Passive Solar Heating

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PASSIVE SOLAR HEATING
Blaine Parker, Richard Hiatt and Sandy Holland

There are 4 basic passive solar construction techniques.

I. Direct gain heating -- allows solar radiation to directly enter the building through south-facing windows. Thermal mass (typically water or masonry materials) is strategically placed in the building for heat absorption and storage.

II. Thermal storage wall -- provides a wall of dense masonry or water between south-facing glazing and the living space. The sunlight absorbed by the wall is converted to thermal energy (heat) which travels through the wall and is redirected to the living space or loss back through the glazing.

III. Attached sun space or greenhouse -- this glazed area adds additional living space to a residence (either year-round or on a part-time basis) in which solar radiation is absorbed and stored. Thermal mass is either built into the common wall between the house and the sun space, in the floor, or in separate containers within the space.

IV. Convective loop or thermo siphoning systems.

1. Liquid systems such as a collector with a water tank above the collector so that the water will circulate by thermo siphoning.

2. Air-type units such as the (a) window box, (b) thermo siphoning collector and rock bed. The collector is normally located below the rock bed and preferably the rock bed is directly below the floor, or (c) the double envelope house which combines a sun space with a thin passage for the air to flow from the sun space over the ceiling, down the north side of the house and under the house before returning to the sun space during sunny days.
Direct gain passive solar heating

Since a certain amount of window area is generally desired for a residence, it is logical that most of the window area be placed on the south side of a residence so as to accept the heat gain from the winter sun when it is available. To have any appreciable affect one-fifth to one-third of the floor area must be used as south-facing window area. This means that for a typical 1500 square foot home, approximately 375 square feet of glazed area should be used on the southern exposure.

However, one will have serious problems of overheating during warm fall and spring days as well as summer unless some means is provided for reflecting or shading unwanted solar radiation. Window coverings are one alternative. Insulated white or aluminized reflective drapes are recommended over ordinary draperies because they provide not only shading but insulation against heat loss through the glazing. Preferably, these drapes should seal so that inside air cannot circulate against the window, and, of course, double-paned windows are to be used. Movable insulation or tight fitting exterior shutters are also satisfactory. In addition to window coverings, horizontal window overhangs can provide shading during the summer months when the sun is located high in the sky. Depending upon the distance from the top of the window these overhangs are roughly one-fourth to one-half the height of the window.

In the direct gain system if the windows on the south exceed 15 or 20 percent of the floor area, it is desirable to provide heat storage in the building to prevent large fluctuations of indoor temperatures. Materials which provide good heat storage are termed "thermal mass". Water is the best material for heat storage in terms of cost and storage capacity. Large containers (vertical tubes and narrow tanks) are sold by some manufacturers to facilitate water storage in buildings. These "water walls" should be dark in color and placed in direct sunlight. Use about one cubic foot (7½ gallons) of water for each square foot of solar window.

Masonry materials (concrete block, poured concrete, bricks, stone, etc) also provide good heat storage. For optimum heat storage, distribute the storage units or provide masonry floors and walls for storage. Use these guidelines for selecting interior surface colors and finishes.

1. Choose as dark a color for masonry floors as is consistent with your other decor.
2. Masonry walls can be any color (reflected radiation will be absorbed by masonry floor).
3. Paint all lightweight construction (little thermal mass) a light color.
4. Do not use wall-to-wall carpeting over masonry floors.

If all surfaces are frame construction and the glazed area is large, the space may overheat even during winter and then cool quickly when the sun goes down.

The direct gain system is undoubtedly the most economical solar heating system, particularly if the windows are going to be built any way.
Thermal storage walls

The thermal storage wall technique uses a water-on-masonry storage wall between the glazing and the heated space. The wall works by absorbing sunlight on the outer black-painted surface and then transfers the heat through the wall by conduction. The amount of mass provided by the wall determines the temperature fluctuations which will occur in the building. Provide one-third to one-half square feet of thermal storage wall per square foot of floor area. Double glazing or night insulation should be used on all thermal storage walls. Without this glazing approximately one-half of the heat gained will be lost through the glazing.

The economics of a thermal storage wall depends upon whether the wall would be built any way as a part of the structure or whether it is necessary with the plan to add the cost of the wall and charge it as cost of solar. Generally, it can be used as a supporting wall. When building with concrete block, fill the block cores with cement-sand mortar in order to add to its thermal capacity.

