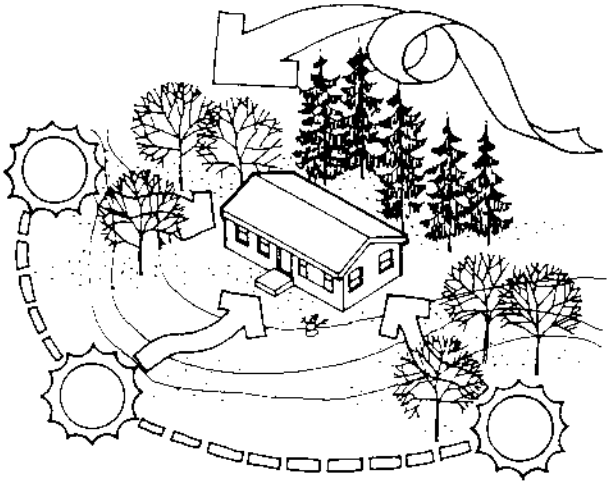
2.3-7 PLANTING STRATEGY: SUMMER



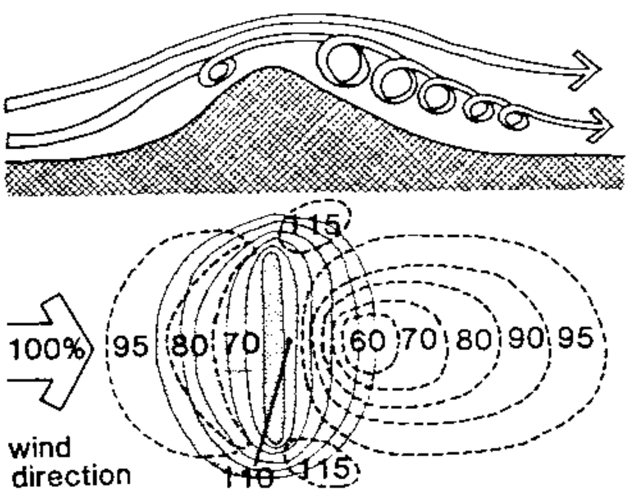
2.3-5 WIND ROSES: OMAHA



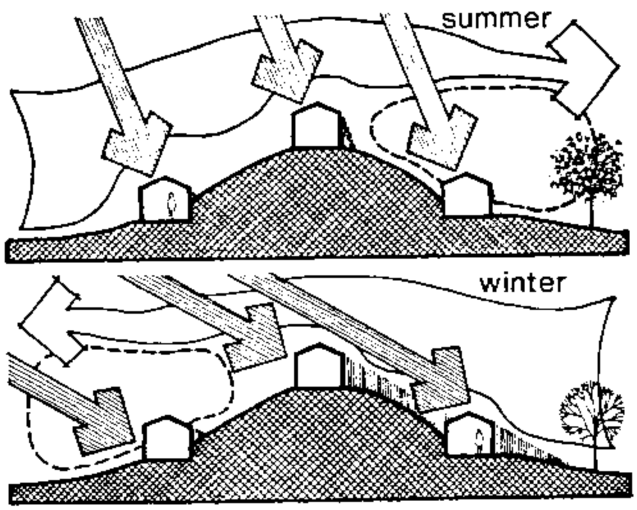
2.3-8 BARE BRANCH SUN PENETRATION



2.3-9 PLANTING STRATEGY: WINTER



2.3-10 WIND SPEED CHANGES AROUND HILL



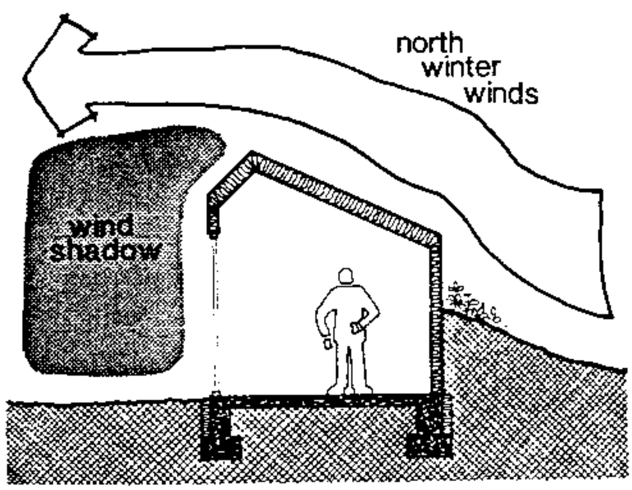
2.3-11 HILL MICROCLIMATE

Conifer trees (evergreens) can be used to advantage to block or channel cold winter winds around or over a house (FIG 2.3-9).

Building location in relationship to the local terrain is another important consideration. When wind encounters a small prominent hill, for example, a calm protected area, or "wind shadow", is formed on the opposite side (FIG 2.3-10). A house located on a south or southeast-facing slope will be situated in the winter wind's shadow, but will receive the full effects of summer breezes (FIG 2.3-11). This is also consistent with good solar placement, since a south slope is conducive to some degree of earth sheltering of the north wall, and it allows a maximum penetration of the incoming winter solar energy (FIG 2.3-12).

The concept of wind shadow is also useful in planning outdoor spaces and placement of glazing areas. Windows protected from the wind will lose less heat due to convection effects.

Another important factor in site selection is unwanted solar blockages from buildings or vegetation (FIG 2.3-13). A row of large spruce trees immediately outside a direct gain solar window may provide an attractive view but is not an example of good site



2.3-12 BUILDING MICROCLIMATE

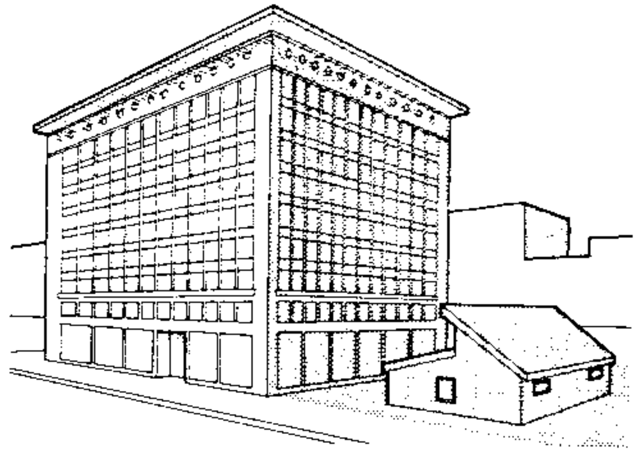
design. The future growth of vegetation should be considered as should possible construction that could affect access to solar energy.

BUILDING ORIENTATION

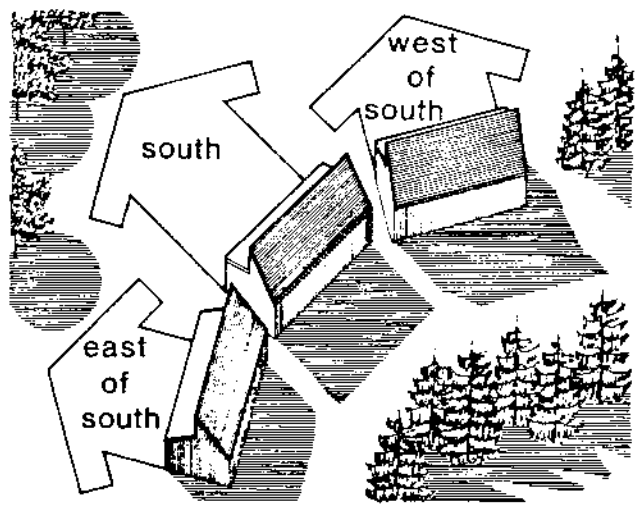
Once an appropriate building site has been selected, the next decision concerns the orientation of the building.

Although a due south-facing solar window will collect a maximum amount of energy on a clear site, some deviation can be tolerated for aesthetics or other site considerations. These other considerations include factors which may actually favor orientations other than due south, e.g., if the site receives unavoidable shade in the afternoon hours, a solar aperture facing east of south would take better advantage of the morning sun. Also, in an area where morning cloudiness or fog is common, a west of south orientation is suggested.

Of non-south orientations, east of south is preferable to west of south, to prevent summer solar gains in the late afternoon, when the house can tolerate it least. In general, on a clear site, orientations within 30 degrees of south will intercept about 90% or more of the maximum amount of solar energy (FIG 2.3-14).



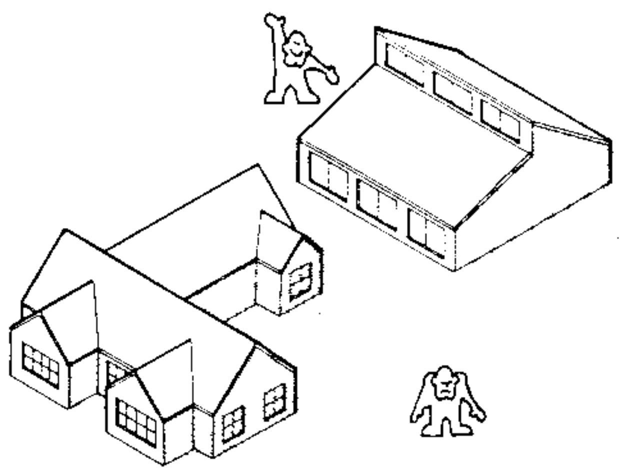
2.3-13 NOT A GOOD SOLAR SITE



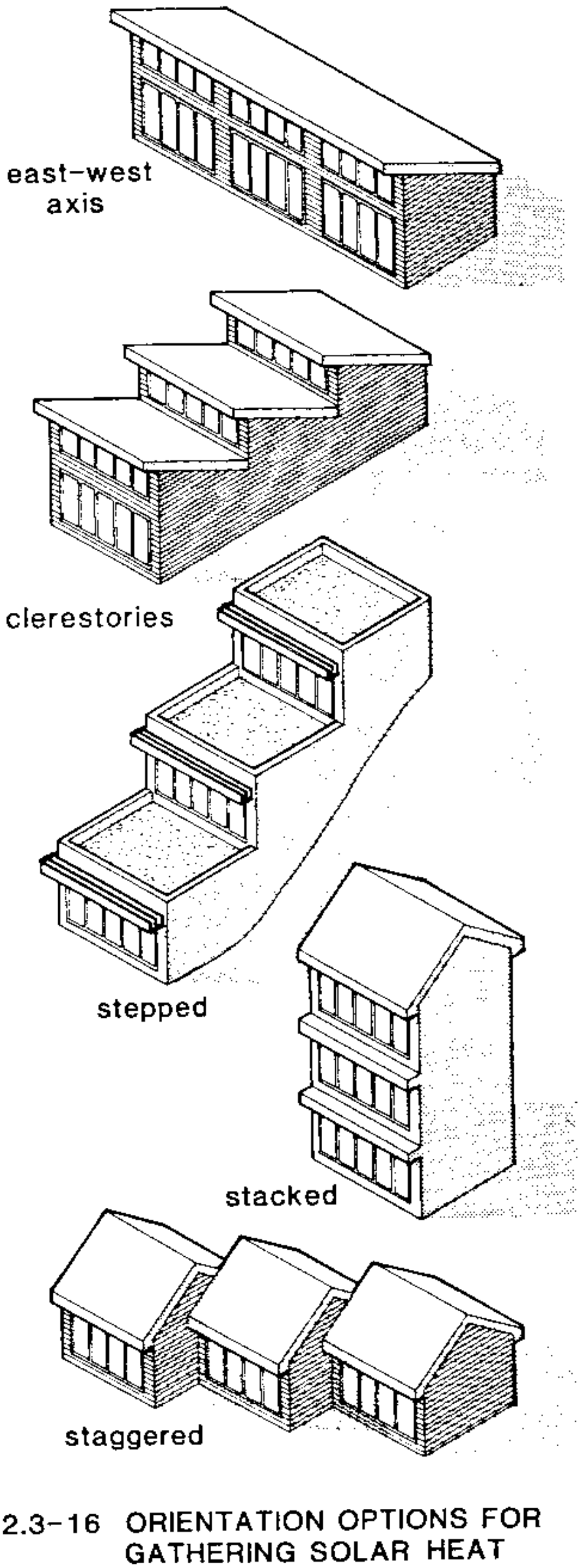
2.3-14 SOME VARIATION FROM DUE SOUTH IS ACCEPTABLE

BUILDING SHAPE AND LAYOUT

Most winter heat losses of residences are so called "skin losses", which occur through the exterior skin of the building -- exterior walls, roof, basement floor and walls, etc.; the more skin area the more heat loss. It is, therefore, important to keep skin area to a minimum to aid in controlling heat loss. Cube and square perimeter shapes offer the least surface area for a given volume. Buildings with more complicated perimeters will have larger skin areas and show larger heat flows through the skin than a structure of simpler perimeter (FIG 2.3-15).



