Chapter 7

Solar Rooms

Without ventilation or thermal mass, the temperatures of spaces having large areas of south-facing windows will fluctuate widely. Temperatures of conventional nonsolar greenhouses, for example, can rise to over 100° on sunny winter days and then drop to below freezing at night. If a sunheated room is permitted to have wider-than-normal temperature fluctuation, then the costs of thermal mass (to store heat) and movable insulation (to reduce heat loss) are avoided. The excess warmth from such a "solar room" can heat the house immediately, or if mass is added, heat can be stored for later use after the sun sets. Almost always, the solar room is warmer than the outdoor temperature, thus reducing heat loss from the building where the room is attached. Examples of solar rooms include greenhouses, solariums, and sun porches.

Greenhouses are the most common solar rooms. Conventional greenhouses, however, are not designed to take maximum advantage of the sun's energy. The problem is that most are built with a single layer of glass, and so they lose more heat at night than they gain from the sun during the day. Consequently, they need expensive auxiliary heat to keep the plants warm.

A solar greenhouse is designed both to maximize solar gain and to minimize heat loss. Usually, only the south facing walls and roof of the solar greenhouses are glazed, while the east and west walls are well-insulated. (Southeast and southwest portions, if any, are also glazed, partly because plants need that low-angle early sunlight.) If at least two layers of glass or plastic are used instead of one, this type of greenhouse will remain above freezing most of the winter in all but the coldest climates of this

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> **A Glazing Experience**
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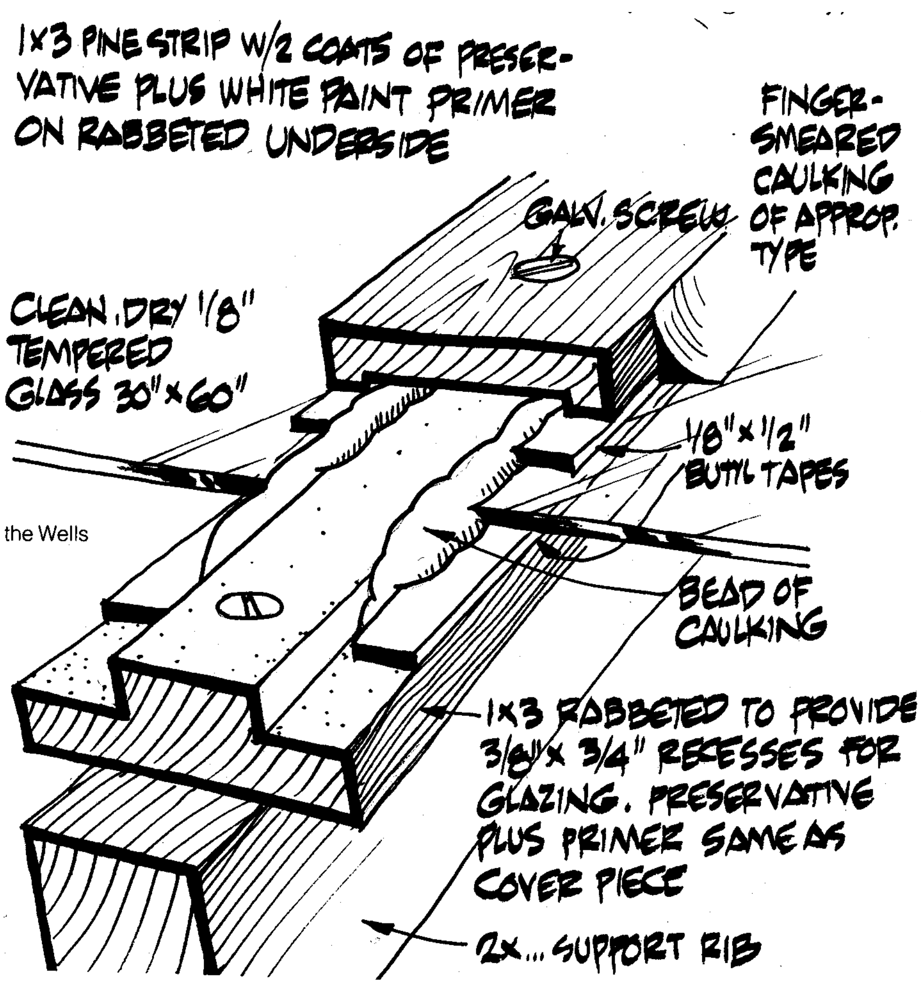
> I had to fire two "expert" glazers when their work on my skylight leaked. Then a master carpenter reinstalled the 92 large panes and actually got a 100% leak proof job. Fingers crossed because I'm always half afraid of finding that first tell-tale drop of water on the floor.

