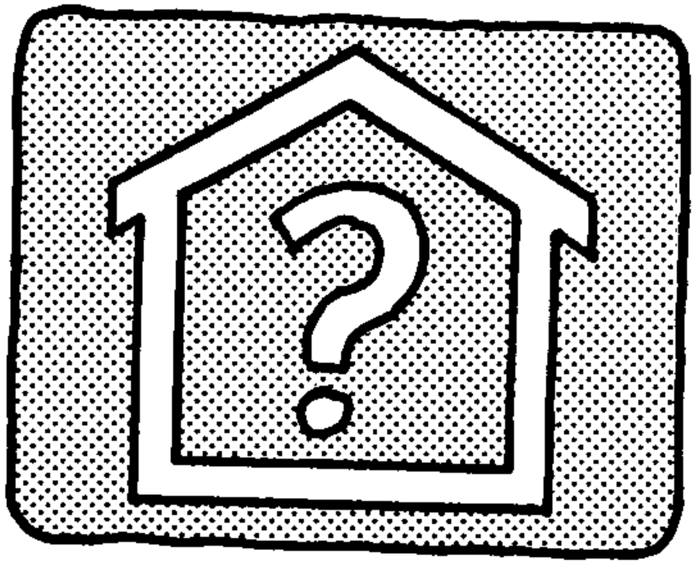
CHAPTER 3
SYSTEMS

This chapter identifies six different passive solar heating techniques. The characteristics, advantages and disadvantages, rules of thumb, and considerations of each passive solar heating system are discussed in detail.



DEFINITION

A passive solar energy system is one in which heat is distributed by natural means of conduction, radiation, and convection. The building itself acts as the collector and its structure may contribute mass. In a pure sense, passive solar energy systems do not use fans, pumps, or separate collectors.

INTRODUCTION

The six passive solar energy techniques discussed in this chapter are DIRECT GAIN, TROMBE WALL, SOLAR GREENHOUSE, CONTINUOUS THERMAL ENVELOPE, THERMOSIPHON, and ROOF POND.

The direct gain is the simplest to understand, most widely employed, and least expensive passive solar heating technique. Its principal drawback is the tendency for wide temperature fluctuations where there is insufficient thermal mass.

The Trombe wall has high temperature stability and, except for occasional cleaning, is virtually maintenance free. Construction costs for a Trombe wall will usually be more than for a direct gain system.

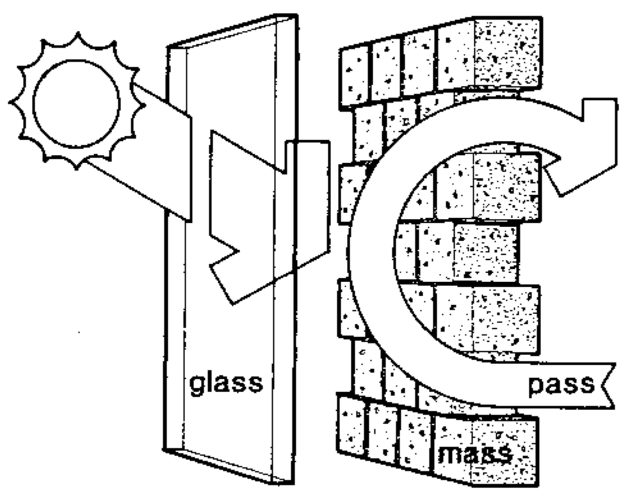
The solar greenhouse (sunspace) is a popular technique for both new home construction and retrofit applications. Potential problems can arise in matching the heating requirements of the home to the desired use of the greenhouse space, as the space will tend to overheat.

The continuous thermal envelope (double shell) is the most recently developed passive solar heating technique. A greenhouse provides a tempered layer of warm air which bathes the ceiling and north wall. At night, the earth beneath the home releases heat to the envelope, thereby eliminating the need for night shutters and thermal mass.