2.3-15 MINIMIZE EXTERIOR SKIN



2.3-16 ORIENTATION OPTIONS FOR GATHERING SOLAR HEAT

This square perimeter rule can be modified a bit by including the effects of sun load on the house.

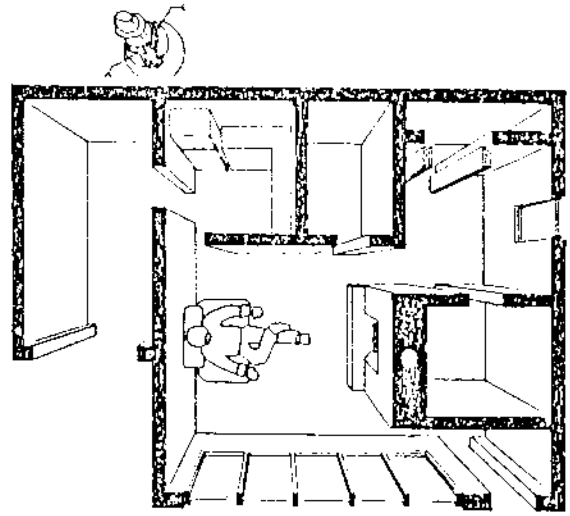
As discussed previously, of the four outside walls of a simple building, the east and west receive most of the summer sun heat. In the winter, the south receives the largest amount. Reduction of the east and west outside wall areas and expansion of the south results in year-round benefits. The optimal shape, then, is a simple rectangle with the short sides facing more or less east and west. The most effective ratios between long and short sides for Nebraska are between 1.6 and 2.4.

Alternate perimeter shapes for special terrain or site constraints might be considered, but the best rule remains to avoid perimeter twists and turns (FIG 2.3-16).

INTERIOR SPACE ARRANGEMENT

A factor that will affect the final choice of perimeter shape will be the arrangement and size of interior spaces. Although rooms should be laid out to fit particular lifestyles and tastes, additional considerations can have an impact on the energy performance of the building.

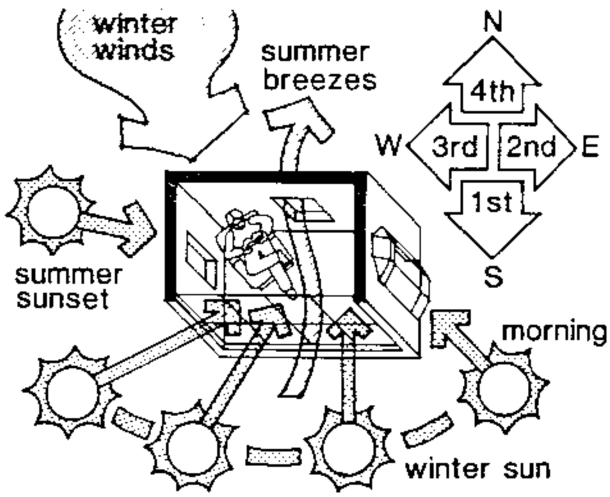
It makes good sense to locate heavily used living spaces along the south side of the house, since this area will require the most direct solar energy heat gains. Non-living spaces -- hallways, closets, laundry rooms, utility rooms, pantries, storage rooms, garages, entryways, and the like -- should be located on the north side of the house, which is generally cooler in the winter. These areas act as "buffer" spaces, in that they isolate the living spaces from the full effects of the outside temperature on the north (FIG 2.3-17).



2.3-17 BUFFER SPACES TO NORTH, SOLAR SPACES TO SOUTH

WINDOW PLACEMENT

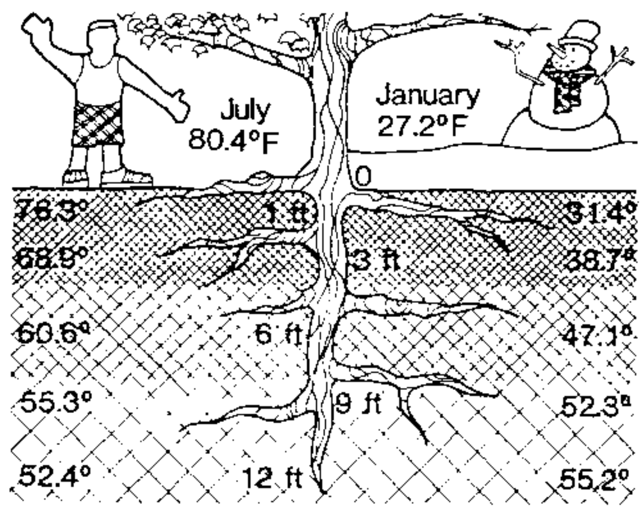
Although all windows are heat losers, some windows can provide a net energy gain by admitting solar energy. Unshaded windows on the west, east, and south have this capability. However, part-time insulating devices need to be used in conjunction with east and west windows to show a net gain. As indicated earlier, east windows are preferred to west to reduce summer cooling requirements (FIG 2.3-18).



2.3-18 PREFERRED WINDOW LOCATIONS

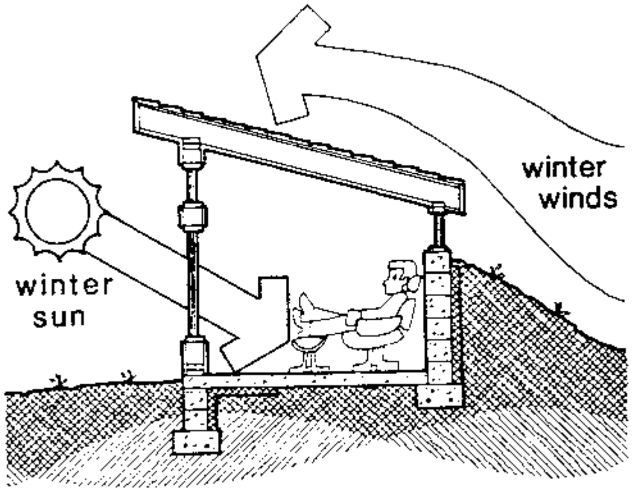
PROTECTING THE NORTH WALL

The north side of a house has the potential for the greatest heat loss of any skin surface, since it gets no direct sun for several months in the winter and is continually assaulted by cold winter winds. One effective treatment for the north wall is earth sheltering. Earth directly outside the north wall seals the wall against infiltration and diverts wind up and over the building. Another factor in the effectiveness of earth sheltering is the fact that sub-surface earth temperatures are moderate throughout the year (FIG 2.3-19). Structures that are

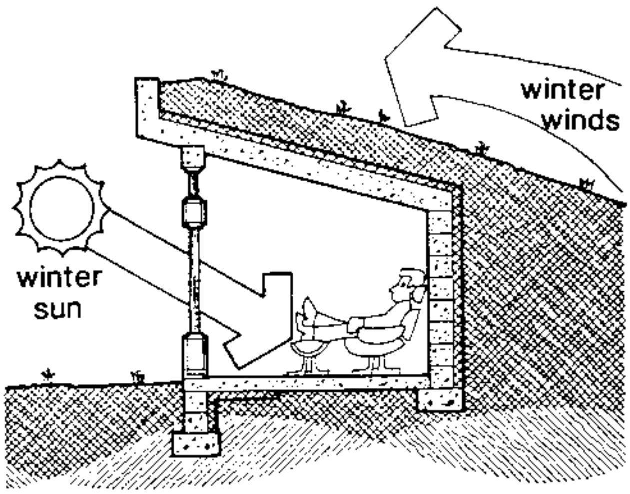


2.3-19 SEASONAL NEBRASKA EARTH TEMPERATURES built into the earth, rather than being bermed, take best advantage of the earth temperature effects (FIG 2.3-20, 2.3-21 and 2.3-22).

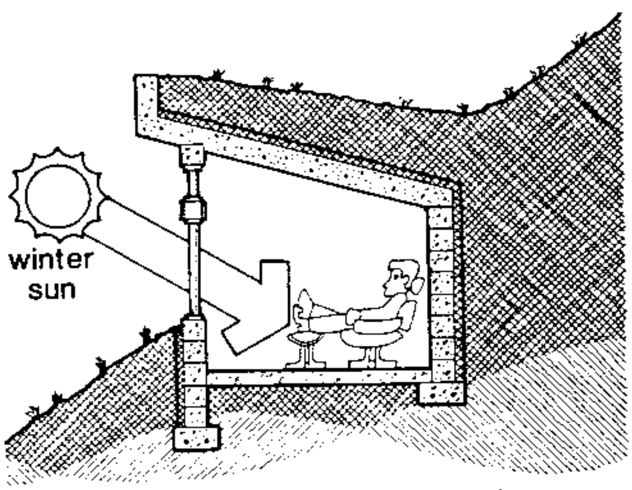
The only thing worse than a north wall -- as far as heat loss is concerned -- is a north wall with a window in it. A north window cannot even partially offset its losses with solar gains. Although building codes and aesthetics may prevent the complete elimination of north windows, their numer and size should at least be minimized. Well-built, triple glazed windows should be used in conjunction with part-time window insulating devices.



2.3-20 EARTH BERMED



2.3-21 EARTH COVERED



2.3-22 BUILT INTO SOUTH SLOPE

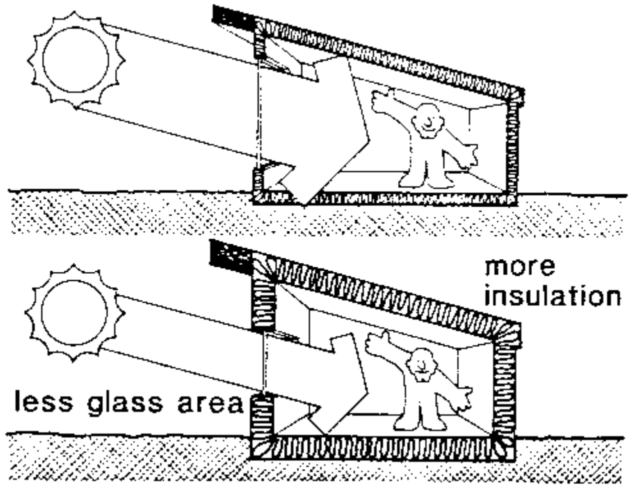
INSULATION

Insulation is the primary means of reducing conduction heat loss in the home.

Insulation comes in many forms, each designed for a specific purpose, however, all insulating materials have in common a high resistance to the flow of heat. The more insulating material that heat must pass through on its way out of the house, the less heat is lost per hour; increasing insulation cuts heat loss.

In theory, a home could be built that is so well insulated that the total building heat losses could be replaced by internal gains alone, assuming, of course, that infiltration losses have been diminished. Some of these "super-insulated" houses exist, and appear to perform quite well. As with any other energy saving approach to home construction, however, economic performance is an entirely different question.

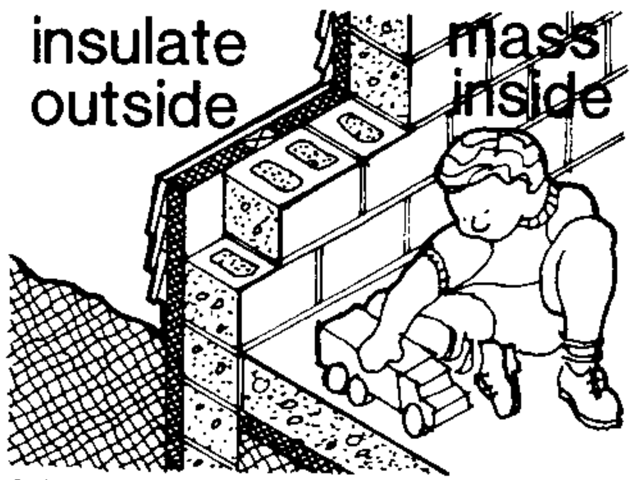
Solar homes derive a unique benefit from good insulation levels. More insulation gives lower heat loss (lower building heat load), and therefore permits smaller glass area to provide the needed replacement heat (FIG 2.4-1). Again, the optimum balance between level of insulation and solar system size is basically an economic question.



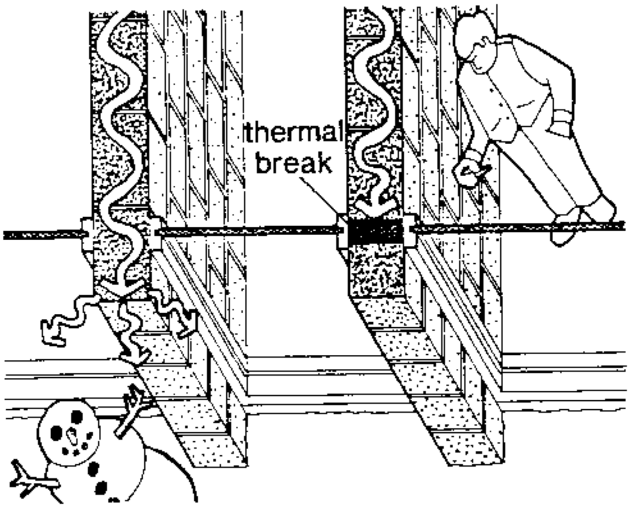
2.4-1 INCREASE INSULATION,REDUCE GLASS AREA

FOUNDATION INSULATION

One result of rising energy costs is the application of insulation where it was not considered necessary a few years ago. Insulation of foundations is an example. Significant heat loss can be eliminated by insulating foundation walls of heated basements. Since the basement walls are thermally massive, some benefit can be gained by including space on the inside of the heated space. For this reason, insulation on the outside of the foundation walls, rather than the inside, is desirable. Moisture-resistant insulation should be used in this application (FIG 2.4-2).