country. However, for maximum heat savings while growing plants year round, three and even four layers of glass and plastic should be used where winters have more than 5000 degree days. Keep in mind that each additional layer of glazing blocks additional sunlight. Therefore, for the highest possible light transmission, the third and fourth layers must be a very clear film, such as Teflon™ or Tedlar™. Each layer must be sealed tightly to prevent structural damage from possible moisture condensation between glazings.

For maximum sunshine, and for minimum heat loss at night, movable insulation is used in combination with double glazing. This can be tough to do, however. Some of the tricky design and construction problems include storing the insulation out of the way during the day,



The leakproof (so far) skylight detail at the Wells house.

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interfering with plants while moving the insulation, and obtaining tight seals against the glazing when the insulation is closed. Additional considerations include the need for insulation to resist mold, other plant and insect life, and moisture damage.

Glazing for solar rooms should be vertical or sloped no more than 30° from vertical (at least 60° from horizontal). Before you build, however, talk to everyone you can find who has ever used glass in a sloping position, and ask about leaks. If you can find someone who can convince you of a leakproof system, do not let any details escape your attention. Also, read the fine print in the sealants literature. Some silicones are attacked by mildew, many won't stick to wood, and all must be applied only to super clean surfaces.

Selecting the Right Glazing Material

Appendix 6 provides assistance in choosing the right materials for glazing solar rooms. Column three of Table 1 in Appendix 6 states the solar transmittance of each material listed. This figure represents the fraction of sunlight that actually passes through the glazing. To find the transmittance of several layers, multiply together (don't add) the transmittance of all of the materials. For example, for a glazing system of two layers of window glass (transmittance of 0.91-see line three) and two layers of Tedlar™ (transmittance of 0.95-see line seven), the total transmittance is

0.91 x 0.91 x 0.95 x 0.95 = 0.75. Do not use glazing systems that have a transmittance of less than 0.70. Lower light levels will jeopardize plant growth.