The last two techniques -- thermosiphon and roof pond -- have not been as widely utilized as the other four techniques. The thermosiphon, however, is used extensively in other regions for domestic hot water production.

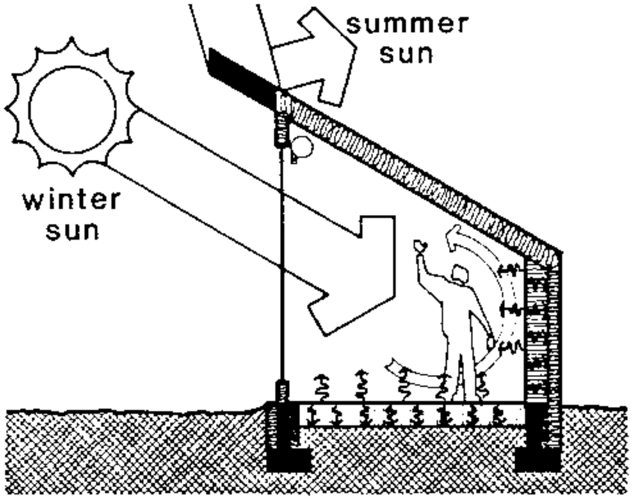
GPM

GPM is the foundation of all passive solar energy heating systems (FIG 3-1). The letters G, P, and M refer to GLASS, PASS, and MASS. Heat energy from sunlight gathered through south- facing GLASS must PASS into the living space by direct gain or indirect means. The Trombe wall, solar greenhouse, double shell, thermosiphon, and roof pond are indirect methods of passing solar energy into a home since they intercept the sun's rays prior to entering the living space. MASS absorbs excess energy and prevents the space from overheating. In sunless periods, thermal mass can release stored energy back to the living space.

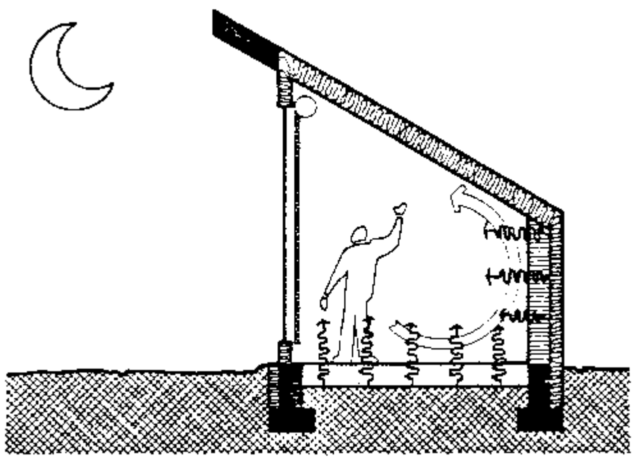


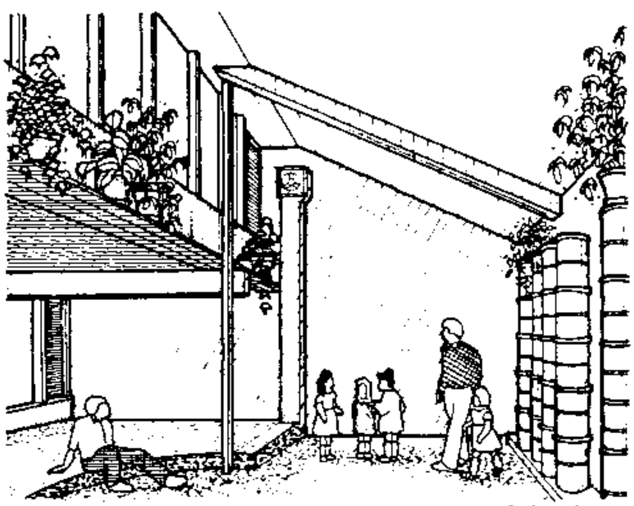
3-1 GLASS MASS PASS (GPM)