2.4-2 INSULATING MASS WALLS



2.4-3 THERMAL BREAKS REDUCE HEAT LOSS

THERMAL BREAK

A thermal break is an interruption of an otherwise unimpeded path for heat to flow to the outside through some building element. A good illustration is a metal window frame. Frames of solid metal provide a direct low resistance path for heat to leak to the outside. By separating the inner and outer parts of the frame with an insulating material, the heat flow is impeded. Another important location for a thermal break is in brick or concrete interior walls exposed to the outside (FIG 2.4-3).

TYPES OF INSULATION PRODUCTS

There are a number of types of insulation products, each with its own applications. Following is a description and table listing the most common types of insulation (FIG 2.4-4).

Blanket or roll. This kind of insulation is sold in widths that will fill the space between studs on either 16" or 24" centers, and in lengths of 16' to 64'. Thicknesses of 3-1/2", and 5-1/2" are available. Fiberglass is probably the most common material. The paper backing provides flanges at both edges for easy stapling to studs. Some types have a built-in vapor barrier.

Batt. Batt insulation is blanket or roll insulation, cut to 4' or 8' lengths, which are easy to use.

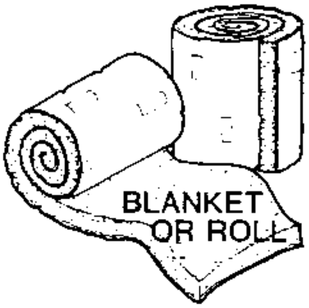
Loose fill. This is loose or granular insulation packaged in bags and poured between ceiling joists or into walls. Alternately, the material can be obtained in bulk and blown in. The R value is usually specified as a "per inch" value.

Rigid board. These boards can be purchased in thicknesses from 1/2" to 4", and in sizes from 2x8 feet to 8x12 feet. They are often used as exterior sheathing under siding and waterproof types are used below grade walls.

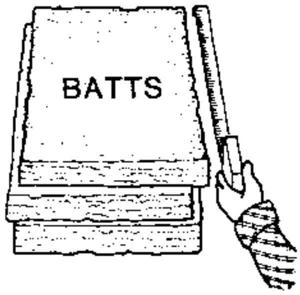
Foam. Foam insulation is a two-part system which is applied or injected into wall cavities, where it hardens to a rigid, porous mass. It penetrates into hard-to-reach places and is a good sealing agent against infiltration. Efficient application requires experience, however, and should be entrusted to a reliable contractor.

Other unique insulation systems are beginning to appear in the marketplace. One such unconventional type of insulation consists of shredded cellulose (newsprint is one source) or other insulating medium, combined with a glue-like solution, and sprayed into wall cavities. The resulting wet pulpy mixture, correctly applied, can support its own weight until it dries to a rigid, fire-resistant insulating wall with good R value and good sealing properties.

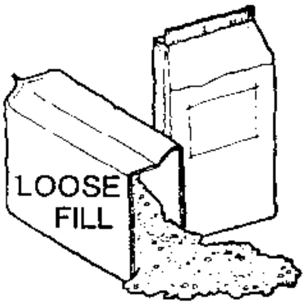
TYPES OF INSULATION PRODUCTS



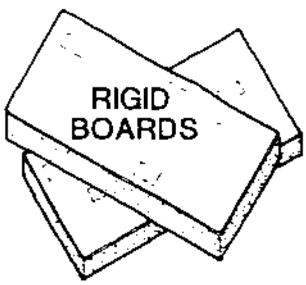
MATERIALS	USE
Fiberglass	Walls
Rock wool	Floors
Cellulose	Roofs
	Attics



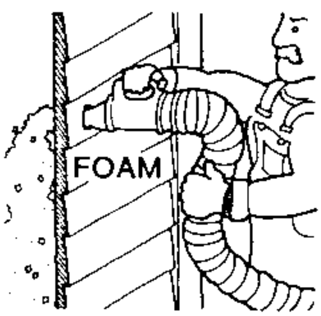
MATERIALS	USE
Fiberglass	Walls
Rock wool	Floors
Cellulose	Roofs
	Attics



MATERIALS	USE
Perlite	Walls
Fiberglass	Floors
Rock wool	Ceilings
Polystyrene	
Cellulose	



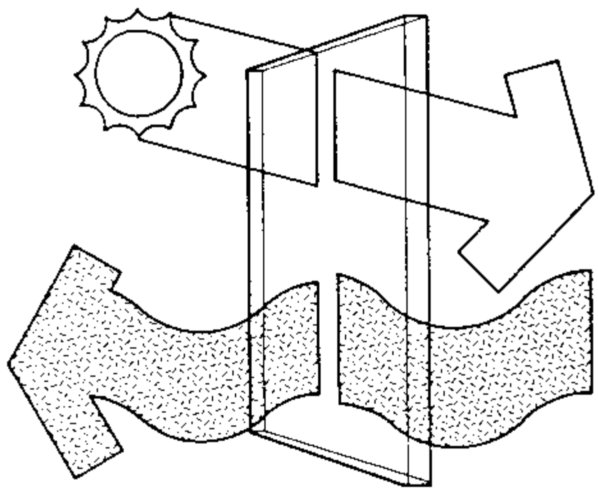
MATERIALS	USE
Polystyrene	Walls
Urethane	Foundations
Isocyanurate	
Fiberglass	



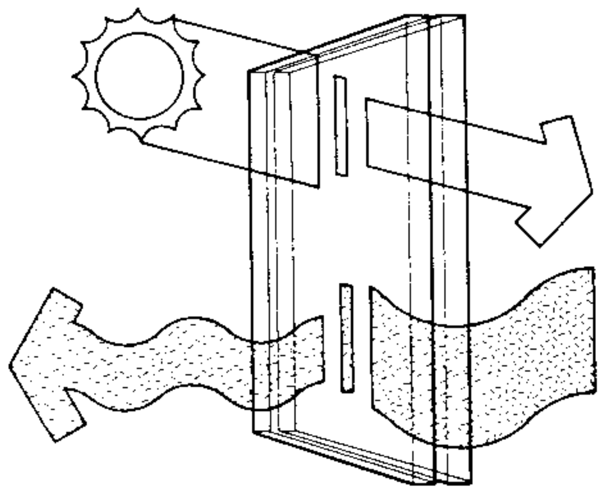
MATERIALS	USE
Urethane	Walls
Urea-Formaldehyde	

2.4-4 INSULATION TYPES

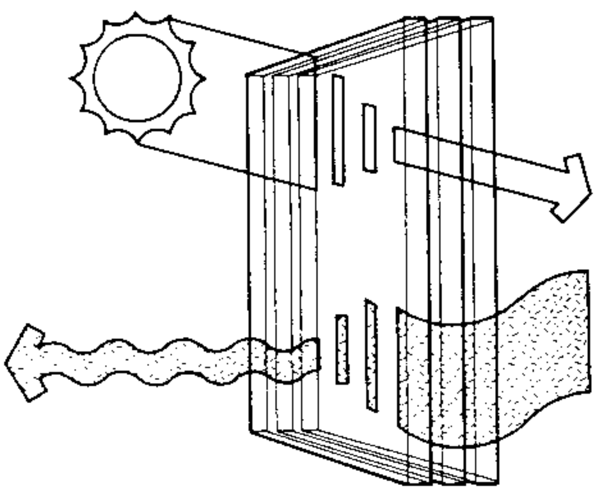
WINDOWS



2.5-1 SINGLE PANE: HEAT LOSS & SOLAR TRANSMITTANCE



2.5-2 DOUBLE PANE: HEAT LOSS & SOLAR TRANSMITTANCE



2.5-3 TRIPLE PANE: HEAT LOSS & SOLAR TRANSMITTANCE

One of the most critical choices to be made in the design of any home is the selection of windows. There are a number of issues which must be addressed before a decision can be made: site selection, cost, passive solar type, lifestyle, aesthetics, availability, and glazing material type are all factors which must be taken into consideration.

One of the first decisions to be made is the number of glazings. Should the window be single, double, triple or even quadruple glazed? With a single glazed window (FIG 2.5-1), energy is gained by the sunlight shining through the window. At the same time energy is lost back through the window due principally to conduction. Not all the sunlight falling on the window passes through. This is due to the window's tilt with respect to the sun's rays and to the properties of the glazing material itself.

When a second glazing is added (FIG 2.5-2), the energy lost to the environment is reduced, however, this is achieved at the cost of reducing the solar penetration. Triple glazing (FIG 2.5-3) shows a further reduction in energy loss but an additional loss in solar transmission occurs. In Nebraska, double glazing is the minimum recommended standard.

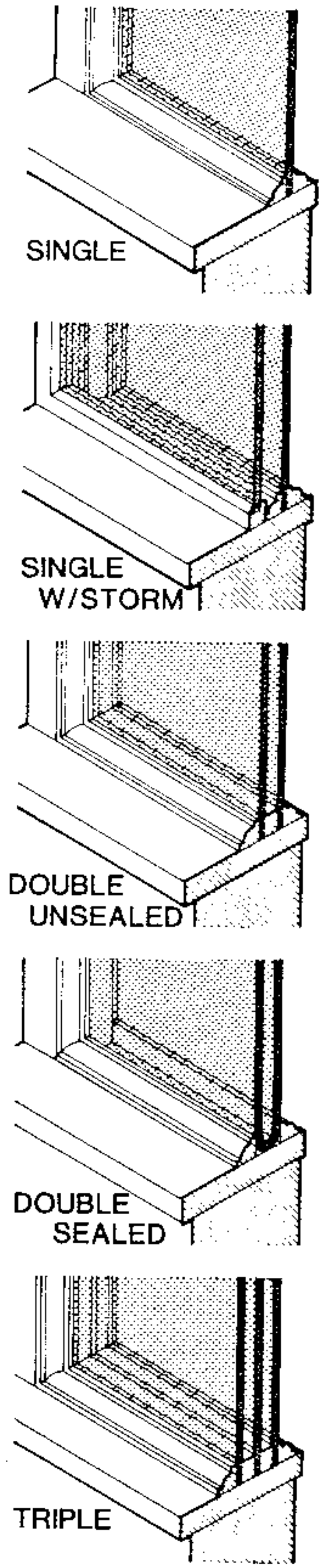
The series of drawings in FIG 2.5-4 show typical glazing arrangements. Single glazing is fairly typical in small windows. Since glass is a good conductor of heat, single glazed windows are not a desirable feature for energy efficient homes.

A single glazing with a storm window provides a dead air space. Motionless air conducts heat very poorly, and this arrangement improves the insulating value between the outdoor and indoor temperature.

A double unsealed glazing arrangement also provides a dead air space. The width between glazings is usually between 3/16" and 3/4". It is important that the width be narrow to prevent air circulation patterns from occurring, since moving air is a good conductor of heat.

The double sealed window has the advantage of preventing any outdoor or indoor air leakage into the dead air cavity between glazings. This ensures that the air space is truly dead. Some commercially-produced thermal windows contain a moisture free gas or desiccant granules to absorb moisture.

Triple glazing is now available. The extra dead airspace further improves the insulating properties of the window. For large expanses of south-facing windows without night shutters, triple glazing is recommended. For additional insulating properties, quadruple glazing is now being introduced into the housing market.



2.5-4 GLAZING

The following table of characteristics identifies the different materials.