Heat Storage

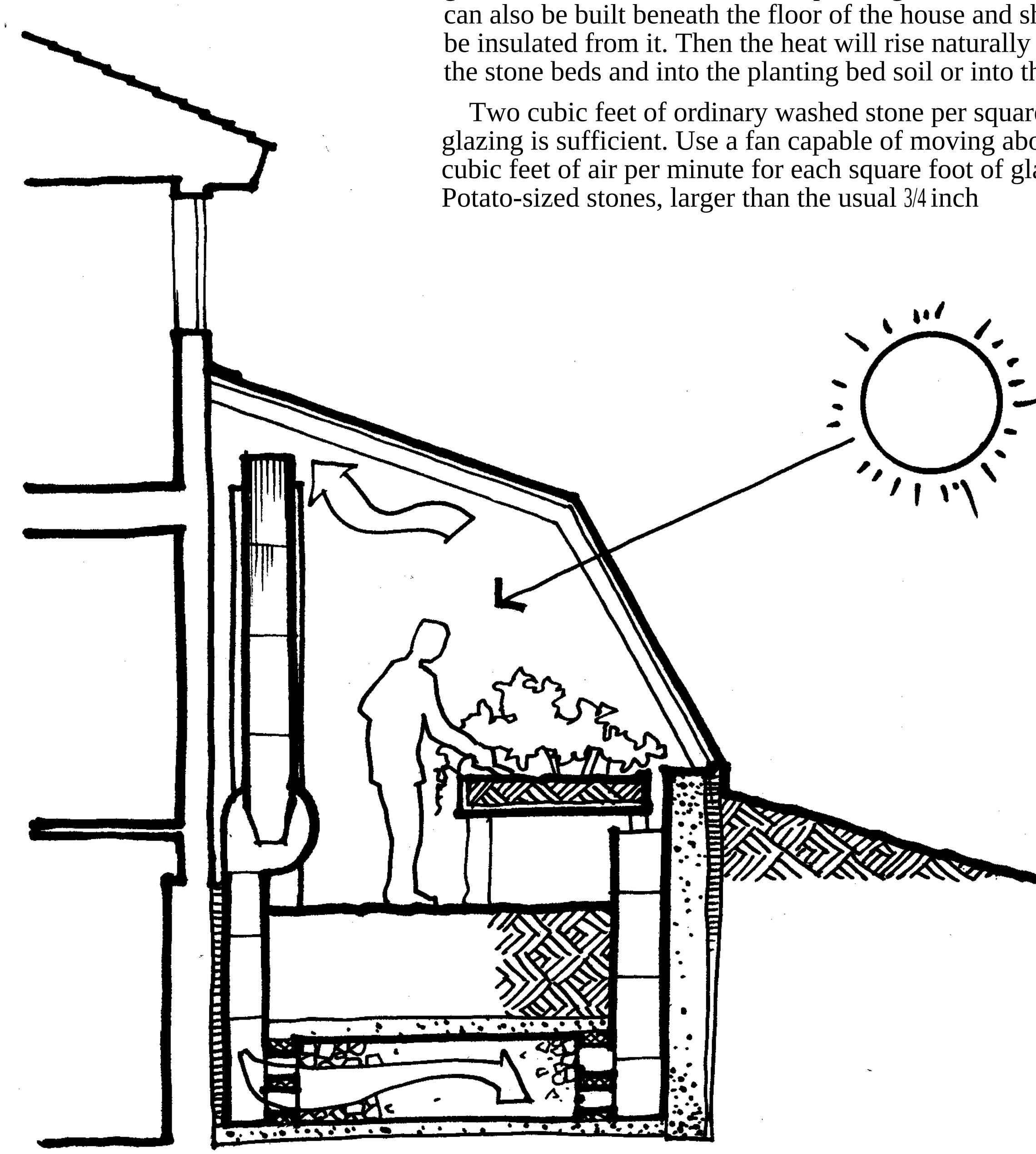
As with other passive systems, thermal mass enhances the performance of a solar room. Thermal storage mass moderates temperature swings, provides more stable growing temperatures for plants, and increases overall heating efficiency. The heat-storing capability of the planting beds can be supplemented with 55-gallon drums, plastic jugs, or other containers of water. Two to four gallons of water per square foot of glazing is probably adequate for most solar rooms.

Many of the most successful solar rooms are separated from the house by a heavy wall that stores the heat. The wall, built of concrete, stone, brick, or adobe, conducts heat (slowly) into the house. At the same time, the wall keeps the solar room cooler during the day and warmer at night. Use the design and construction information for solar walls, but eliminate the glazing.

Earth, concrete, or the floors store considerable heat. So do foundation walls if insulated on the outside. Be sure to use insulation with an R-value of at least 12 (3 inches of Styrofoam™). Insulate at least 3 to 4 feet deep and more in deep-frost country. This gives better protection than insulating 2 feet or so horizontally under the floor.