SYSTEMS



3-2 DIRECT GAIN: DAYTIME OPERATION


3-3 DIRECT GAIN: NIGHTTIME OPERATION


3-4 DIRECT GAIN MONTESSORI SCHOOL OMAHA, NEBRASKA

DIRECT GAIN

The most simple of the passive solar energy concepts is the direct gain system (FIG 3-2); most homes have some direct gain if they have any south-facing windows. In a direct gain system, sun shines directly into the occupied space which functions as a collector. The room air is heated first. Exposed walls, floors, and other thermal mass are then heated by the sun and the warmed air. Without sufficient mass, living spaces tend to overheat and undergo significant temperature fluctuations. Double or triple glazed windows with nighttime insulating shutters are strongly recommended, particularly for Nebraska and the upper midwest (FIG 3-3).

DIRECT GAIN CHARACTERISTICS

ADVANTAGES

1. Direct gain is the lowest-cost passive solar energy system to build.

2. Direct gain is the easiest passive solar energy technique to comprehend and to incorporate within a structure (FIG 3-4).

3. The south glazing admits solar radiation and provides a view of the surrounding environment.

4. When small solar savings fractions are needed, direct gain systems may not require much thermal mass.

DISADVANTAGES

1. There is a possibility of unacceptable glare during sunlit periods.

2. Unless shutters are employed, there may be a problem of privacy.

3. Direct sunlight may cause ultraviolet degradation of materials, fabrics, and artwork.

4. Relatively large temperature fluctuations may occur over a daily cycle.

5. There may be unacceptable nighttime losses through the south glazing. Double glazing with night insulation or triple and quadruple glazing without night insulation is required in a northern climate.

RULES OF THUMB

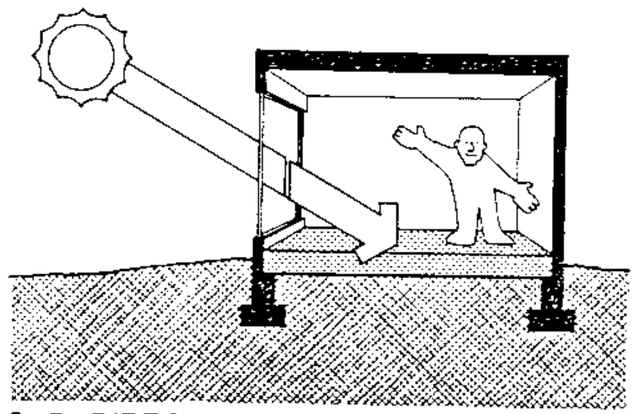
1. The ratio of window area to floor area should range from 0.21 to 0.33. Thus for a 1000 sq ft home the amount of south glazing should be between 210 to 330 sq ft. For super insulated structures (minimum R 35 walls and R 50 roofs) the ratio should be from 0.08 to 0.12.

2. Because direct gain systems tend to overheat, the placement and sizing of thermal mass is critical to optimizing performance. Sunlight may shine directly upon the thermal mass, it may be reflected onto the mass, or the thermal mass itself may be removed from both direct or reflected light and must be heated by warmed air. The ability of various thermal mass materials to absorb heat is dependent on the material's thermal conductivity and specific heat.

The following tables present a general set of guidelines for determining the surface area of thermal mass required for each square foot of window area. The values listed are for specific thicknesses of material used and for lighting patterns upon the mass.

DIRECT SUN ON WALL OR FLOOR (TABLE 3-1)

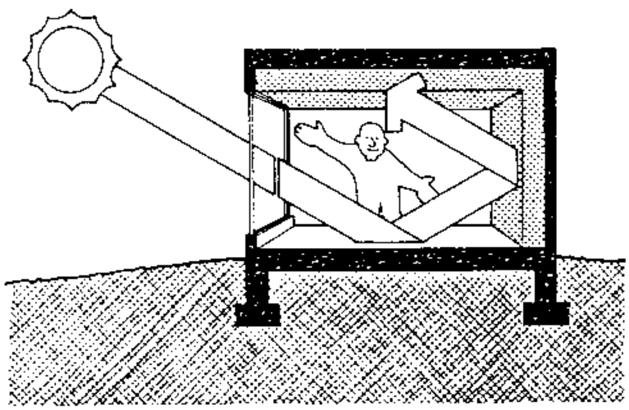
TABLE 3-1 is used to determine the sizing of mass exposed to direct sunlight in situations where sunlight strikes a wall or floor directly for at least six hours of the day (FIG 3-5). Read down the column of thermal mass material and across from the material thickness column. This number



