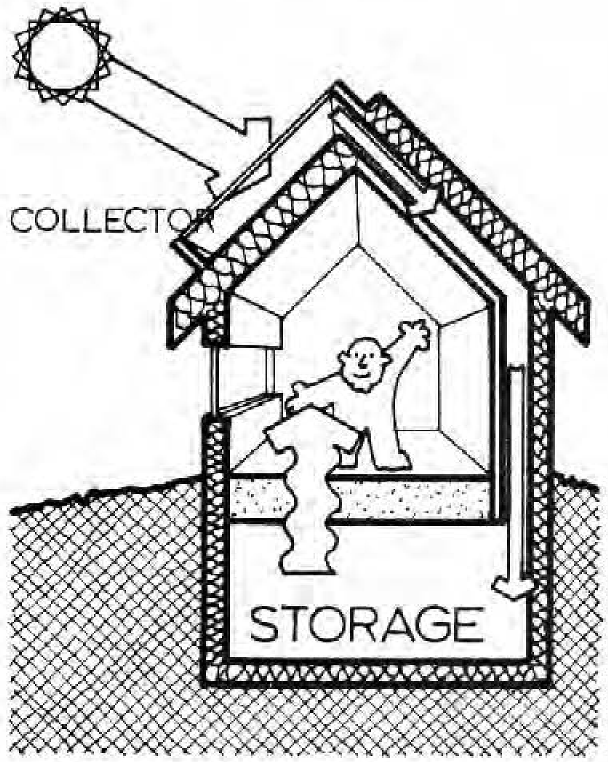
INTRODUCTION

The two principal solar heating methods for residential space heating and domestic water heating are passive solar (FIG 1) and active solar (FIG 2). Each method has its own unique characteristics and applications. Energy efficient homes frequently combine more than one solar heating technique, and these techniques are also often coupled with conservation strategies such as earth sheltering (FIG 3) and superinsulation (FIG 4).

SPACE HEATING: PASSIVE SOLAR

The passive solar space heating techniques are direct gain, Trombe wall, greenhouse, double shell, thermosiphon, and roof pond. Passive solar heated buildings are oriented so that the majority of windows face south, and the structure itself acts as a collector. Building mass such as tile floors and brick walls absorb and store the solar heat which is released when interior air temperatures drop after the sun sets.



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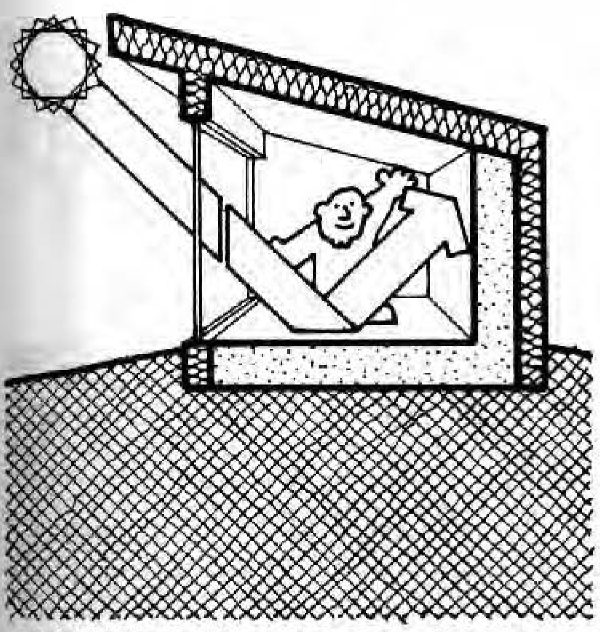

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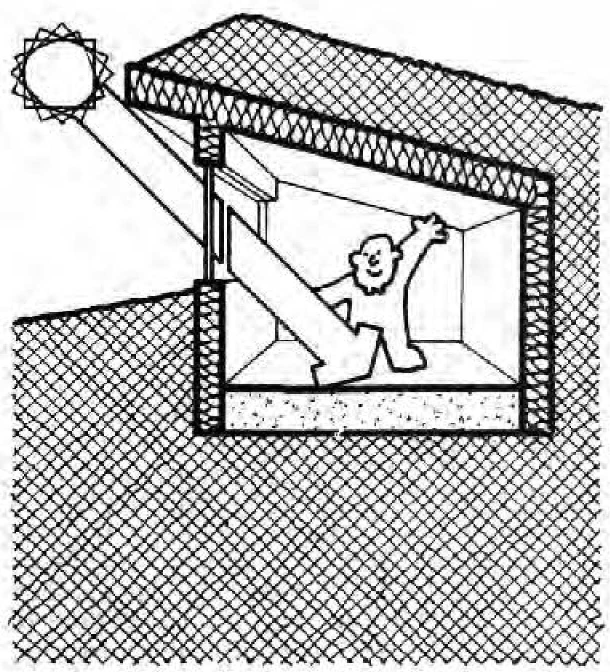