When solar rooms larger than 200 square feet reach 90°, a fan can be used to circulate the collected heat. Because plants benefit from having warm soil, hot air can be blown horizontally through a 2-foot-deep bed of stones below the greenhouse floor or under raised planting beds. Stone beds can also be built beneath the floor of the house and should not be insulated from it. Then the heat will rise naturally through the stone beds and into the planting bed soil or into the house.

Two cubic feet of ordinary washed stone per square foot of glazing is sufficient. Use a fan capable of moving about 10 cubic feet of air per minute for each square foot of glazing. Potato-sized stones, larger than the usual 3/4 inch



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to 1 1/2 inch size, will allow freer air movement. Consult with a local mechanical engineer or heating contractor for the best fan and ducting design. (Keep it simple!)

Costs

Solar rooms can be relatively simple to build, yet they can be very expensive if they are of the same quality and durability as the rest of your house. For example, with a few hundred dollars worth of materials, you can build a simple, wood-framed addition to your house to support thin-film plastics. The resulting enclosure will provide considerable heat, especially if it is not used for growing plants. On the other hand, good craftsmanship and quality materials can result in costs of several thousand dollars. In general, solar rooms are most economical when you can use them for more than providing heat and when they are built to a quality that will both enhance the value of your house and appreciate in value as your house does. Solar rooms are often exempt from local property taxes. Check with your local officials.

Large Solar Rooms

Most of the information in this chapter is applicable for relatively small solar rooms of 100 to 200 square feet. Unless your house is super insulated or in a mild climate, a solar room of this size will provide less than 25 percent of your heat. For big leaky houses, small solar rooms will provide as little as 5 or 10 percent of the heat.

Another way of approaching the use of solar rooms to heat your house is to think of them as rather large spaces that are incorporated into, rather than attached onto, your house. There are a number of advantages with this approach:

1. Both the solar room and house will lose less heat.
2. Heat will move easily from the solar room to your house.
3. Natural light can be made to penetrate deep into your house.

Growing Plants; some things to remember

An important function of some solar rooms is the growing of food-and flowers. Warm soil and sufficient light are critical for successful plant growth. Remember that the multiple layers of glass or plastic you may need to use will reduce light levels, a crucial issue in climates with below-average sunshine. Circulation of warm air through gravel beds under the soil can raise planting bed temperatures, increasing the growth rate of most plants.

Cold weather plants, such as cabbage, can tolerate cold temperatures, sometimes even mildly-freezing ones. Few house plants can be permitted to freeze, but many can endure rather cool temperatures. On the other hand, some plants, such as orchids, require stable, high temperatures. When warm, stable temperatures are required, the solar room must retain most of its solar heat; little heat should be allowed to move into the house. Three or four layers of glass or plastic (or movable insulation) and plenty of thermal mass are required to trap and contain the heat in cold climates.

Evaporation of water from planting beds and transpiration by the plants causes humidity. Each gallon of water thus vaporized used roughly 8000 Btus, nearly the same amount of energy supplied by 5 square feet of glass on a sunny day. Also, water vaporization reduces peak temperatures. It may be undesirable to circulate moisture-laden air into the house, unless the house is very dry.

Greenhouse environments are rather complex ecological systems. Unexpected and sometimes undesirable plant and animal growth may proliferate. Indications are that the greater mix of plants and animals, the more likely a natural balance will eventually be reached. To obtain this balance, some owners leave the door of their solar room open to the outside during the warm and mild weather.

New Alchemy Institute, among others, has pioneered work in natural pest control and companion planting as a step toward successful greenhouse management. They have also investigated fish-raising in large "aquariums," which also serve as thermal mass. Human, animal, and/or plant wastes are integrated into the total ecology of many advanced greenhouses, which are sometimes referred to as bioshelters. A more thorough understanding of the many natural cycles that are possible in greenhouses will offer rewards.

* New Alchemy Institute, E. Falmouth, MA 02536.