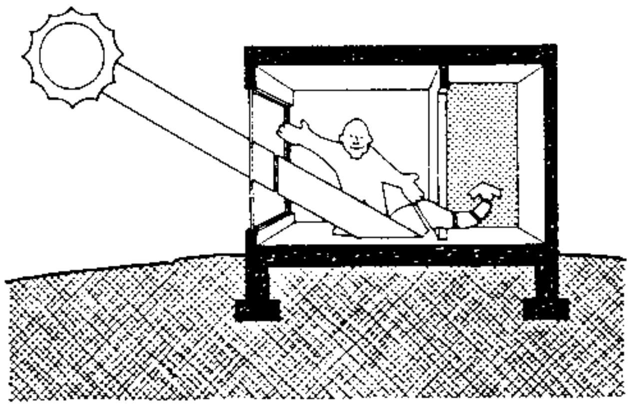
3-5 DIRECT SUN ON WALL OR FLOOR MASS

TABLE 3-1 MASS SIZING (DIRECT SUN)

MATERIAL THICKNESS	THERMAL MASS AREA TO GLAZING AREA RATIO					
	Concrete	Brick	Water	Gypsum	Pine	Slate
0.5"	28	36	13	63	78	16
1.0"	14	18	7	32	39	8
1.5"	9	12	5	22	27	5
2.0"	7	8	4	17	21	4
3.0"	5	6	3	14	18	3
4.0"	4	5	3	15	18	2
6.0"	3	5	4	16	20	2
8.0"	3	5	4	16	20	3



3-6 INDIRECT SUN ON MASS



3-7 DIRECT GAIN TO REMOTE MASS

represents the square feet of thermal mass required for each square foot of south-facing window. For example, a 4" brick wall which receives direct sunlight for six hours per day requires 5 sq ft of brick surface for each square foot of window. A 10 sq ft window would require 50 sq ft of exposed wall.

INDIRECT SUN ON FLOOR, WALL, OR CEILING (TABLE 3-2)

Where sunlight is reflected onto the thermal mass (FIG 3-6), more surface area is required for each square foot of glass in comparison with a system where sunlight shines directly on thermal mass. A 4" brick wall that does not receive direct sun will now require 9 sq ft of surface area for each square foot of glazing compared with the ratio of 5 for sunlight shining directly on the brick wall.

THERMAL MASS REMOTE FROM DIRECT OR REFLECTED SUNSHINE (TABLE 3-3)

Thermal mass which is located in a space which receives no direct or reflected sunlight is warmed by air that has been heated elsewhere (FIG 3-7). This configuration requires more thermal mass for each square foot of south window in comparison with the two previous methods.

TABLE 3-2 MASS SIZING (INDIRECT SUN)

MATERIAL THICKNESS	THERMAL MASS AREA TO GLAZING AREA RATIO					
	Concrete	Brick	Water	Gypsum	Pine	Slate
0.5"	49	63	23	111	136	28
1.0"	25	32	12	56	69	14
1.5"	16	21	8	38	47	9
2.0"	12	16	6	30	37	7
3.0"	8	11	6	25	31	5
4.0"	6	9	6	26	32	4
6.0"	5	9	7	28	35	4
8.0"	5	9	7	29	36	5

TABLE 3-3 MASS SIZING (REMOTE LOCATION)