Attached sun space

The attached sun space is built like a greenhouse and may or may not contain plants. Some persons have the idea that they will produce vegetables in the greenhouse and obtain heat from it for the house. Generally, vegetable production and heat production are competitive objectives. For instance, the interception of solar radiation by prolific plant growth reduces heat available and transpires water into the atmosphere which also requires heat. It may be necessary to remove some of this excess moisture by ventilation. So, generally, relatively little heat can be obtained from a productive greenhouse. In addition, for many types of plants, it is necessary to maintain some minimum temperature at night. Although some heat might be obtained from heat loss from the house, it will usually be necessary to add heat for most vegetable production. In addition, one must consider the control of disease and insects in an attached greenhouse. Since few if any insecticides are appropriate for using in a residence, the disease and insect problem may be a significant one. Thus, vegetable production will require close management as well as some heating on cold nights. The highly productive greenhouse should be considered as a separate building.

If there are few plants in the attached sun space, then it is generally thought that a massive wall and floor can be used to store the heat for use in the residence. Generally, a thermal storage wall unit with a larger sun space area makes a very nice living space in a garden-type atmosphere. With this system, a door or vents might be opened during the day so that some heat will enter the house during the day. However, since less heat is needed during the day, the quantity of heat one can use coming directly from a sun space during the warmer part of the day is somewhat limited. In addition, if a large mass is used in the sun space and it becomes heated during the day, then after sundown the heat loss from the glazed area (assumed uninsulated) will cause the temperature to drop below the house temperature. During this time no heat can be directly moved from the greenhouse or sun space into the residence. However, energy stored in the thermal wall might well provide some additional heat to the house or at least reduce the loss from the house to the point where the greenhouse temperature reaches outside temperature.
**Liquid Thermo siphoning on convective loop systems**

A liquid heating solar collector panel can be used below a water heating tank in such a manner that thermo siphoning of the cold water from the tank down to the collector and up, due to heating, will heat water. Many of these type units were built in Florida in the 1930's with the collector on the roof and with the water heater contained in a false chimney at the peak of the house. Some of these units are still in operation although many of them were not kept in good repair when cheap natural gas was brought into Florida in the '40's. The problem of freezing causes problems with the use of water-filled collectors in Kentucky. The system either requires diligent effort to see that it is drained or some automatic drainage system which will positively work every time. Since the latter does not exist, many resort to the use of an antifreeze which requires the addition of a heat exchanger and pump for the collector loop. The use of an active type collector in Kentucky may be economically justified for domestic water heating where the unit is used year-round and the individual can take advantage of the 40% federal tax credit, particularly if electricity is the currently used fuel for heating water.

**Air thermo siphoning or convective loop systems**

The window box system may appear to provide considerable heat for a single room; however, feeling the heat is not a reliable method of determining how much heat one is obtaining. Usually the window boxes do not provide sufficient glazed area to be effective residential heaters.

Another system uses a large collector with a very large rock storage unit. For this system it is necessary that the collector be on the same level or preferably lower than the rock bed so that the air will circulate through the rock. A steep hillside house might be adaptable to this type system. The system generally uses two or three cubic feet of rock per square foot of collector area, and provides rather large, air passages through the collector and two-to-four inches diameter rock so that it will offer very little resistance to air flow. Several systems of this type have been built in New Mexico and Arizona.

The double envelope type house combines the sun space with the convective loop. Heated air in the sun space circulates through an air space in the ceiling then down the north wall and underneath the house before returning to the sun space. An advantage of the system is lack of noise from fans or pumps. The system requires a double-walled construction over the entire ceiling and the north wall to provide the air passage. The cost of such double-walled construction is questionable since the system has several inherent disadvantages.

1. It exposes the warmest air collected to the entire ceiling surface and the north wall surface so that heat loss will be increased although the loss of heat is limited by the extremely thick insulation recommended in this design.

2. The system as proposed by some claims to transfer heat to the soil during the day and then to have a reversed air-flow direction at night. Such a reversed air-flow direction is based on the fact that heat is being lost from the sun space in order to cool the air which then falls and moves underneath the house. No one has proven that the reversed air-flow direction actually works and, if it does, this movement of air is caused by heat loss. Since air can be moved much more efficiently with a fan than by heat loss, this is a serious defect in the system.
Most houses constructed with double envelopes use wood as a back fuel so it is difficult to determine how much actual additional heat is used. This writer believes that the heat from the sun space can be utilized much more economically by placing a pipe at the top of the sun space and using a fan to blow the excess heat into a rock storage unit then using the same fan to deliver heat to the house when needed at night. This construction of a rock bed with fan should be more economical than constructing a double envelope around the ceiling and north side of the house. If a house has equal insulation to a double envelope house and the sun space is isolated from the house at night, there will be less heat loss at night as well as during the day. Thus, the fan and rock bed storage must have greater thermal efficiency.