5. The solar room can be easily heated by the house if necessary and so is unlikely to freeze.
6. The solar room can be readily used as an expanded living space.
7. You can build your house compactly and the solar room will provide a feeling of large exterior wall and window area.

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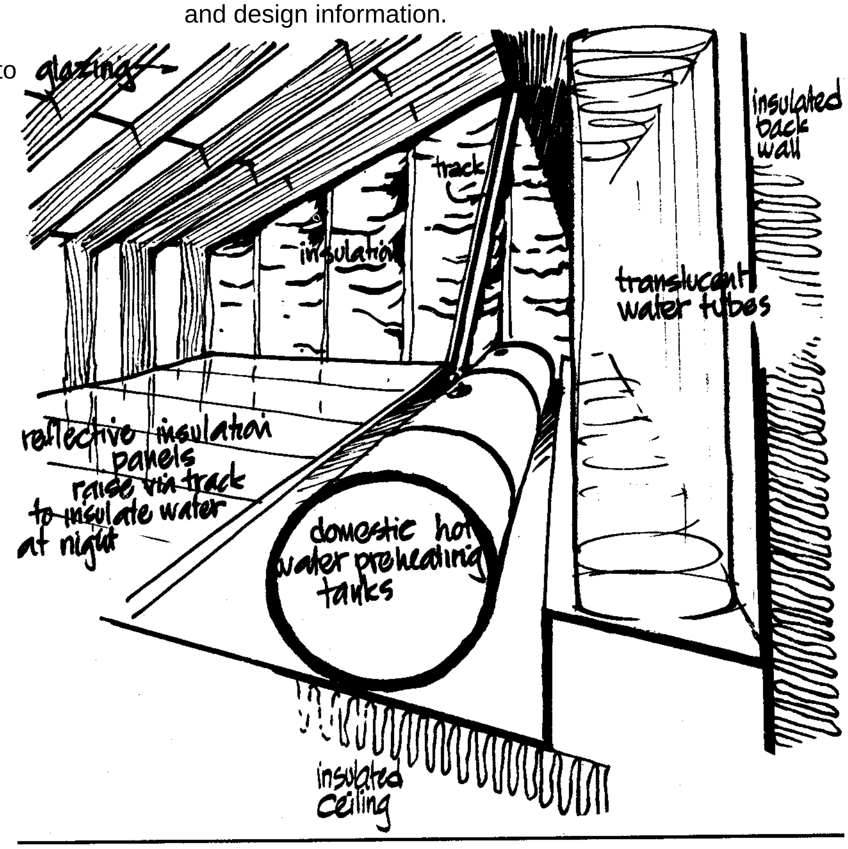
Attic Solar Rooms

Attics are often great places for solar rooms, particularly if their only purpose is to heat your home. Frame the roof in a conventional manner. Glaze the south slope with one sheet of glass or plastic. Insulate the end walls, the north roof, and the floor. Paint all of the surfaces black. When your house needs heat and the solar room is hot, a fan can circulate solar heated air from the attic to the house.
Be sure to insulate the sun-trap from the rest of the house. Place back-draft dampers on the air ducts to prevent house air from rising up into the attic at night when the attic is cold and the house is warm. This solar room design gets very cold on winter nights but heats up quickly when the sun shines.

Because it has no thermal mass to store the heat that the house doesn't need, it is unable to reduce fuel bills by more than 20 to 25 percent. In order to reduce fuel bills further, the design must be altered in a number of ways. First, the glazed . portion of the roof must exceed 15 to 20 percent of the floor area of the house.

Second, thermal mass must be added to the attic. This is frequently done by placing containers of water along the north wall of the attic.

Third, movable insulation must cover the glazing at night to significantly reduce heat loss from the attic so as to trap and store the sun's heat. In climates of 3,000 degree days or less, double or triple glazing is an alternative to movable insulation. Kalwell Corporation (see p. 161 of the appendix) has developed detailed construction and design information.