MATERIAL THICKNESS	THERMAL MASS AREA TO GLAZING AREA					
	Concrete	Brick	Water	Gypsum	Pine	Slate
0.5"	50	64	26	112	137	30
1.0"	27	34	16	58	70	18
1.5"	20	24	15	41	50	15
2.0"	17	20	14	35	42	13
3.0"	14	17	15	32	38	13
4.0"	14	17	15	34	40	13
6.0"	14	18	16	36	44	14
8.0"	14	19	16	37	44	14

OTHER CONSIDERATIONS

1. Night shutters or movable insulation of at least R 9 are strongly recommended to improve thermal performance.

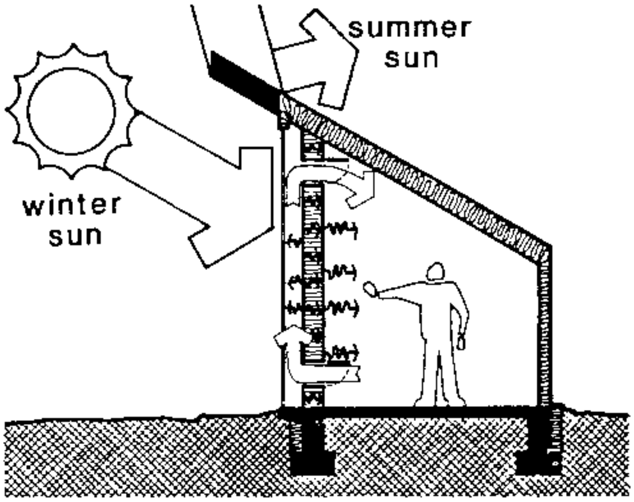
2. For northern climates like Nebraska's, triple or quadruple glazings with airgaps between glazings should be used to reduce conductance losses.

3. Carpets and wall hangings that cover thermal mass should be kept to a minimum. Otherwise unacceptable temperature swings may result.

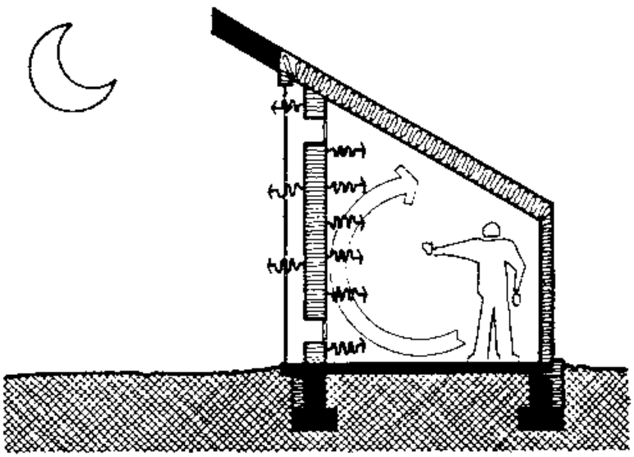
4. Althouah some reflection may be desirable for better heat distribution, the average of the solar absorptance for the total sunlit area should not fall below 0.5. Table 3 contains typical values of solar absorptance for different colors.

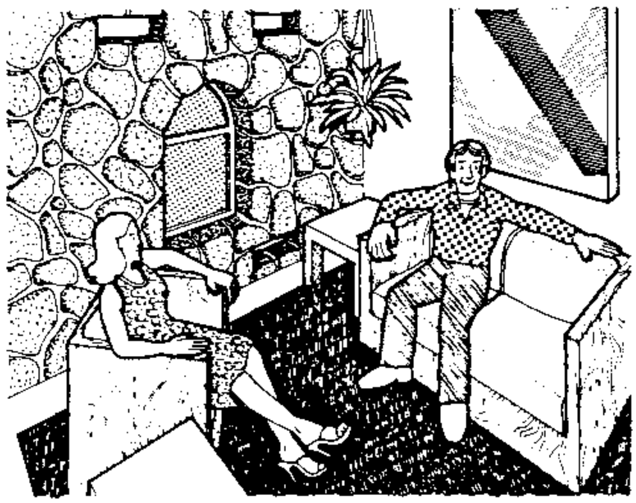
TABLE 3-4 SOLAR ABSORPTANCE

Flat black paint	0.98
Black concrete	0.91
Dark brown paint	0.88
Brown concrete	0.84
Red bricks	0.70
Uncolored concrete	0.65
Medium yellow paint	0.57
Light green paint	0.47
White semi-gloss	0.30
White gloss paint	0.25
Polished aluminum	0.15
Reflector sheet	0.12