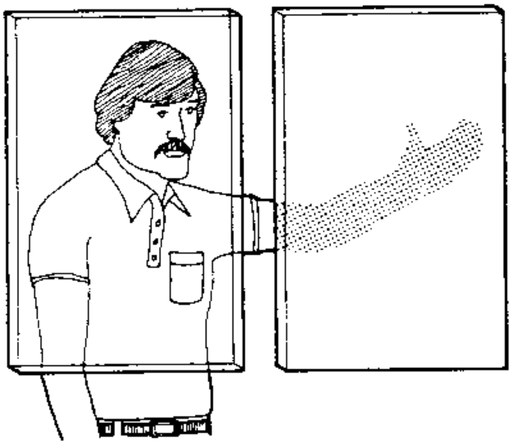
WINDOWS

COMPARISON OF GLAZING MATERIALS

	Thickness (inches)	Cost ($/ft²)	Transmittance (lb/ft²)	Weight	Thermal Expansion
GLASS					
Water white glass	0.125	0.99	0.90	1.60	0.47
Float glass	0.125	2.35	0.84	1.60	0.47
Window glass	0.090	1.80	0.91	1.20	0.47
FIBERGLASS REINFORCED POLYESTER					
Sunlite Premium 11 (Kalwall)	0.040	0.60	0.88	0.29	2.00
Filon with tedlar (Vistron)	-----	1.00	0.86	0.25	2.30
Flexiguard 7410 (3M)	7 mil	0.38	0.89	0.053	----
PLASTIC FILM					
Tedlar (Dupont)	4 mil	0.05	0.95	0.029	2.80
Teflon FEP 100A (Dupont)	1 mil	0.58	0.96	0.02	5.85
Swedcast 300 Acrylic (Swedlow)	0.125	0.81	0.93	0.77	4.00
RIGID PLASTICS					
Lucite Acrylic (Dupont)	0.125	1.14	0.92	0.73	4.00
Tuffak-Twinwall (Rhom & Haas)	-----	1.25 (2 layers)	0.89 per layer	0.25	3.3
Acrylite SDP (Cyro)	-----	2.15 (2 layers)	0.93 per layer	1.00	4.00
INSULATING PANELS					
Sun-lite Insulated Panels (Kalwall)	-----	2.50 (2 layers)	0.88 per layer	0.7	-----
Solar Glass Panels (ASG)	-----	2.99 (2 layers)	0.90 per layer	4.5	0.47

Ease in handling	Strength	Sheet Size	Remarks
poor	good when tempered	2x8,3x8,4x8	no degradation
poor	good when tempered	4x8	no degradation
poor	poor	4x7	fragile
excellent	very good	4' or 5' rolls	maximum temperature 300°F
very good	very good	4.25 x 16	maximum temperature 300°F
fair	good	4x150 roll	maximum temperature 275°F
fair	good, some embrittle-ment	up to 64" roll	4 to 5 year lifetime at 150°F
poor	fair, not for exterior glazing	58" wide roll	maximum temperature 300°F
excellent	very good	9' wide	maximum temperature 200°F
very good	very good	4x8	maximum temperature 200°F
very good	high impact strength fatigue cracking	4x8	5% reduction in transmittance over 5 years
very good	good	6x8	maximum temperature 230°F
good	good	4x8,4x10, 4x12,4x14	maximum temperature 300°F
poor	good	3x6,4x6, 3x8,4x8	very durable

WINDOWS



2.5-5 GLAZING CHARACTERISTICS

An important design consideration is the type of material used as glazing. Although glass is the most common material used, there are many other materials available on the market, including fiberglass reinforced polyester (FRP), plastic films, rigid plastics, and insulating panels. Deciding what material to use will be dependent upon cost, appearance, durability and performance. The glazing should be resistant to heat, light, and weather degradation, have a high solar transmittance, be easy to handle and install and attractive. A brief comparison of the advantages and disadvantages of each material is below. Some materials like fiberglass may not be transparent like glass (FIG 2.5-5).

MATERIAL	ADVANTAGES	DISADVANTAGES
GLASS	Rigid, chemical and weather resistant, no light deterioration	High cost, heavy weight, fragile
FIBERGLASS REINFORCED POLYESTER	Can be made ultra-violet (UV) resistant, easy to handle and install, can be cut and drilled	May have a wavy appearance, Potential thermal degradation and may require venting
FILMS	Inexpensive,high transmittance, good resistance to temperature	High expansion coefficient which can cause sagging when used as an inner glazing, can have short lifetime due to UV embrittlement
RIGID PLASTICS	Attractive, easy to handle, high impact and fracture resistant	Acrylics soften at 180°F high coefficient of expansion; polycarbonates have lower transmittance, are subject to UV degradation, and have a high expansion
INSULATING PANELS	Ease of installation	UV degradation, high thermal expansion, low transmittance when polycarbonates are used; low melting point and high thermal expansion when using acrylics

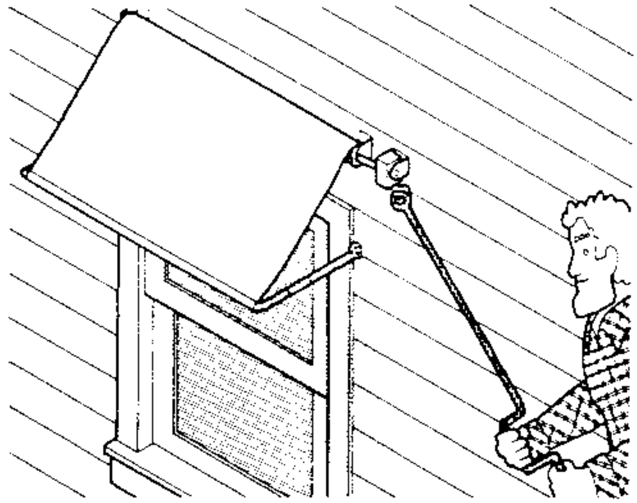
Although solar collection for space heating may be desirable in winter, it is not desirable during the summer. The use of an overhang helps to alleviate some of the problems of summer sun by blocking direct sunlight from entering the window (FIG 2.5-6). In the wintertime, however, the sun is lower in the sky and the overhang does not prevent solar penetration. Awnings provide an alternative technique for solar control (FIG 2.5-7). Movable awnings can be particularly valuable during the months preceding and following winter.

The use of insulating shutters is another way of adding insulation to windows. There are two principal types of shutters: interior and exterior.

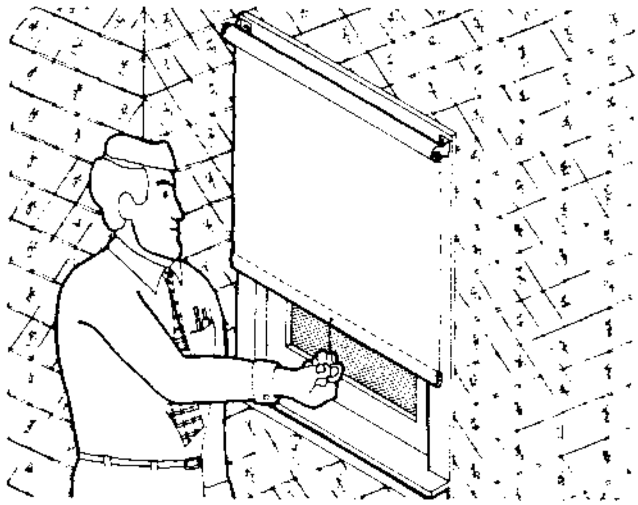
Interior Shutters

Canvas Roll Down Shade: Although they usually do not make a tight seal to keep wind out, canvas roll down shades (Fig 2.5-8) may reduce window losses by as much as 25%. An additional benefit is that they are inexpensive.

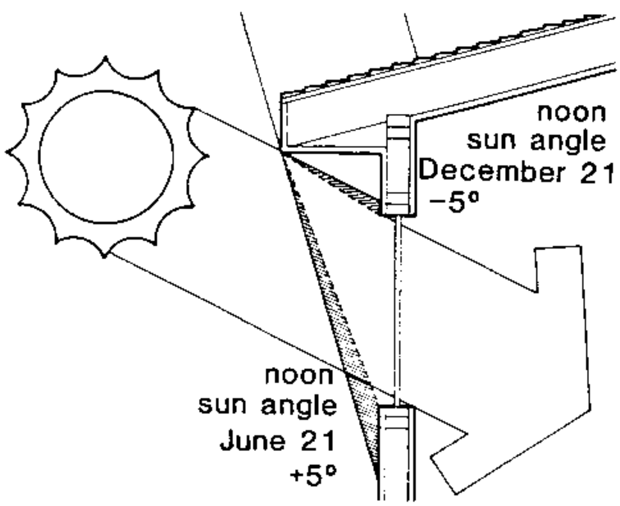
Wooden Shutter: Wooden shutters (FIG 2.5-9) may double the insulating value of single pane glass. Cost is $2 and up per sq ft. Tight fits are generally hard to achieve.



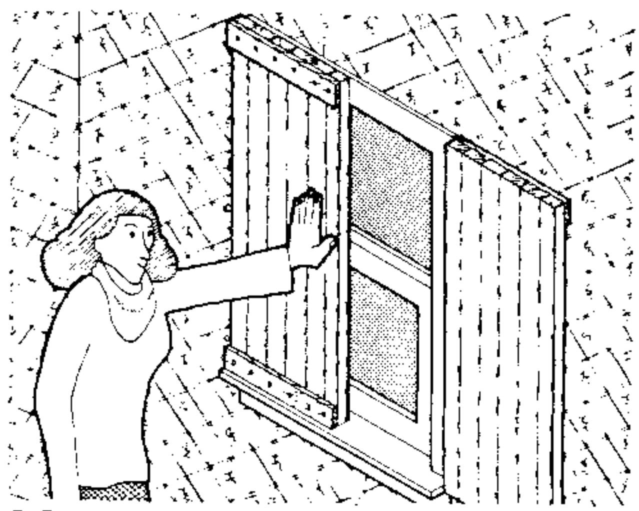
2.5-7 MOVABLE OVERHANG



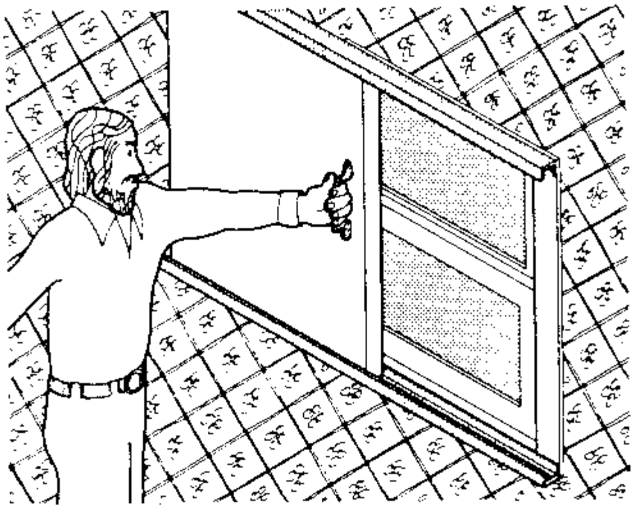
2.5-8 CANVAS SHADE: INSIDE



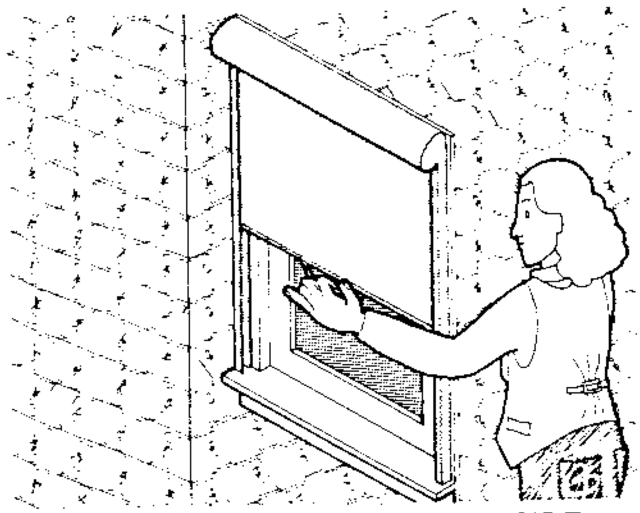
2.5-6 FIXED OVERHANG



2.5-9 WOODEN SHUTTERS: INSIDE



2.5-10 SLIDING INSULATED PANEL: INSIDE



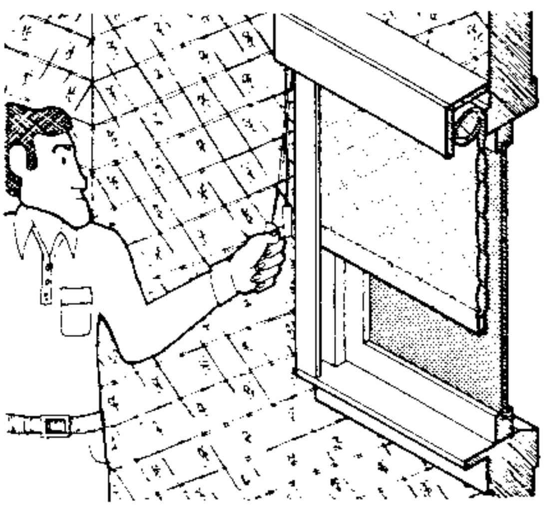
2.5-11 INSULATED SHADE: INSIDE

Sliding Insulated Panel: Depending on thickness and the material being used, sliding insulating shutters (FIG 2.5-10) can improve performance by factors up to 5 and more when compared with single pane glass. Tightness of fit may be a problem as well as flammability. An additional covering may be necessary for aesthetics. Such panels are inexpensive, approximately $1 per sq ft.