Ventilation

Even the best designed solar rooms will require ventilation at times of too much heat or humidity or too little carbon dioxide. Ventilation should be able to replace all of the room's air up to six times each hour.

Natural ventilation is preferred to energy-consuming mechanical ventilation. The greatest amount of ventilation occurs when the exhaust vents are positioned as high as possible and the intake vents as low as possible. Air flow rates and, in turn, necessary vent sizes, can be estimated. The velocity of the air, in feet per minute is approximately

$$V = 486\sqrt{\frac{h(T_0 - T_i)}{T_i + 460°}},$$

where

h = the height between the intake vent and exhaust vent,

T_0 = the temperature at the outlet vent, and

T_i = the temperature at the intake vent.

For example, if the outdoor temperature at the intake vent is 85°, the temperature at the outlet vent is 100°, and the height is 10 feet, then the velocity is

$$V = 486\sqrt{\frac{10(100 - 85)}{85 + 460}}$$

$$= 255 \text{ cubic feet per minute (255 cf/min).}$$

For solar rooms that taper at the top (as in lean-tos), smaller values should be used. Air can carry 0.018 Btu per cubic foot for each degree it increases in temperature (0.018 Btu/cf-°F). The amount of heat exhausted through one square foot of vent each hour is, therefore

$$(255 \text{ cf/min}) \times (100° - 85°) \times (0.018 \text{ Btu/cf-°F}) \times 60 \text{ min}) = 4131 \text{ Btus.}$$

A representative value for solar heat gain through glass is 200 Btus per square foot each hour. Therefore, each square foot of vent can accommodate 20 square feet of glass.

Solar rooms must sometimes be ventilated in midwinter, when heat from the bright sunlight builds up too quickly to be dissipated through the house or absorbed by thermal mass. Just be sure that such vents are sealed tightly on winter nights, and on cold sunless days.

7. The costs can be less than for solar rooms that are simply added onto conventional house designs.
8. The excess humidity of the solar room can be somewhat reduced by, and profitably used by, the exclusively dry winter house.

Perhaps the most notable example of this approach to solar rooms is the Balcomb residence in Santa Fe, New

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How to Get the Heat from the Solar Room into your House

A. Windows

Windows in the walls between the solar room and the house let light pass right into the house (just as in direct gain systems), especially during winter months when the sun is low in the sky. The roof of the solar room can shade the windows during the summer, helping to keep the house cool. Since the house windows are protected from the weather, you can keep their construction simple and inexpensive.

B. Natural Air Movement

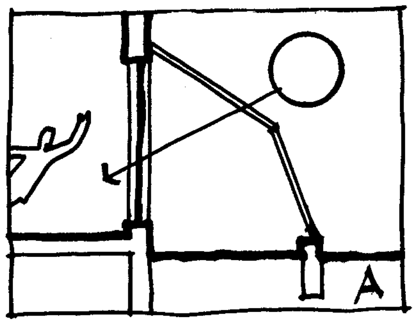
When your solar room is warm, just open the windows and doors and let the heat flow into the house. The higher the windows or other openings, the more heat will flow inside. And you can use curtains to control the flow of heat. However, don't forget about odors, insects, and humidity. Screens over the openings are usually a must. A fan on a simple thermostat can regulate the amount of air flow into the house. The small extra expense will ensure that your "solar system" works when you're not home.