3-8 MASS WALL: DAYTIME OPERATION


3-9 MASS WALL: NIGHTTIME OPERATION


3-10 MASS WALL INTERIOR VIEW

TROMBE WALL (THERMAL STORAGE WALL)

The Trombe wall, named for Felix Trombe, is also referred to as a thermal storage wall. Instead of placing thermal mass inside the building, as in a direct gain system, the thermal mass is located directly behind the south glazing (FIG 3-8, FIG 3-9). Sunlight passing through the glazing strikes the thermal mass wall and most of the solar energy is absorbed by the mass. This energy migrates through the mass wall via conduction and radiates into the living space.

The energy transfer through the thermal mass may take a number of hours. This delay may be offset in two ways: 1) vent openings placed at the top and bottom of the mass wall provide a natural convection path which permits warmed air to enter the living space when the sun comes up, and 2) placing a window in the mass wall allows sunlight to heat the space directly (FIG 3-10).

TROMBE WALL CHARACTERISTICS

ADVANTAGES

1. Ventless thermal mass walls tend to have the most temperature-stable living spaces in comparison with other passive heating systems.

2. The mass wall can serve as a structural element of the building.

3. Depending on the type and thickness of the wall material, a thermal lag of several hours may occur. This may be desirable if the space is used most often during the evening hours.

4. Fabric degradation and glare problems caused by ultraviolet light are reduced or eliminated.

5. A variety of different materials such as brick, stone, concrete, block, water, and phase change salts can be used as thermal mass.

6. Commercially built thermal mass walls are available as modular construction components.

DISADVANTAGES

1. Thermal mass walls can obstruct views to the outside.

2. Additional costs may be incurred with the construction and installation of thermal mass walls.

RULES OF THUMB

1. In Nebraska, the ratio of mass wall area to floor area is between 0.51 and 0.93 for a masonry wall and between 0.38 and 0.70 for a water wall.

2. During the process of preliminary design, the amount of thermal mass required to achieve a certain solar savings must be considered. TABLE 3-5 is intended to provide general sizing guidelines.

TABLE 3-5 SIZING OF THERMAL MASS

Expected Solar Savings (%)	Recommended Thermal Mass Per Square Foot Of Glass: Water (lbs)	Masonry (lbs)
10%	6	30
20%	12	60
30%	18	90
40%	24	120
50%	30	150
60%	36	180
70%	42	210
80%	48	240
90%	54	270

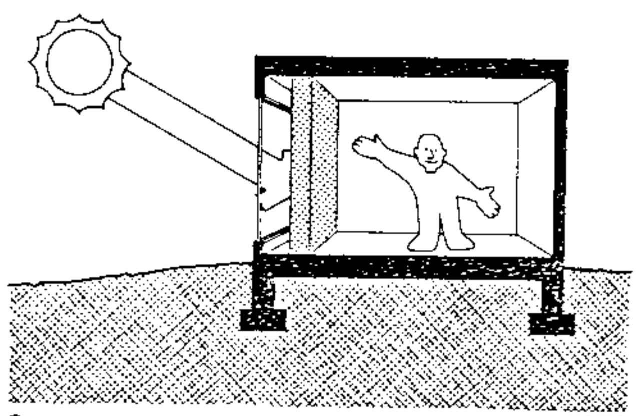
The density of water is 62.4 pounds per cubic foot in comparison with mortar-filled concrete block which is approximately 130 pounds per cubic foot.