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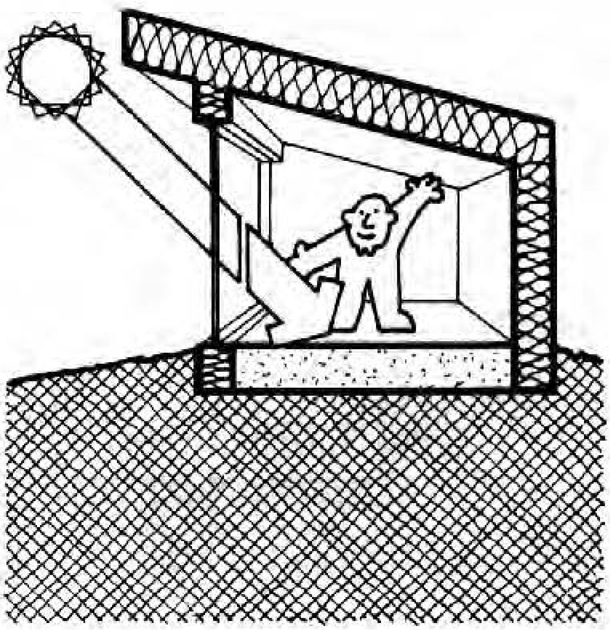

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Direct Gain

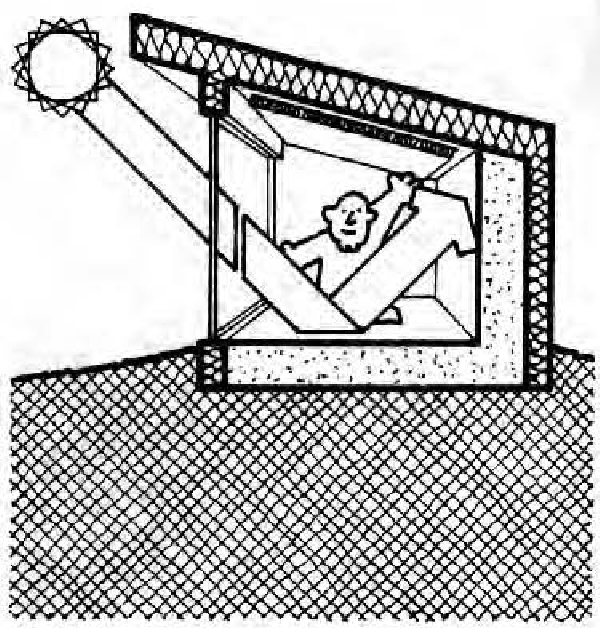
In a direct gain structure (FIG 5), sunlight shines directly into the building where walls, floors, and other mass storage are heated. When room temperatures drop after the sun sets, heat stored in the mass radiates to the living spaces. The use of night shutters is strongly recommended to help reduce heat loss to the outdoors through windows. Although direct gain systems are relatively economical and easy to build, buildings using direct gain must be carefully designed to avoid winter overheating.

Trombe Wall (Thermal Storage Wall)

The Trombe wall (FIG 6), or thermal storage wall, is a heat storage medium located directly behind south facing glass. The sun's rays are absorbed by the mass, and the heat slowly conducts through the mass and radiates to the living space. Concrete, brick, stone, and water are common Trombe wall materials. The absorbing surface of the storage system is frequently painted a dark color to better absorb sunlight. Buildings with Trombe walls tend to have stable temperatures without the extreme temperature fluctuations associated with direct gain systems.

Solar Greenhouse (Sunspace)

Solar greenhouses (FIG 7), or sunspaces, are a very popular passive solar space heating technique, particularly in retrofitting existing homes. They provide additional living space and can act as a buffer between the interior of the home and the outdoors. During sunny weather, warmed sunspace air is drawn through open windows, doors, and vents to heat the interior of the home. Thermal mass -- in the form of brick or tile floors, and walls of brick and/or water containers -- will often be included in a sunspace.