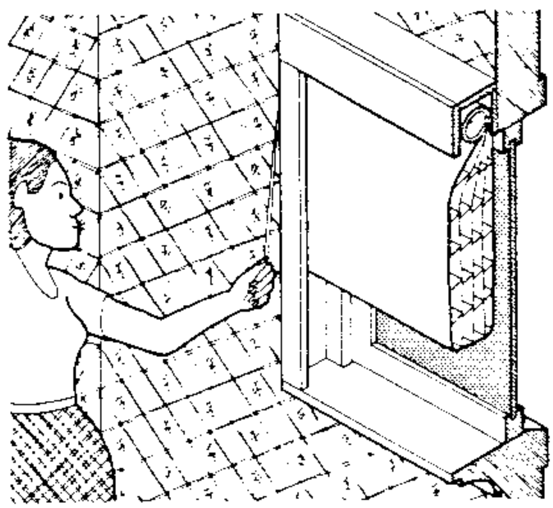
Insulated Shades: Insulated shades (FIG 2.5-11) improve insulating efficiency by a factor of 4. Such a system usually consists of a number of shades on guided tracks to provide a tight seal. Cost is typically $6 per sq ft and up.

Quilted Shade: Quilted shades (FIG 2.5-12) can improve insulating efficiency by a factor of 4. Such shades usually consist of an insulation sandwich with reflective Mylar at the center surrounded by layers of polyester batting and polyester rayon. Side tracks and weights assure tightness. Quilted shades generally cost $4 per sq ft and up.

Multiple Layer Shade: Multiple layer shades (FIG 2.5-13) can improve the insulating value by a factor of 15. The shade consists of five layers of aluminized mylar which expand to baffled air spaces when drawn.



2.5-12 QUILTED SHADE: INSIDE



2.5-13 MULTILAYERED SHADE: INSIDE

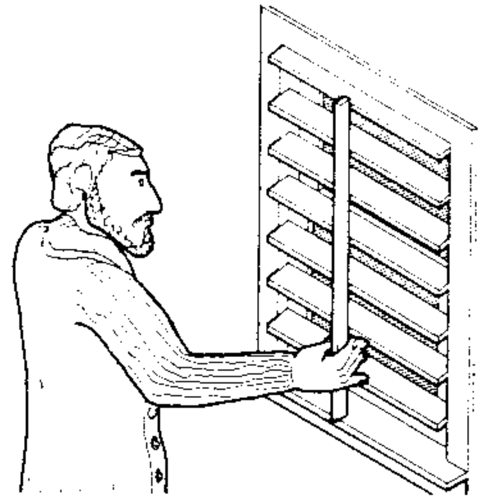
Beadwall: Styrofoam beads are blown into a cavity by means of a fan at night and are evacuated in the daytime (FIG 2.5-14). There is a central tank where the beads are stored.

EXTERIOR SHUTTERS

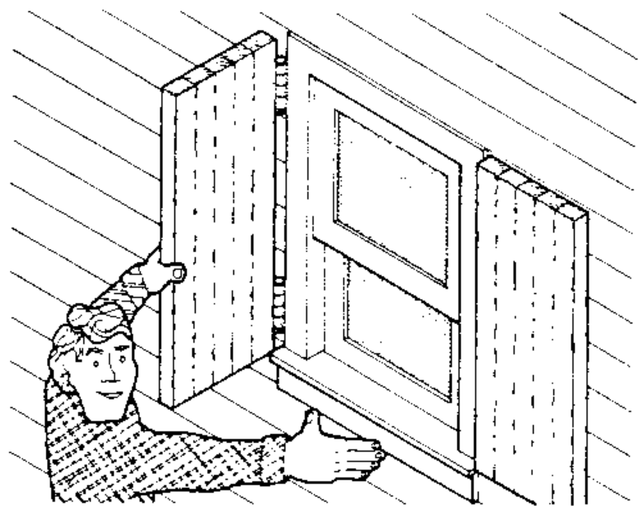
Wooden Louvers: Wooden louvers (FIG 2.5-15) can be used indoors as well as outdoors. They can be controlled to admit sunlight and fresh air. Sometimes aluminum is used as the material. Cost is approximately twice that of solid wooden shutters.

Wooden Shutters: Although tightness of fit may be a problem, wooden shutters (FIG 2.5-16) can reduce losses by one-half when compared with unprotected single pane glass.

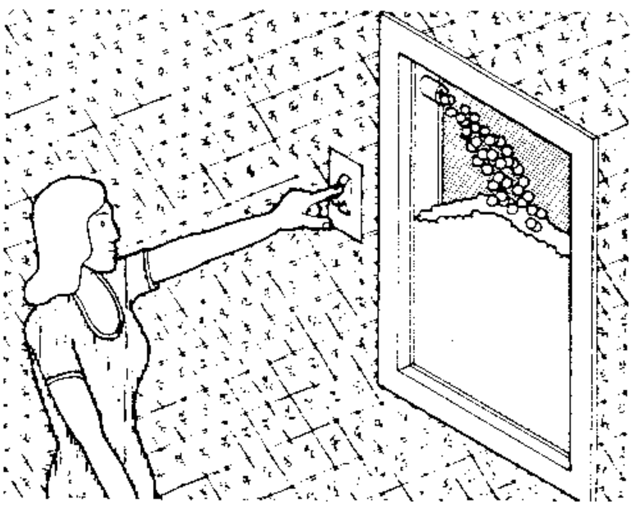
Insulated Reflector Panel: Insulated reflector panels (FIG 2.5-17) provide additional solar reflectance into the living space. The principal disadvantage may be due to snowloads and weight.



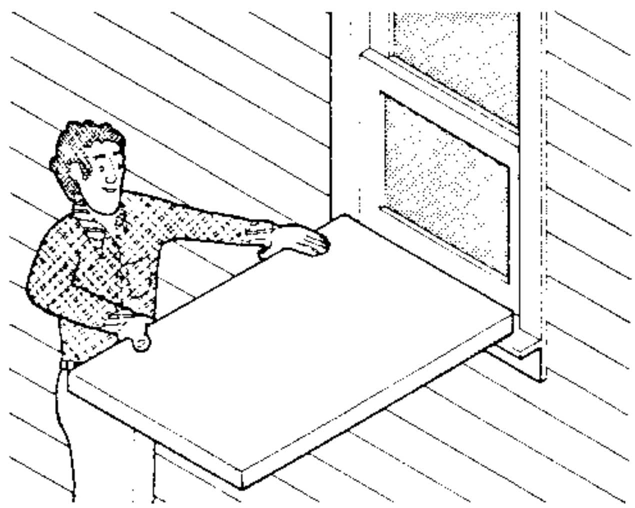
2.5-15 INSULATED LOUVERS: INSIDE OR OUTSIDE



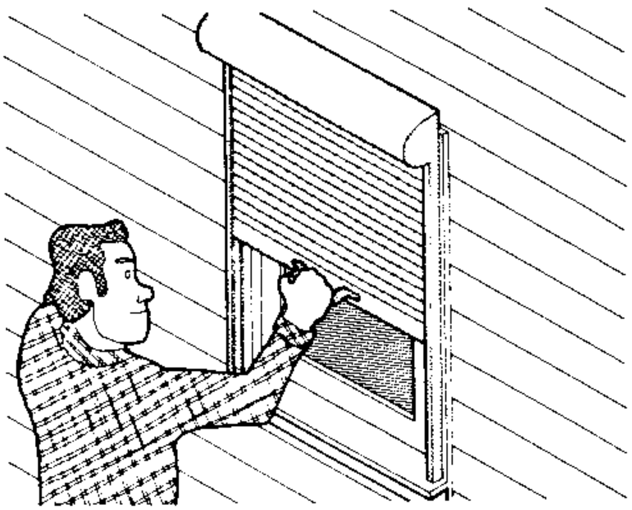
2.5-16 WOODEN SHUTTERS: OUTSIDE



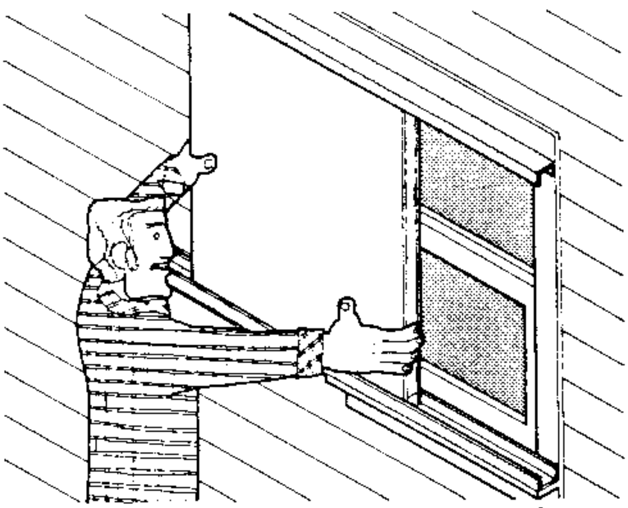
2.5-14 BEAD WALL



2.5-17 INSULATED REFLECTOR PANEL: OUTSIDE



2.5-18 ROLLING INSULATED SHUTTER: OUTSIDE



2.5-19 INSULATED SLIDING PANEL: OUTSIDE

Rolling Insulated Shutters: Rolling insulated shutters (FIG 2.5-18) have been popular in Europe under the product names of Rolladen and Roll-Awn. They are made from a variety of materials and may triple the insulation value of single pane unprotected glass. When cranked down, they provide a double air space between ambient environment and window. They can be arranged so that some light can be admitted when left in a loosely closed position.

Insulated Sliding Panels: Insulated sliding panels (FIG 2.5-19) can be inexpensive and have properties similar to interior sliding panels. The advantage to having the panel outdoors is that flammability and toxicity problems are reduced.

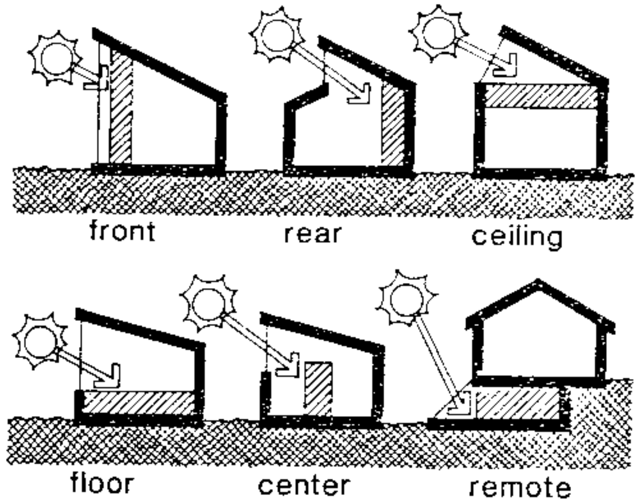
MASS

Thermal mass is an integral component of any passive solar design. Because air is not a good storage medium for heat, there is a potential problem of having a home overheat if there is insufficient thermal mass to absorb and store the solar gains. Mass can include brick, stone, block, earth, water, and phase change materials. The mass can be distributed for solar collection in a number of different ways (FIG 2.6-1).

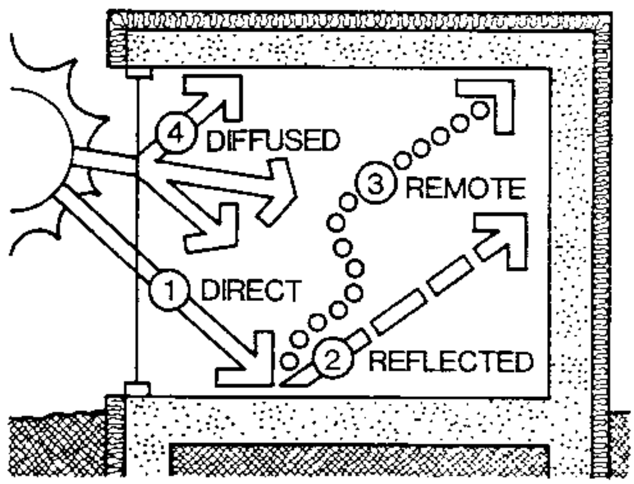
Solar energy entering a building may be absorbed by mass in a number of ways: it can be absorbed directly by a mass; it can be reflected onto a mass; sun-warmed inside air can transfer heat to a remote storage location where it is then absorbed; finally, the diffuse component of sunlight can also be absorbed (FIG 2.6-2).

Thermal lag, the time it takes heat to pass through the mass, is a characteristic of thermal mass which must be considered during the planning and placement phase. For example, it may take several hours for heat to pass through a thick masonry wall (FIG 2.6-3). This lag time is a function of the material used and its thickness. In certain instances it may be desirable to have the thermal wave delayed, e.g., to supply heat for a bedroom.