PATTERNS OF DISTRIBUTING THERMAL MASS

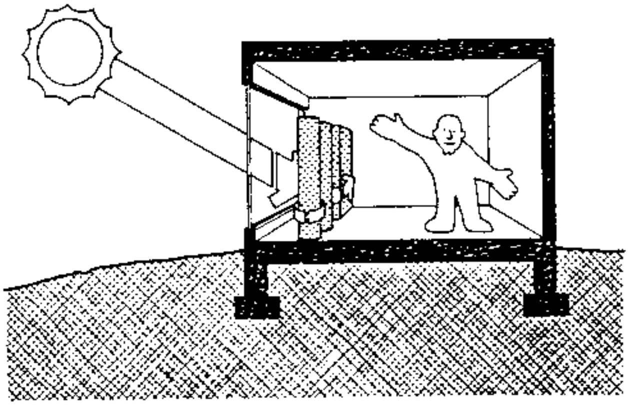
A Trombe wall is typically placed behind a window and the mass wall area equals the window area (FIG 3-11).

TABLE 3-6 MASS WALL IN DIRECT SUNLIGHT

MATERIAL	THERMAL MASS AREA TO GLAZING AREA RATIO
Brick 8"thick	1
Concrete 12"thick	1
Waterwall 8"thick	1



3-11 MASS WALL IN DIRECT SUNLIGHT



3-12 MASS WALL AND DIRECT GAIN

In many instances there may be a combination system of mass wall and direct gain (FIG 3-12). This is especially true when water is employed as the thermal mass.

TABLE 3-7 MASS WALL AND DIRECT GAIN

MATERIAL	THERMAL MASS AREA TO GLAZING AREA RATIO
Brick 8"thick	2
Concrete 6"thick	2
Drums or tubes of water	7 gallons or more of water per square foot of glazing

3.Vents in a Trombe wall provide a means for quick heat gain. This is especially important when the thermal mass wall is very thick (beyond 18") or has poor heat conductivity. Vents are also recommended when a solar savings fraction of 30% or less is to be obtained. At these lower solar savings fraction levels, it is advantageous to reduce the daytime heating load as much as possible; vents will provide heated air to the building to reduce daytime heating loads. As a percentage of the total wall area, the vents should not exceed the values shown in TABLE 3-8.

TABLE 3-8 SIZING VENT OPENINGS FOR MASS WALLS

Expected Solar Savings Fraction (%)	Vent Area (%)
25	1.5
50	0.5
75	0.25

Provisions must be made to prevent a backflow of warm air from the room to the window glazing area during sunless periods.

OTHER CONSIDERATIONS

1.Night shutters or movable insulation of R 9 or higher should be used.

2.Selective surface coatings should be applied to the exterior face of the Trombe wall. These coatings will reduce heat radiating from the wall back through the glass.

3.Conduction losses to the outside can be reduced through the use of triple glazing.

4.Reflectors can be used to increase the amount of solar energy striking the thermal mass.

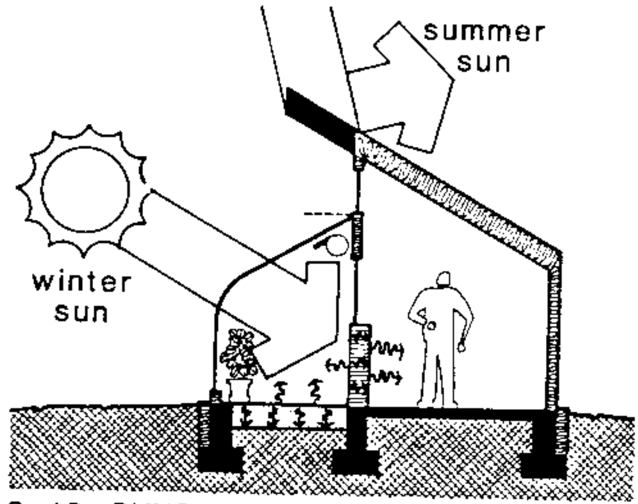
5.Overhangs or shading of the glazing surface should be provided during the summer months.