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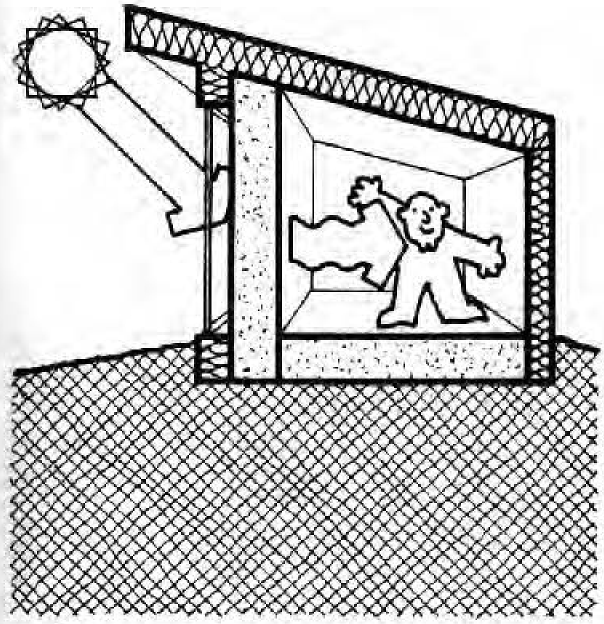
Double Shell (Continuous Thermal Envelope)

The double shell (FIG 8), or continuous thermal envelope, is essentially a house within a house, with the outer shell enclosing a sunspace. During the day, heated air from the sunspace rises into the plenum between the inner and outer walls, and the slowly migrating column of warm air circulates around the plenum chamber warming the inner walls. At night the air flow direction is reversed because the plenum air is warmed by an upward migration of heat from the earth beneath the home.



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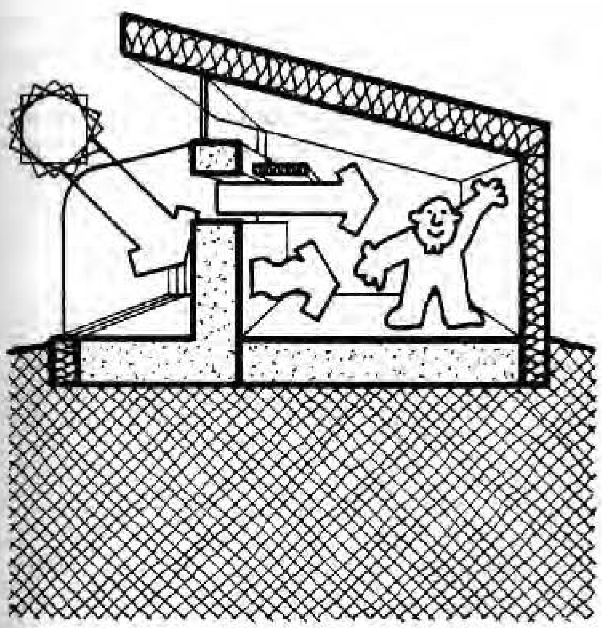

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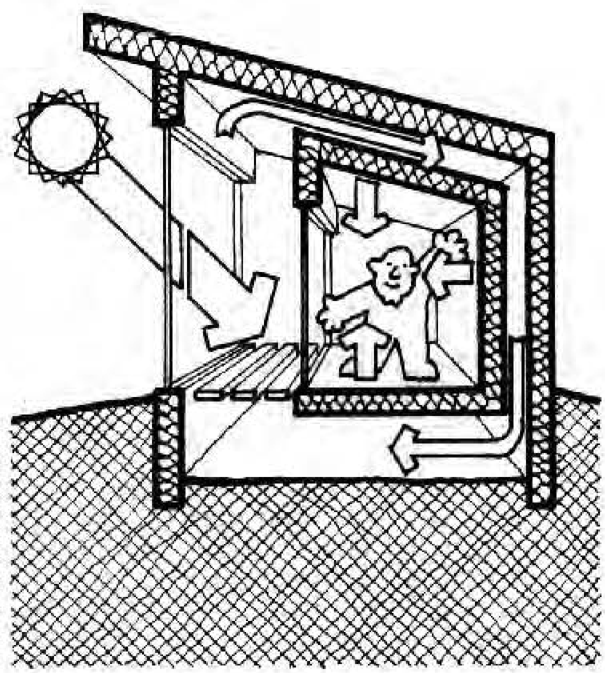