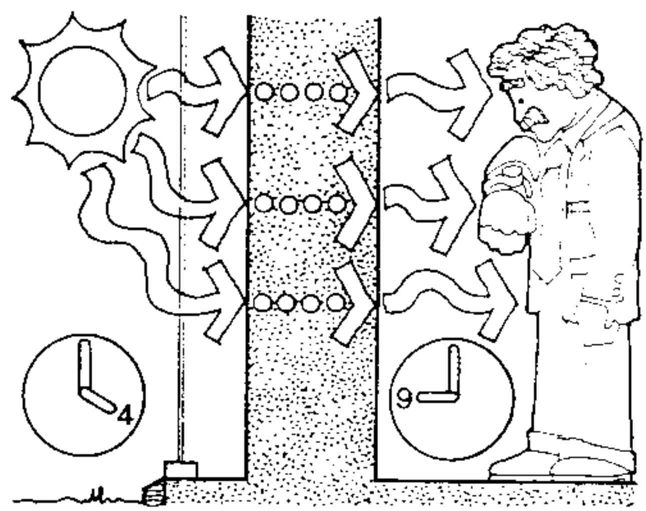
Many kinds of materials can serve as thermal mass and they can be arranged in myriad ways (FIG 2.6-4).



2.6-1 POSSIBLE MASS LOCATIONS

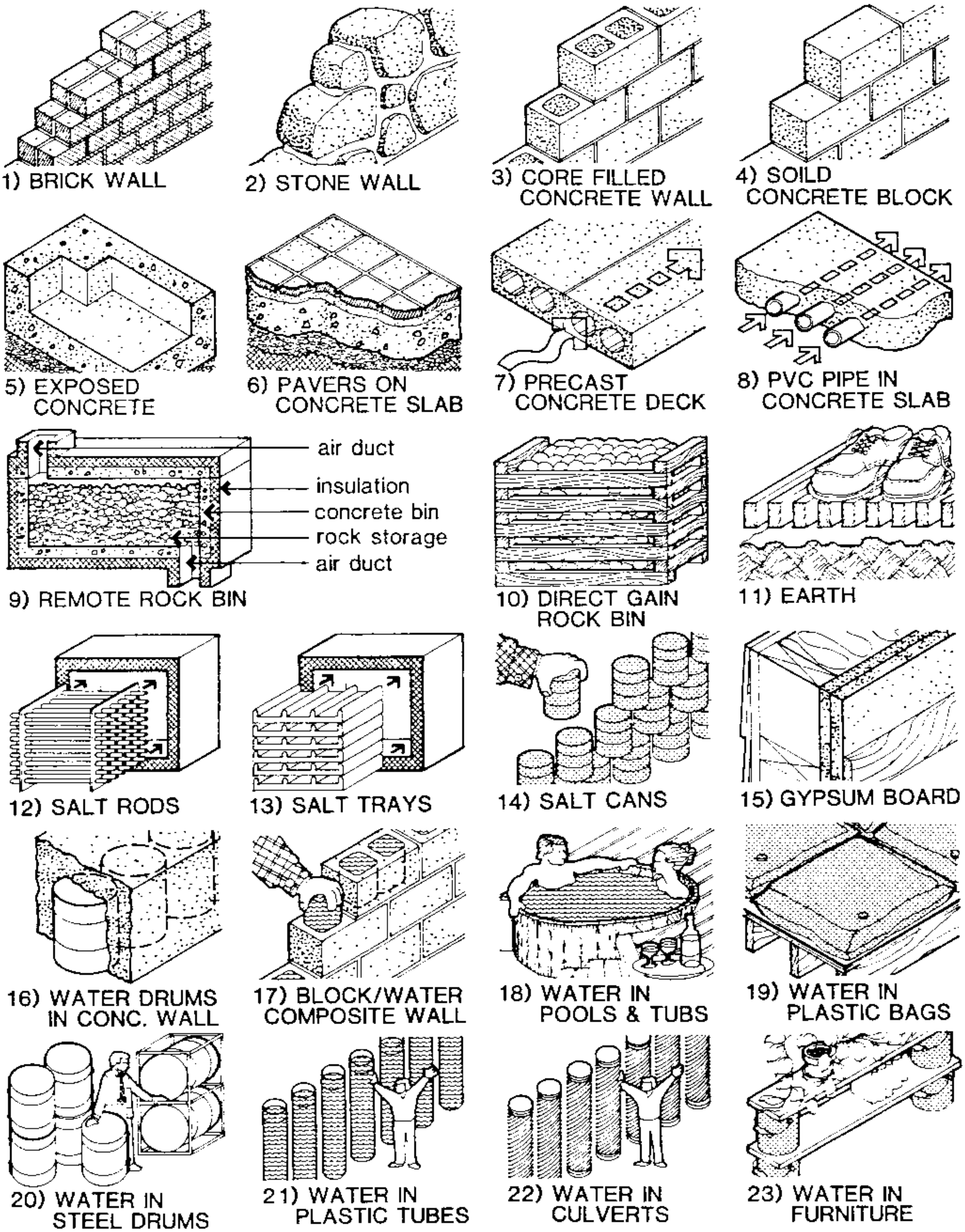


2.6-2 HOW SOLAR HEAT MOVES TO MASS



2.6-3 TIME LAG THROUGH STORAGE

MASS



2.6-4 TYPES OF MASS STORAGE

Thus far, the discussion of energy efficiency has been concentrated primarily on the heating season. Nebraska has approximately 6000 heating degree-days of heating requirement, and accordingly, the emphasis has been on heating season energy efficiency; Nebraska's 1000 cooling degree-days should not be ignored, however, because substantial summer energy savings can be realized by intelligent planning to maximize comfort and minimize the use of conventional air conditioners -- another expensive energy user.

One of the most important contributors to summer comfort is proper ventilation. Moving air, which enhances evaporative cooling of the skin, carries away body heat by convection and prevents humidity buildup in a structure. Proper site planning -- including proper shading and channeling of summer breezes -- aids all of the general natural home ventilation schemes discussed following.

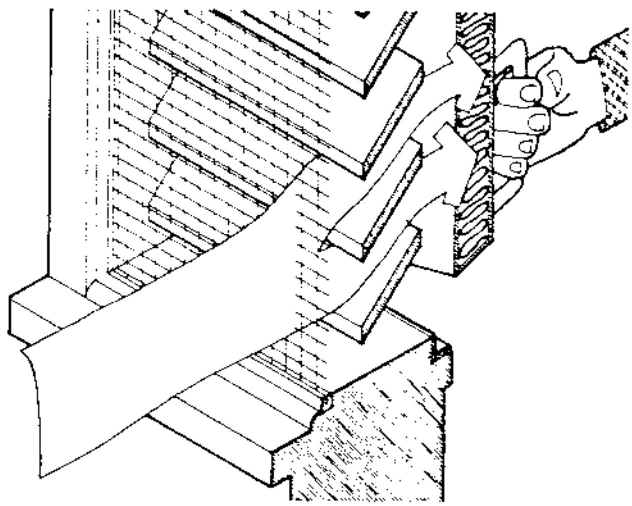
NIGHT COOLING

In those parts of Nebraska blessed with cool summer nights, a house can be opened and cooled at night, often through the use of special louvered panels. These panels are designed with fixed windows or windows that do not need to be opened (FIG 2.7-1). With the first morning heat, the panels are closed and the house otherwise sealed against hot outside air. In comparison to a conventionally-built home, a passive solar home is better suited to take advantage of night cooling since the mass can store more "coolness" than ordinary lightweight building materials. It has been known for many years that this is why some ancient stone temples and other buildings seldom need air conditioning.

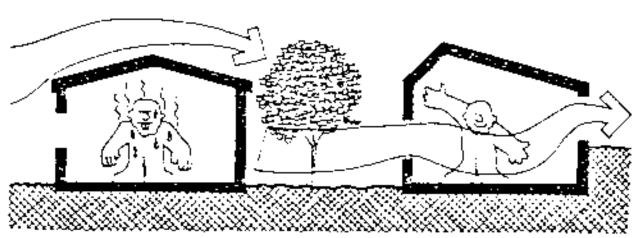
CROSS VENTILATION

Natural air flow through a house in the summer months aids in cooling for the following reasons: 1) moving air feels cooler than still air, and 2) without some airflow through a house, internally generated heat will build up to make the inside of the house significantly warmer than the outside.

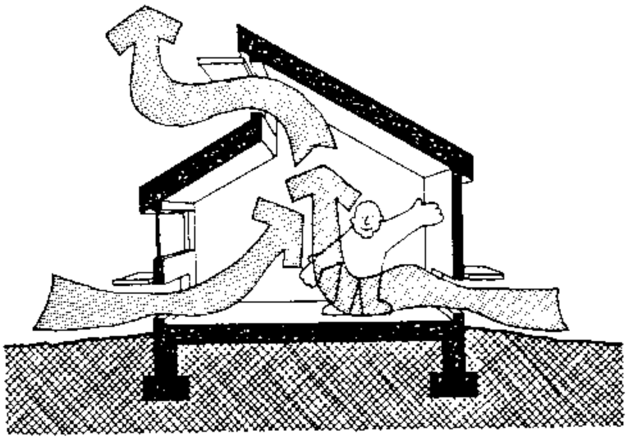
Prevailing summer breezes can provide this natural air flow, if they are impeded as little as possible. An air exit as well as an entrance must be provided, preferably such that the breeze is forced to change direction as little as possible (FIG 2.7-2).



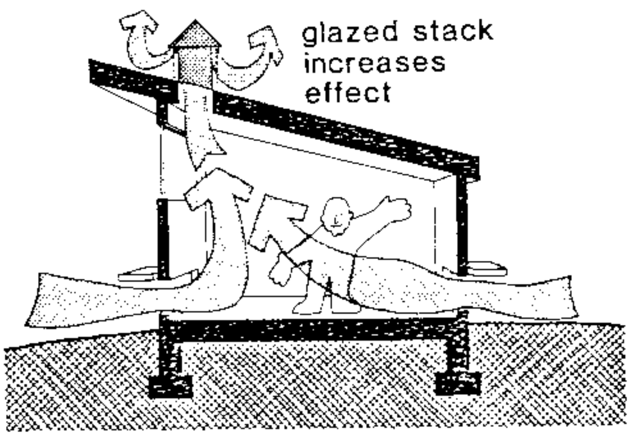
2.7-1 LOUVERED VENTS WITH INSULATED SHUTTER



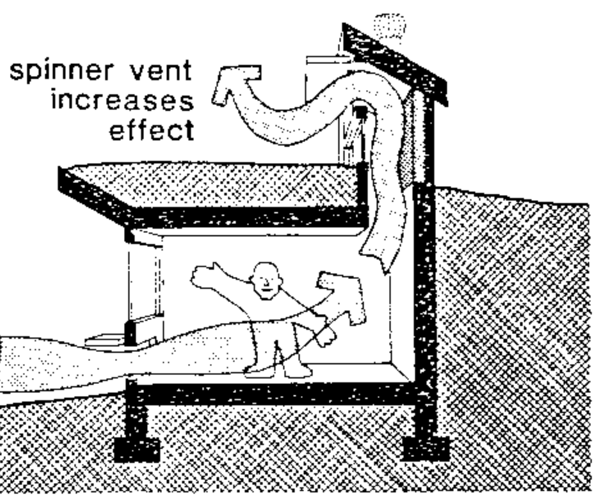
2.7-2 CROSS VENTILATION



2.7-3 CONVECTIVE VENTILATION



2.7-4 HEAT STACK VENTILATION



2.7-5 SOLAR CHIMNEY VENTILATION

The effect of natural cross ventilation can be enhanced by placing air exits high on the wall (since the warmest air will be near the ceiling), and entrances near ground level, where there can be some cooling of the air by ground and foliage.

CONVECTIVE VENTILATION

Convective effects can be used to drive air through a house even when there is little or no natural breeze. Inside air, heated by internal gains and the sun, rises to the top of the structure. If a vent is provided at a high point of the indoor space, the warm air will rise out of the building and fresh, cooler air will be drawn in at a lower level (FIG 2.7-3). This technique works best in homes with open, high interiors.

HEAT STACK

The convective ventilation technique can be enhanced by reinforcing the natural tendency for heated air to rise. A stack, painted black or other dark color, is mounted at the high point of a house (FIG 2.7-4) and the air within is heated to a relatively high temperature by the sun. The air rises, pulling air from the house. The effect is identical to that in convective ventilation, except that the driving force is much greater.

The effectiveness of the stack can be increased by surrounding it at a distance of 1" to 2" with a clear cylinder to prevent air from circulating around the outside of the stack. The stack will reach a higher temperature, increasing the driving force of the system.