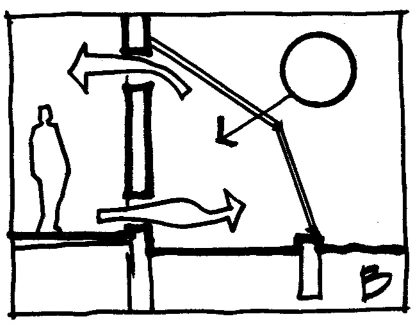
C. Conduction

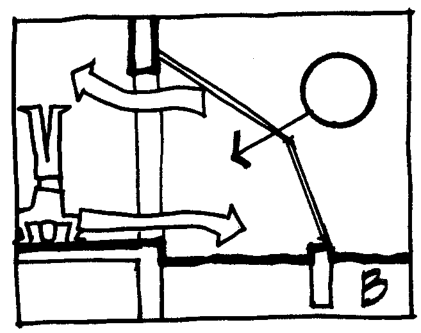
Conduction through an unglazed thermal storage wall is one of the best ways of transferring heat into your house. The wall should not be insulated. In the summer, the wall will protect the house from the solar room's heat. If the wall is wood-framed, it should be insulated. Be sure to protect the wood from the moisture of the solar room.

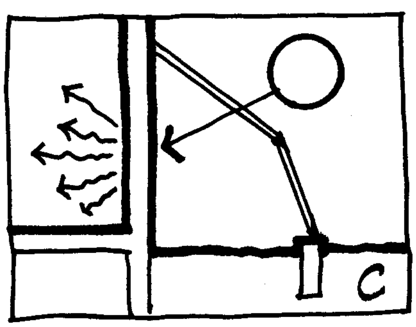
D. Gravel Beds

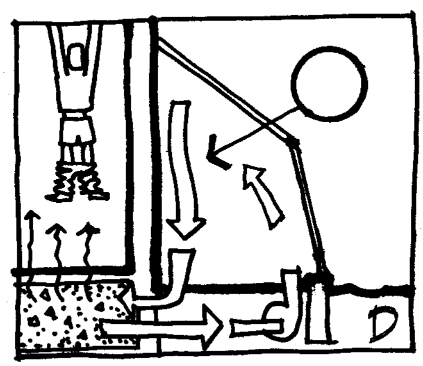
Use fans to blow warm air from the solar room through gravel beds under uninsulated floors of your house. Heat will radiate up through the floor into the room that is to be heated. The fans can be kept off during mild weather. Do not use fans to circulate the air from the gravel beds directly into the house as there could be dampness and musty-smell problems. Radiant heat through the floor is much more effective and comfortable.











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Mexico (see p. 124). The long edge of the two-story triangular-shaped sunspace faces south. The house wraps around the northeast and northwest faces of the triangle. The annual electric heating bill is less than $100.

Another example of this approach is the "Solar Envelope" house developed by Lee Porter Butler (see p. 125). The entire south side of the house is a two-story solar room. Warmed, greenhouse air rises through a roof plenum down a plenum in the north wall, through the crawl space or cellar, and back through the greenhouse. The roof and wall plenums extend the full east-to-west length of the house and are, in effect, a cavity or "envelope" buffering the house from the extremes of the outdoor weather. Both faces of the plenum are well insulated.

During the summer, the excess heat from the solar room is vented at the peak of the house to the outside, helping to ventilate the house and, in some climates, pulling the outside air through tubes, buried in the earth, that dehumidify and cool the air. Many houses of this design have heating and cooling bills of less than $100 per year.

An All-Purpose Solar Room Design

It is difficult to sort through the confusing multitude of designs for solar rooms and to choose the one that makes the most sense. This all-purpose solar room will work throughout most of the country. Its net energy contribution to a house will vary depending on the severity of the climate.

Summer temperatures can be kept close to outdoor temperatures with adequate ventilation. Mechanical ventilation and/or additional shading may be needed in hot, humid climates.