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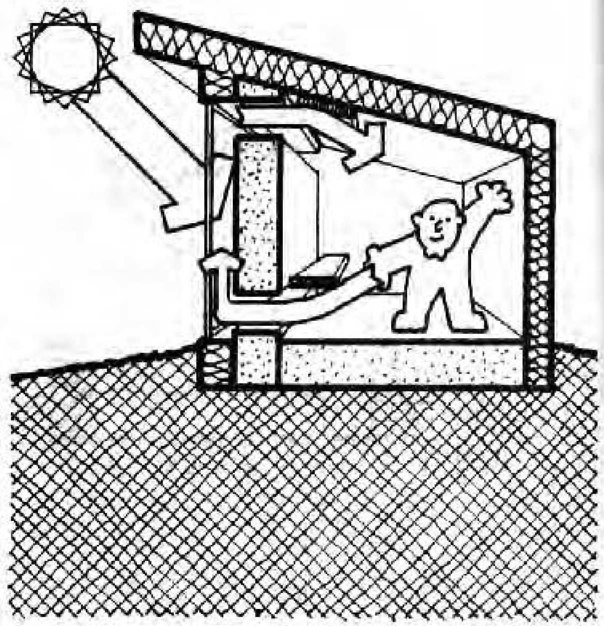
Thermosiphon

In a thermosiphon system (FIG 9), air warmed in the collector area is vented to the living space, and, as it cools and falls during its circulation, it is drawn back to and through the bottom of the collector area where the cycle is repeated. Thermosiphon systems are often used in conjunction with Trombe walls because the thermosiphon provides a faster means of getting warmth to the living space. For existing buildings, a thermosiphon collector can be site built and attached to the south wall.



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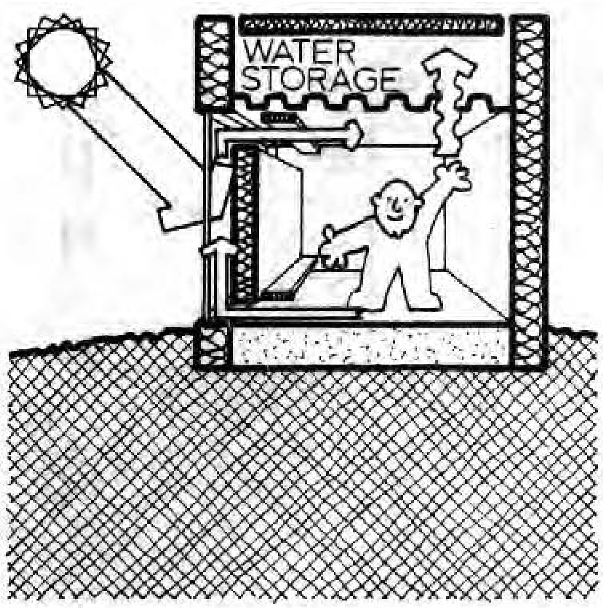
Roof Ponds

In a roof pond system, water stored in a membrane liner located above the ceiling of the structure functions as mass storage. For the heating mode in a typical roof pond, shutters above the storage are opened during the day to collect direct solar gain. At night, the heat stored in the roof pond radiates to the living space -- the shutters are closed to prevent heat loss to the night sky. In the summer cooling mode, the shutter operation procedure is reversed; the roof pond absorbs heat from the living space while the shutters are closed, and at night, the shutters are opened to allow the stored heat to radiate to the outdoors. The typical thermosiphon strategy would not be feasible in the Nebraska climate, so a modified strategy is undergoing testing by the PSRG. In the modified scheme (FIG 10), the roof pond is covered at all times, in this case, by a cover of floating, cement coated rigid insulation panels cut to fit over the mass storage. In the heating mode, heat to mass storage is provided by a thermosiphon system. In the cooling mode, a pump circulates storage water over the cover. The water loses heat through night sky radiation and evaporation and, after the water is cooled, it sinks back to storage through cracks between the insulation panels.



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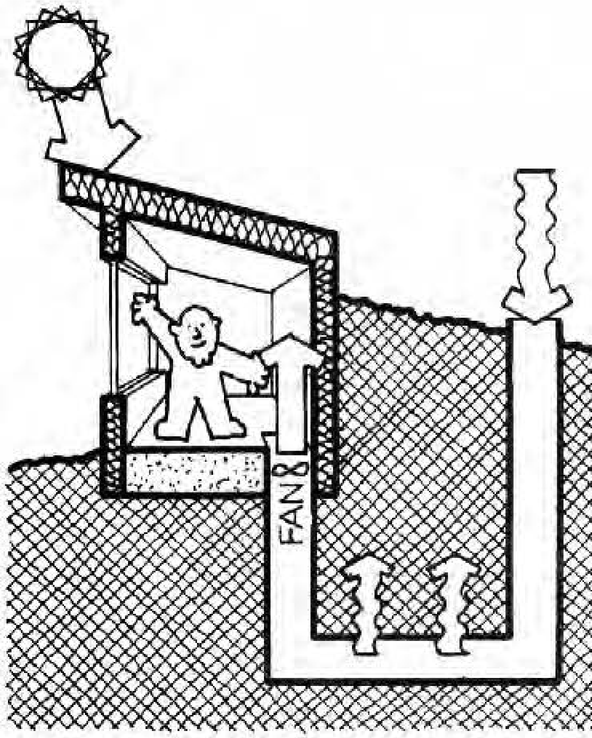
SPACE COOLING: PASSIVE SOLAR