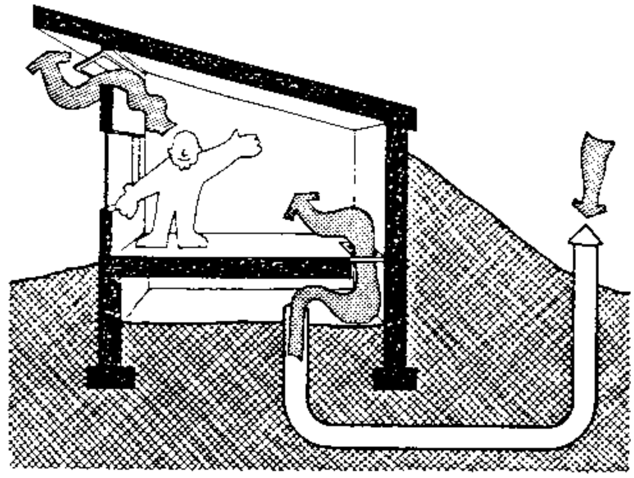
SOLAR CHIMNEY

The solar chimney is similar to the heat stack, except that the air is heated in a cavity built into the structure, rather than in a stack added to it (FIG 2.7-5). Thermal mass added to the solar chimney system will continue to vent the structure after the sun sets.

EARTH TUBES

These ventilation techniques can be augmented by the use of earth tubes. Air from a remote location is drawn through buried tubes into the building. The tubes are placed at a depth where the earth temperature is relatively cool all summer and are made long enough to reasonably cool the air before it enters the house (FIG 2.7-6).

All natural ventilation techniques discussed above can be aided further by strategically-placed fans or blowers.



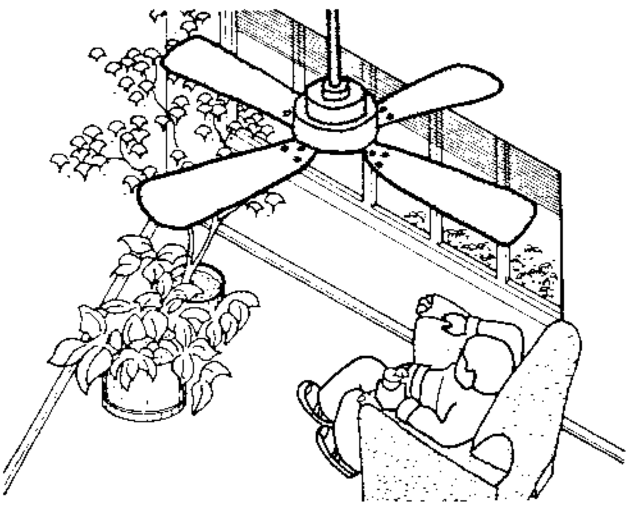
2.7-6 EARTH COOLING TUBE

MISCELLANEOUS

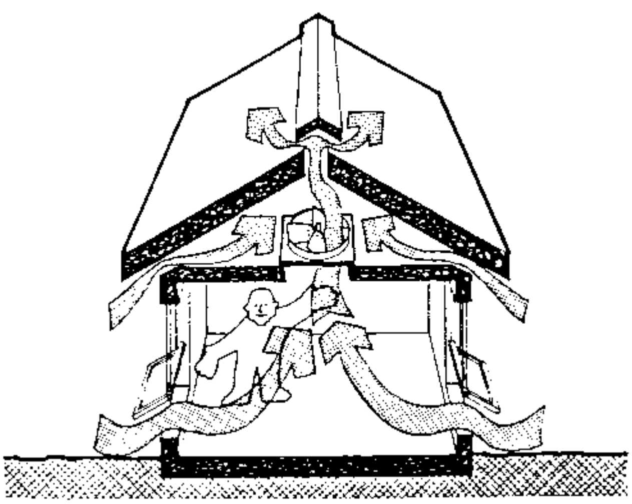
MISCELLANEOUS ENERGY RELATED TECHNIQUES

FANS

Although primary emphasis has been placed on air circulation during the cooling season, air movement is also important during the heating season, although for slightly different reasons. Because warm air rises, the warmest air in a room is normally near the ceiling. Since thermostats are located below the ceiling level, air temperatures are comfortable at thermostat level and overheated near the ceiling. This results in higher than necessary heat losses and higher than necessary furnace use.



2.8-1 OVERHEAD FAN



2.8-2 WHOLE HOUSE FAN

To maximize efficiency, it is advantageous to break up this air stratification. Properly designed forced-air furnace systems can help, but only if the fan is allowed to run constantly. Even then, however, there is often little effect in some areas of a room because of the placement of vents. High or cathedral ceilings further exacerbate the stratification problem. Radiant heating systems provide no circulation benefit.

Ceiling fans provide a solution to the stratification problem (FIG 2.8-1). While the use of a fan may not appear to be energy efficient, a typical ceiling fan consumes less than 75 watts of electricity on its high speed setting, and as little as 20 watts on slow speed, as compared to 200 to 300 watts for a furnace blower. The fan forces the warm ceiling air to circulate and mix with room air, maintaining a more even temperature.

In warm weather, ceiling fans operated at high speeds can produce pleasant breezes, thereby reducing cooling requirements. An alternate warm weather approach is to provide air circulation for the entire structure through the use of a whole house fan (FIG 2.8-2). These fans, typically mounted at a point high in the attic or roof, draw air from the house and exhaust it to the outside. Fresh air inlets must be provided in each room that is to be ventilated, and a clear path for air movement must exist to the fan and then to the outside.

UNCONVENTIONAL FAN USE

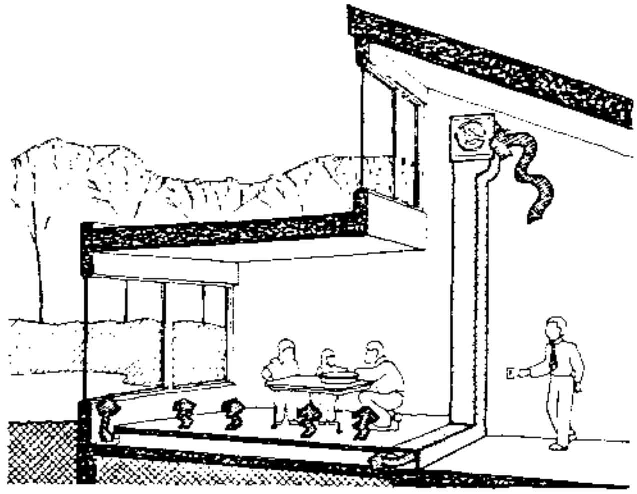
In structures with very high ceilings, a fan and duct system can be utilized to pull warm air from the top of the space and direct it through pipes set in the concrete mass floor. The air then exits through vents near the windows. In this system, some of the heat from the high warm air is stored in the mass for later use and the remainder is recirculated near the window area, which otherwise may tend to be cool (FIG 2.8-3).

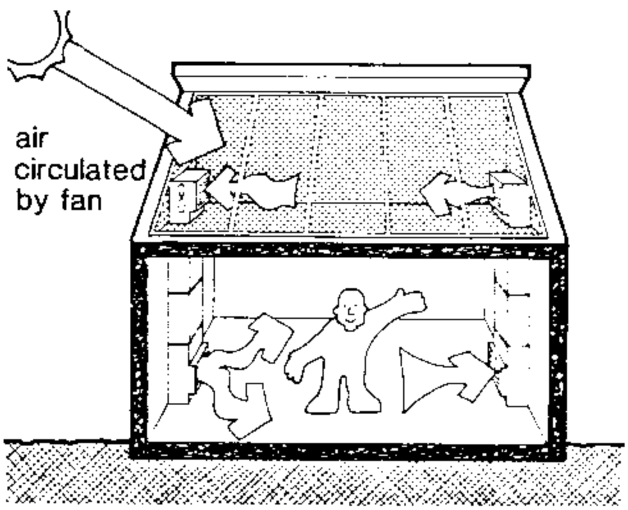
Another unconventional fan approach is a system called a "volume collector". A remote direct gain type space, possibly an attic, is heated by the sun to relatively high temperatures, and a fan circulates this warm air through ducts into the living space (FIG 2.8-4). Although thermal mass is not necessary for daytime-only heating, thermal mass can be added to allow some nighttime storage.

DOMESTIC HOT WATER (DHW)

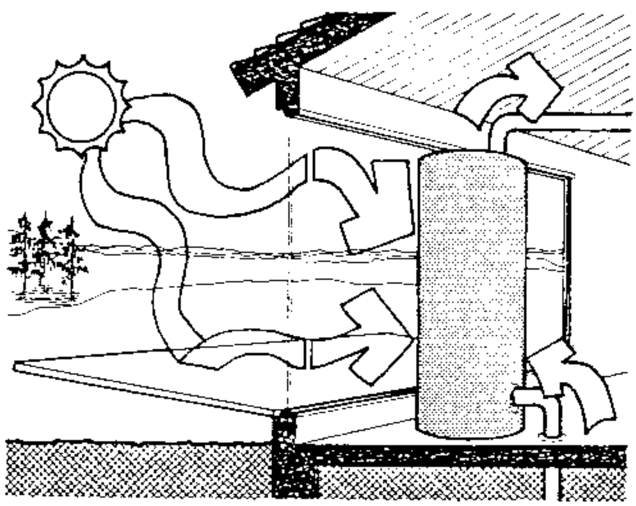
A significant non-space-heating use of energy is the heating of domestic hot water. In a conventional system, water at 55-65°F is drawn into a tank where it is heated to a preselected hot water temperature (100-140°F) and stored in the tank for use. Ignoring heat losses from the tank, the amount of energy required in this process is a function of the number of degrees to which the water must be heated, i.e., it takes only half as much energy to heat a quantity of water from 80 to 100°F than to heat it from 60 to 100°F.

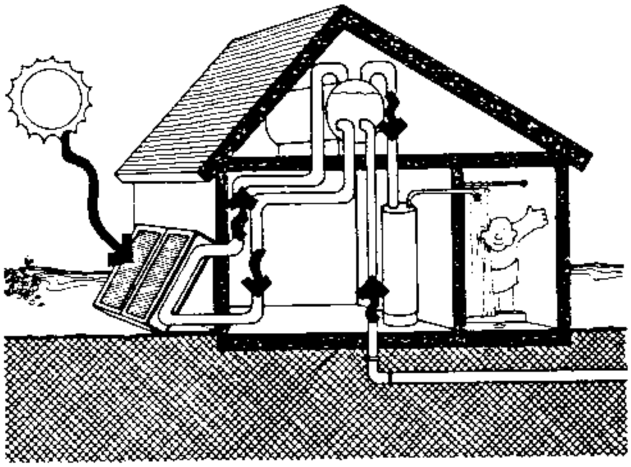
This energy usage can be reduced by utilizing a hot water preheat system. In a simple preheat system, water in a tank heated directly by the sun passes to the conventional hot water heater as it is needed (FIG 2.8-5).


2.8-3 HIGH AIR HEAT RECOVERY



2.8-4 VOLUME COLLECTOR


2.8-5 HOT WATER PREHEAT



2.8-6 HOT WATER THERMOSIPHON

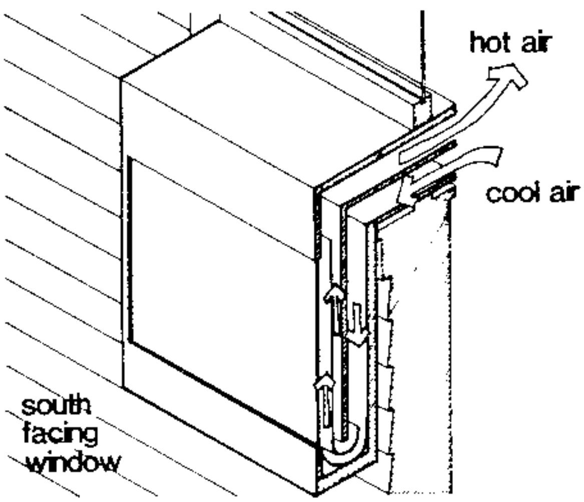
In a slightly more ambitious system, active-type solar collectors heat a water/antifreeze mixture, which rises naturally to pass through coils inside a water preheat tank (FIG 2.8-6). Heat is transferred to the water in the tank, and the antifreeze mixture returns to the collectors. This naturally-circulating closed loop is called a thermosiphon system. The warmed water in the preheat tank goes to the conventional water heater on demand and is replaced with fresh main water. One strength of a thermosiphon system is that it is normally self-terminating during periods of no sun. At night, for example, the thermosiphion loop simply stratifies, with cold liquid at the bottom and warm water at the top. This explains the need for a separate liquid loop for the collectors, which must be freeze protected. Systems without a separate collector loop require either a mild climate or drainage on cold nights.

RETROFITTING

Retrofitting is the application of passive solar techniques to existing homes.