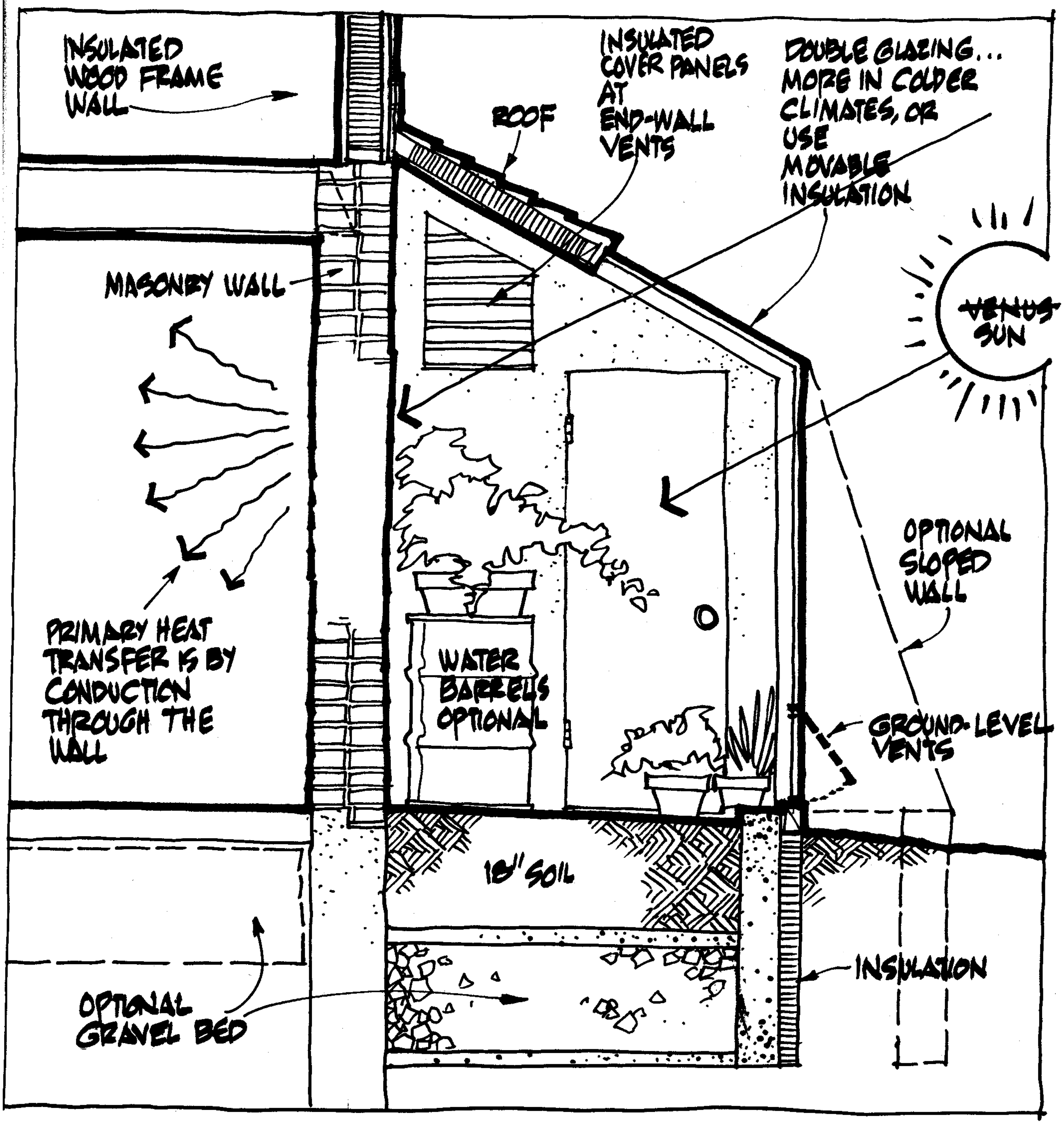
Winter temperatures in the solar room are likely to be as follows:

Up to 8000 degree days and more than 70% possible sunshine: 45°-85°

Up to 8000 degree days and less than 70% possible sunshine: 35°-85° with occasional need for backup heat

More than 8000 degree days and more than 70% possible sunshine: 35°-85° with occasional need for backup heat

More than 8000 degree days and less than 70% possible sunshine: up to 85° with frequent need for backup heat.



The www.BuildItSolar.com website provides hundreds of
free plans for solar and renewable energy projects