Buried Pipe Cooling

In addition to earth sheltering and roof ponds, buried pipe cooling (FIG 11) is being utilized as a cooling technique in homes in Nebraska. The results, however, have been mixed. In this method of cooling, air drawn through an underground pipe is cooled as heat is transferred to the earth. Extreme care is required in designing cooling tube systems; cooling is a function of tube length, depth, diameter, material, fan speed, and soil conditions. Research by the (PSRG) indicates significant cooling potential in long pipes buried deep underground.

Annual Cycle Cooling

Before the widespread use of refrigerators, ice blocks cut from lakes in winter were stored for use during the summer. This procedure, with modifications, is being given serious consideration for space cooling purposes today. In annual cycle cooling systems (FIG 12), water in storage is allowed to freeze during the winter. In summer, a heat exchanger is used to transfer heat from the living space to the frozen water storage. Because of the abundant cold furnished by Nebraska winters, annual cycle cooling holds some promise, and experiments by the PSRG are underway to determine the technical feasibility of annual cycle cooling systems.



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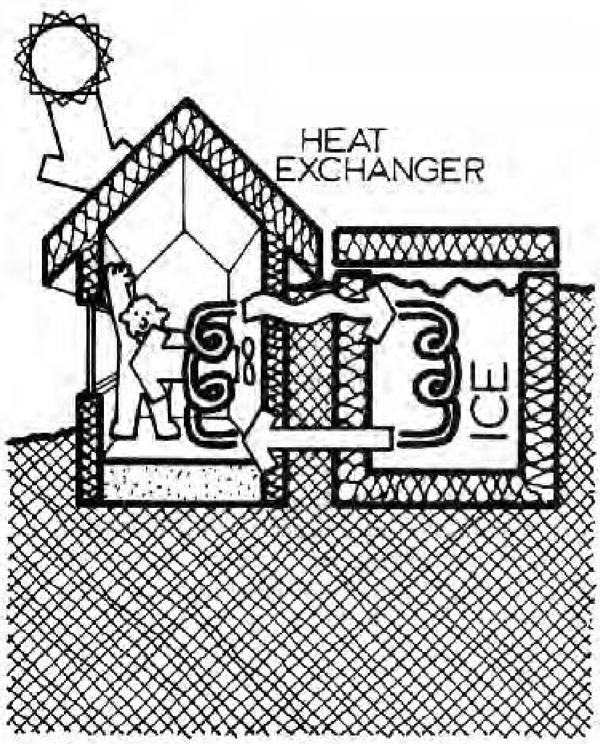

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SPACE HEATING: ACTIVE SOLAR

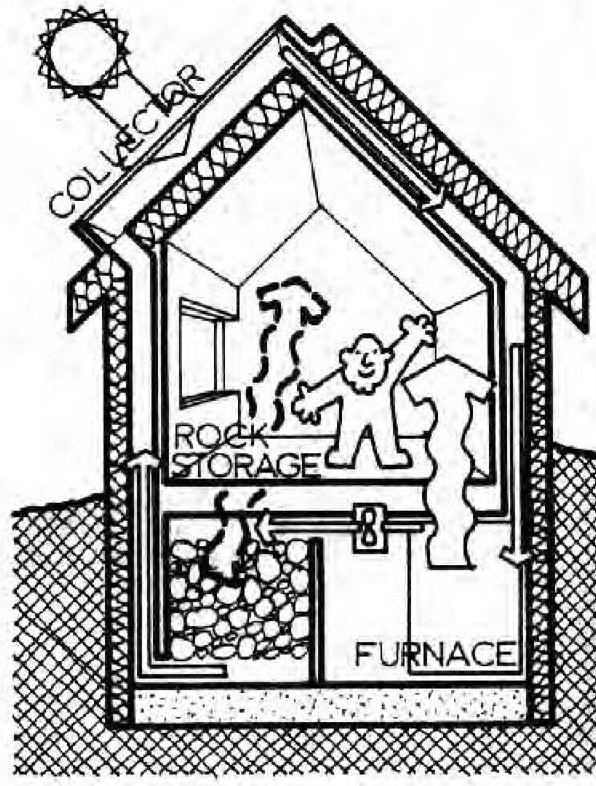
Active solar residential space heating techniques are comprised of air and liquid systems. In active solar systems, air or liquid passing through a collector -- typically consisting of glazing and an absorber plate -- is heated, and, by the operation of fans or pumps, the heated air or liquid is transported through ducting to storage.