THERMOSIPHON WINDOWBOX

A thermosiphon windowbox consists of an insulated cavity with a south-facing glass aperture (FIG 2.8-7) hung below a south window. Sunlight passing through the aperture falls on a dark-colored baffle which divides the cavity in half except for an air passage at the bottom. The baffle is warmed by the absorbed energy and heats the air in the outer portion of the cavity. This warm air rises and passes into the house. Replacement air is drawn from the house, and the cycle is repeated. At night, the unit shuts down because it is a thermosiphon system -- cold air stagnates at the bottom. Although commercially built units are available, a thermosiphon windowbox is a good do-it-yourself project.



2.8-7 RETROFIT: AIR THERMOSIPHON

GREENHOUSE RETROFIT

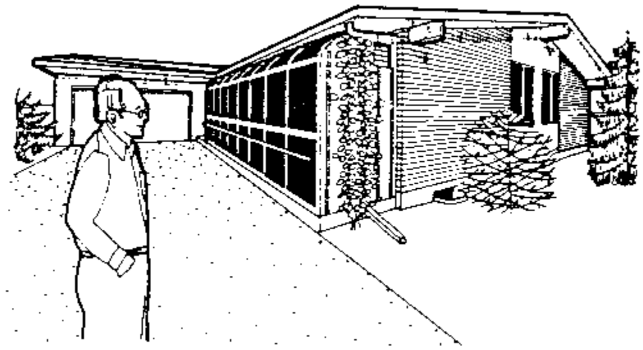
A greenhouse is a light construction addition to the south-facing side of a house. It includes a relatively large glass area, which is well-insulated, and thermal mass for storage. A means of drawing heated air into the home is also needed. Retrofit greenhouses vary from permanent frame or brick home additions to temporary "lean-to" structures with thin plastic film glazing supported by light metal conduit (FIG 2.8-8).

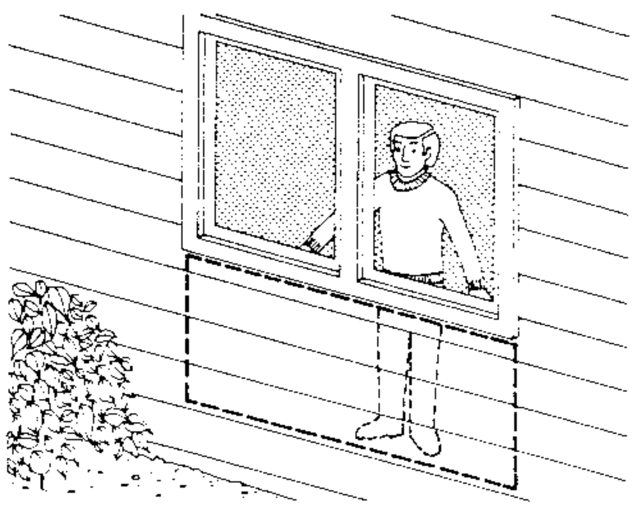
APERTURE ENHANCEMENT

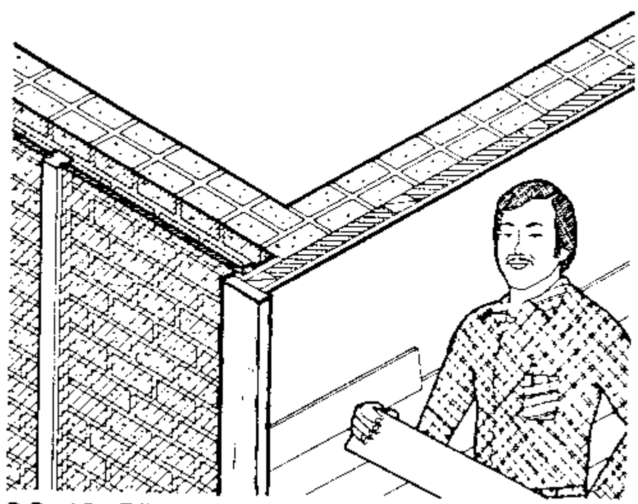
Another way to maximize solar benefit in an existing house is to increase direct solar gain through the south-facing window area. Of course, not all houses will lend themselves to this kind of modification. The effects of extra glazing can be enhanced by including a system of thermal mass to store increased thermal gains. (FIG 2.8-9).

RETROFIT TROMBE WALL

A brick, stone, or masonry home has considerable thermal mass. Unfortunately, this mass is on the outside of the structure where it does little good in stabilizing indoor temperatures. This situation can be rectified by applying insulation to the outside of the mass and removing any insulation barriers on the inside. For example, the south side of a building can be converted to an indirect gain system by applying a double layer of glass on the outside and removing the insulation on the inside (FIG 2.8-10).


2.8-8 RETROFIT: GREENHOUSE


2.8-9 RETROFIT: INCREASED GLAZING


2.8-10 RETROFIT: MASONRY BUILDING

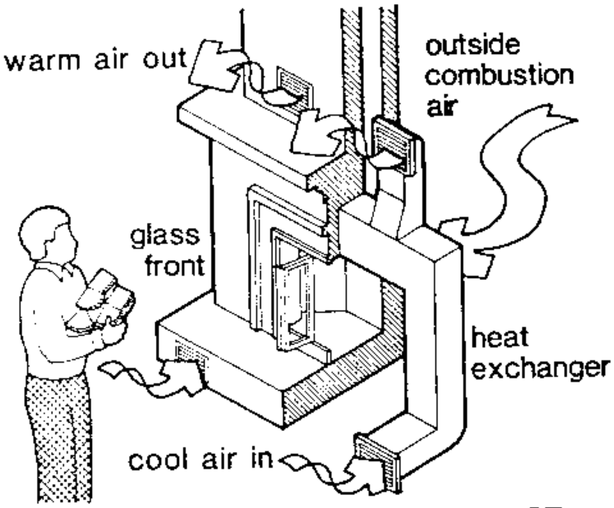
MISCELLANEOUS

AUXILIARY HEAT ALTERNATIVES

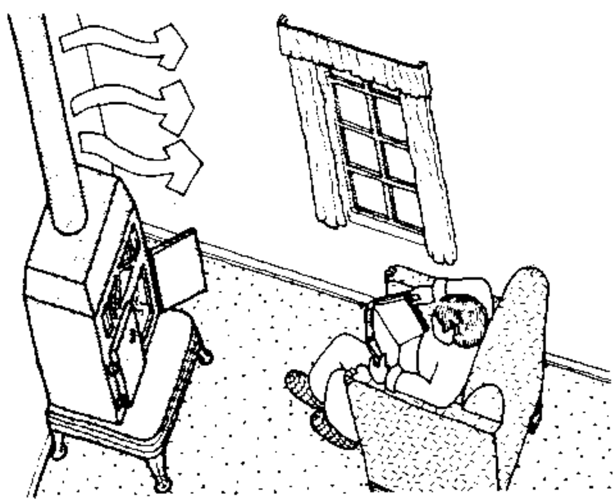
Very few solar designs provide 100% of the required heating energy over an entire season and backup (auxiliary) heating units are a necessity.

FIREPLACES

The energy performance of fireplaces varies widely. The use of most fireplaces results in a sizeable net energy loss from the house because the draft created by the fire draws heated air from the living space and sends it up the chimney. The area directly around the fireplace seems warm because



2.8-11 ENERGY EFFICIENT FIREPLACE


2.8-12 LET THE FLUE HANG OUT

the heated house air is funneled toward it and because of the radiant heating effects of the fire itself; the rest of the house becomes cooler, forcing increased output from the furnace.

There are a number of solutions to this problem, and many are incorporated in modern energy-conserving fireplace designs.

Because a fireplace offers primarily radiant heat, it is not necessary that the firebox be open to the living space. A fireplace with a sealed front allows heat to radiate into the living space without any air flow, eliminating the air loss problem. This technique necessitates drawing combustion air from the outside.

Efficiency of the fireplace can be further improved by reclaiming some of the heat that is otherwise lost in the chimney gasses. This is done by drawing room air, either by natural or forced convection, into channels surrounding the firebox and flue where it is heated and then released to the living space (FIG 2.8-11).

Many of the concerns that apply to built-in fireplaces also apply to free-standing fireplaces and stoves. For these free-standing devices, additional heat can be gained by exposing the flue to room air for the maximum length possible, rather than running it directly through the nearest wall (FIG 2.8-12).

Capturing flue gas heat is accomplished in a slightly different way in what is called a "Russian stove", or "Russian fireplace", a type of stove that has been used in Eastern Europe for centuries and, in fact, appears in the history of the Nebraska settlers in the 1800's. In the Russian fireplace, the hot flue gasses are led through a long, zig-zag path before being allowed to escape. The chamber material, usually brick or a type of masonry, absorbs much of the heat from the gasses (FIG 2.8-13). The fireplace has a relatively large thermal mass itself, so that it can stay warm for long periods of time between uses.

WOOD STOVES

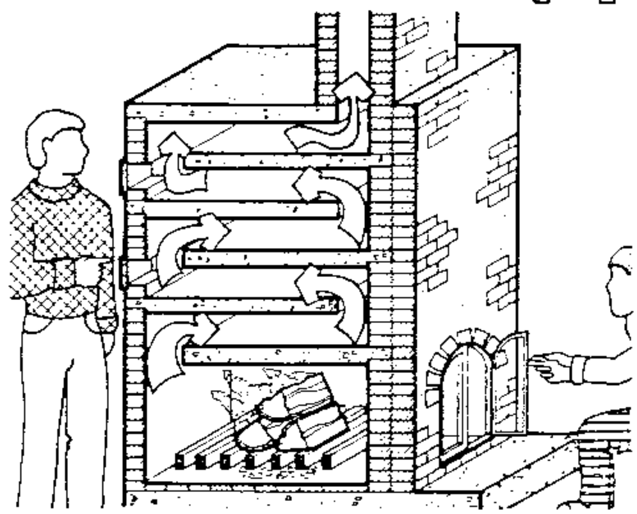
The wood stove is becoming a popular alternative for providing auxiliary heat (FIG 2.8-14). Like fireplaces, wood stoves vary greatly in their efficiency.

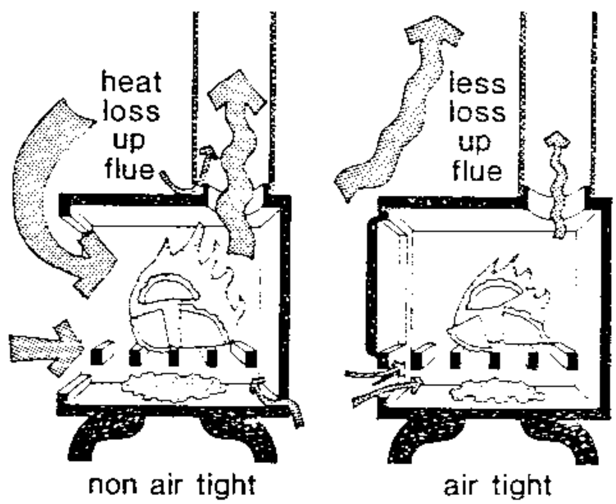
Wood stoves are of two basic types -- airtight and non-airtight. Airtight stoves have carefully sealed joints so that the amount of air admitted for combustion is easily controlled by adjustable vents. By restricting the entry of air into the stove, room air losses are cut substantially and the rate of combustion can be controlled to permit slower, longer burning.

Non-airtight stoves can suffer from some of the same problems as open fireplaces. One advantage of stoves, however, is that heat is more easily transferred to the room air than with a conventional fireplace. This is because the metal body of the stove has good conductivity, the flue is exposed, and air surrounds the free-standing stove on all sides.

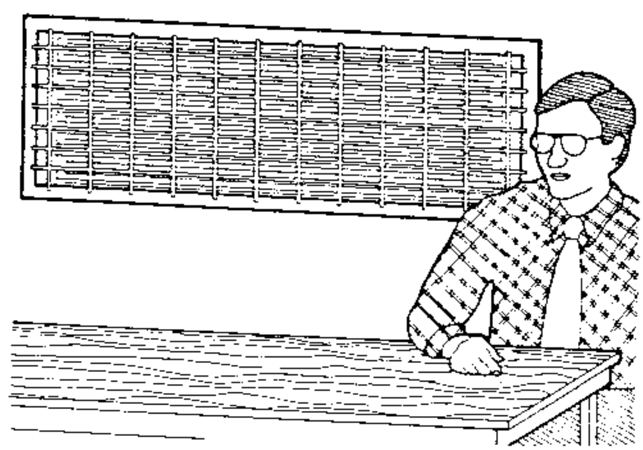
RADIANT PANELS

Radiant heating panels increase radiant temperature in a space while reducing air temperature requirements for the same comfort level. Radiant panels can reduce heating needs in selected parts of a home, especially in areas of sedentary activity. The panels are most commonly electric, although natural gas or propane models may be found. They are easy to install and provide good intermittent spot or zone heating (FIG 2.8-15).


2.8-13 RUSSIAN STOVE



2.8-14 WOOD STOVE


2.8-15 RADIANT HEATING PANELS