The purpose of the storage is to provide a source of heat during the night or cloudy periods. Rock bed storage (FIG 13) is usually used with air systems, although the Colgan home in the book uses a phase change material (PCM) in place of rock as the storage thermal mass. Water -- in membrane lined storage or glass-lined steel or fiberglass tanks -- is the common storage medium for liquid systems (FIG 14). The collector fluid is usually an alcohol/water solution or a specialized oil.

A number of add-on space heating kits are available to the consumer. These kits provide a simple and sometimes economical means to provide space heating, but only while the sun is shining, since the kits do not have storage capabilities.

DOMESTIC WATER HEATING: ACTIVE SOLAR

From a cost effective standpoint, active solar systems utilizing flat plate collectors are likely to provide their highest rate of return in the production of domestic hot water. As a general rule, liquid systems are more thermally efficient than air systems for heating water. To ensure that the liquid system does not freeze, an antifreeze solution in a closed loop system (antifreeze system) is used, or the water is either drained to storage at night (draindown system) or simply drained from the system (drainback system).



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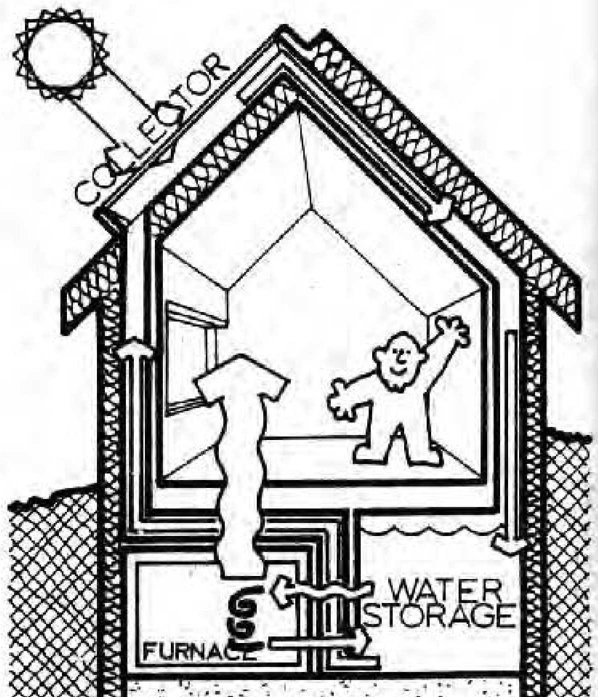

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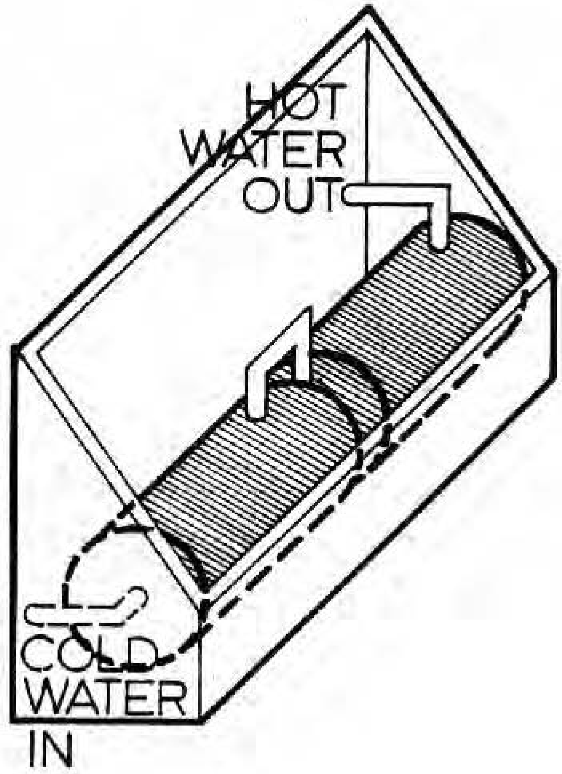
DOMESTIC WATER HEATING: PASSIVE SOLAR

The passive solar hot water heating systems are batch heaters and thermosiphon heaters. They are characterized by simplicity -- they have no moving parts or pumps -- and low cost, usually providing preheated water to a conventional hot water heater. Most of the summer domestic hot water load can be supplied by passive solar water heaters. The operation of the thermosiphon water heating system is the same as the thermosiphon space heating system except that water, rather than air, is circulated in a closed loop system. Batch water heaters (FIG 15) rely on tap water pressure and usually consist of little more than one or more black painted water tanks housed in a well-insulated, weather-tight enclosure. Sunlight shines through the glazing of the enclosure and heats the water. As with active liquid water heating systems, passive water heating systems need protection against freezing, and batch heaters are often located in attached greenhouses rather than separate enclosures.



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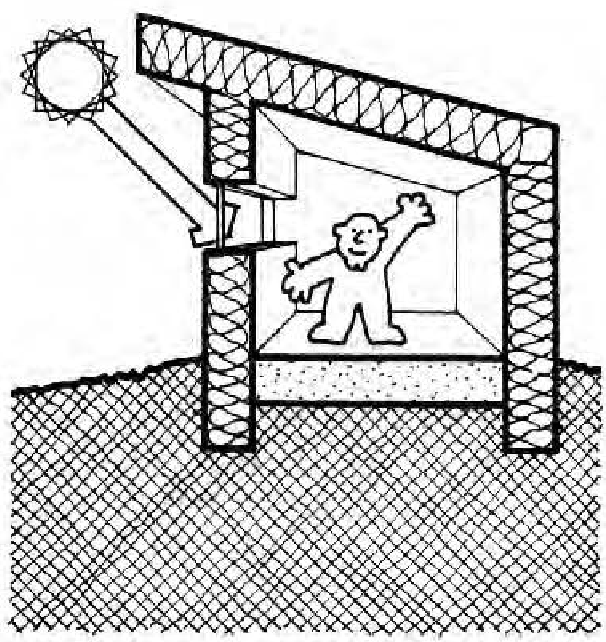
CONSERVATION STRATEGIES:

Superinsulation

Superinsulation (FIG 16) is a means of achieving thermal efficiency and is sometimes used when conditions do not permit the use of passive or active solar heating techniques. It is, as the name suggests, the placing of extra insulation in walls, roof, and below grade. Increased insulation levels limit heat loss in winter and heat gain in summer. During construction care must be taken in taping joints and installing vapor barriers. Because superinsulated structures have low air infiltration rates, the use of air-to-air heat exchangers to ensure proper ventilation should be considered.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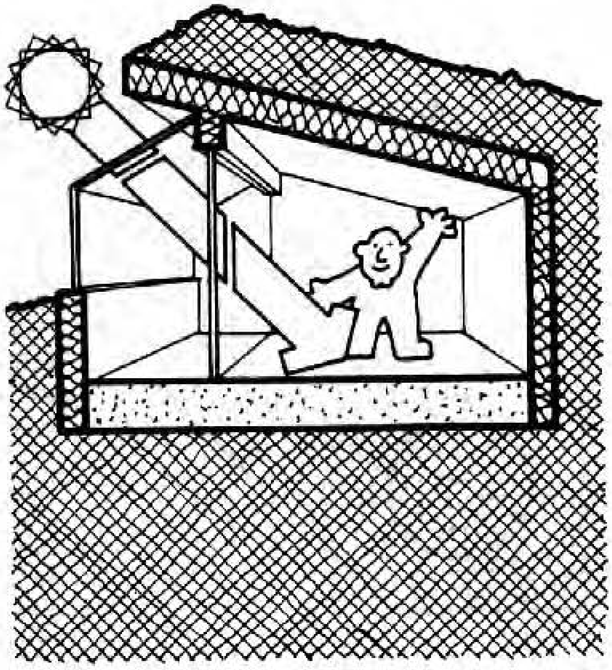

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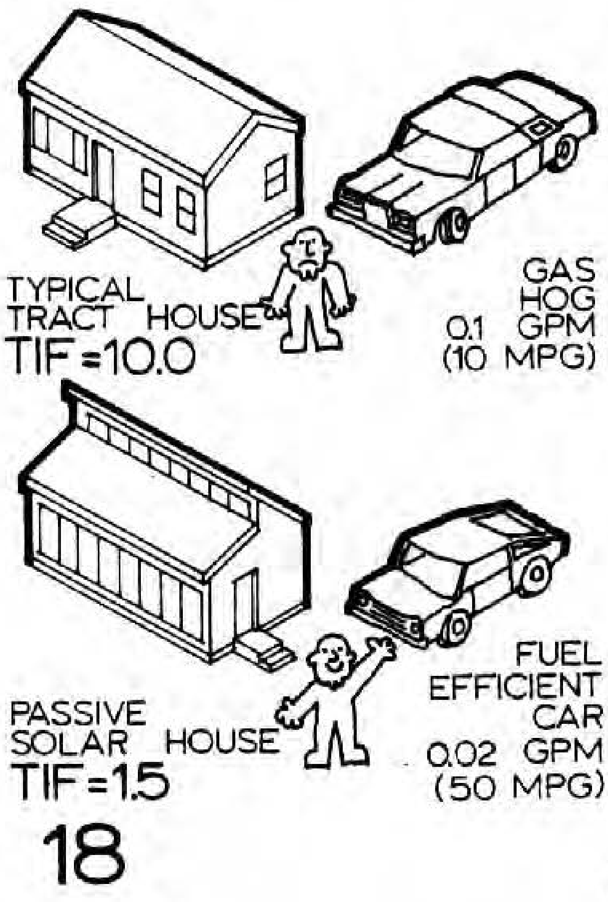

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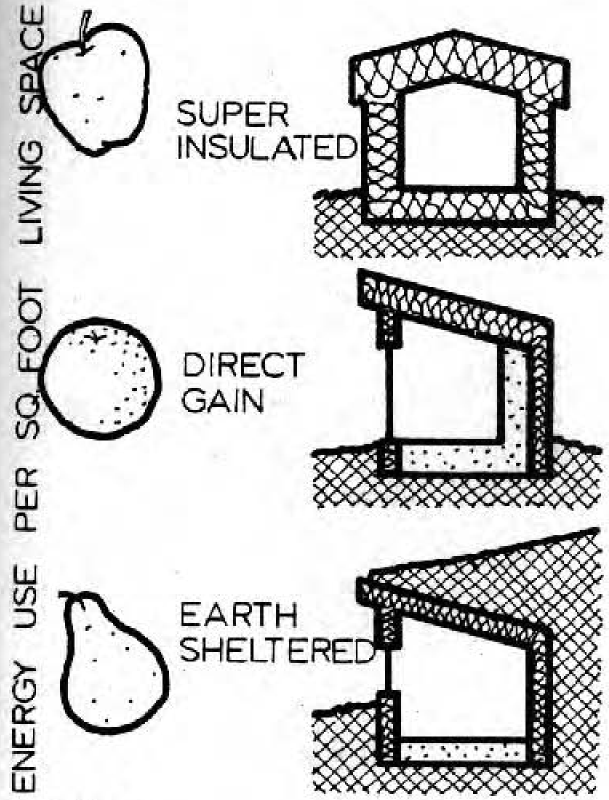
Earth Sheltering

Earth sheltering (FIG 17) has become a very popular conservation technique in Nebraska. Earth cover protects a structure against wind chill and eliminates unwanted air infiltration on the covered sides. Although the earth is not an insulator, the earth drastically reduces air temperature fluctuations so the earth sheltered building is nestled into a more temperature stable environment than above ground buildings; earth shelters are naturally warm in winter and cool in summer. In an earth shelter of concrete construction, the large thermal mass of the structure is ideal storage for passive solar heat gain. Properly designed and constructed earth shelters can be as light, open, and spacious as other energy efficient above-grade buildings; they need not be cave-like.

THERMAL INTEGRITY FACTOR (TIF)

Although there are a number of yardsticks which can used to judge the thermal performance of a home, the most valuable measurement is the thermal integrity factor (TIF) (FIG 18). The TIF value measures the number of Btus of auxiliary heat required per square foot of living space per degree day of heating for each year (Btu/ft^2-DD) and allows the thermal performance of solar as well as non-solar homes to be compared to each other. The lower the TIF value, the higher the efficiency. For example, a homeowner deciding among a superinsulated, direct gain, and an earth sheltered home can compare the thermal efficiency of each. Thus apples, oranges and pears can now be compared (FIG 19). Whenever possible, the TIF value is computed for the homes in the book to serve as a guide to the reader.


ENERGY USE PER SQ FOOT LIVING SPACE
SUPER INSULATED
DIRECT GAIN
EARTH SHELTERED

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