6.If vents are used, some means for venting hot air to the outside during the summer is desirable.

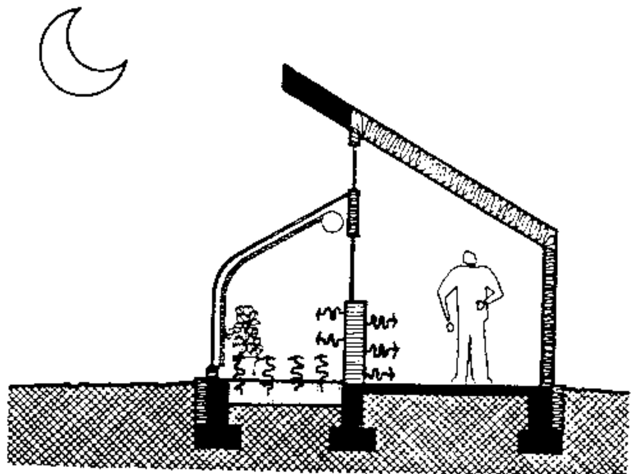
7.If the mass wall has vents, provisions must be made for cleaning the inside surface of the glazing.

SUNSPACES (ATTACHED SOLAR GREENHOUSES)

The sunspace is one of the most popular passive solar heating techniques. Winter sun shines through the south glazing of the greenhouse onto the common wall between the living space and sunspace (FIG 3-13). The heat migrates through the wall, as it does through a Trombe wall, and radiates into the living space. Vents, operable windows, and sliding glass doors located in the common wall between the sunspace and living space provide a means to heat the living space directly. Mass in the sunspace helps to reduce temperature fluctuations over a 24 hour period in the sunspace. The use of insulating curtains is recommended to retain energy captured during daylight hours, particularly if freezing temperatures are not desired in the sunspace during the night (FIG 3-14). Perimeter insulation should be placed down to the footings of the sunspace in order to reduce losses.



3-13 SUNSPACE: DAYTIME OPERATION


3-14 SUNSPACE: NIGHTTIME OPERATION

ATTACHED SOLAR GREENHOUSE CHARACTERISTICS

ADVANTAGES

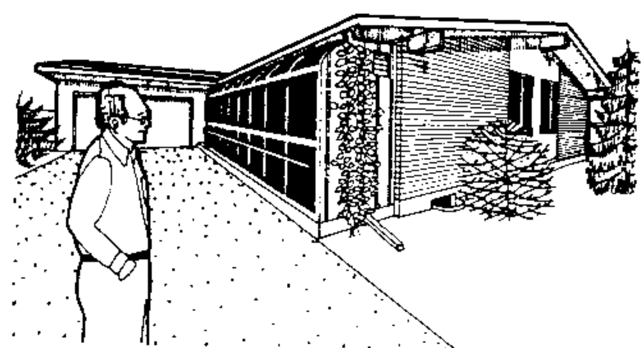
1. The sunspace serves as a buffer between outdoor ambient conditions and interior living space.

2. Sunspaces designed as solar greenhouses can be used to grow flowers, plants, and vegetables.

3. Sunspaces serve as an aesthetic focal point when used as extensions of living spaces.

4. Existing buildings can be retrofitted with attached sunspaces (FIG 3-15).

5. Sunspaces can be utilized to provide preheated water by the use of an inline tank that has been painted black.


3-15 SUNSPACE RETROFIT: THOMSEN HOUSE LINCOLN, NEBRASKA

DISADVANTAGES

1. Construction costs of a solar greenhouse may be significantly higher in comparison with other passive solar heating methods.

2. Thermal performance may be difficult to compute accurately due to the many variations in design.

3. Humidity (condensation), carbon dioxide levels, insect infestation, drainage, water supply, and temperature fluctuation must be considered when sunspaces are used as greenhouses.

4. Night shutters and/or movable insulation may be required to maintain nighttime temperatures above freezing to ensure plant survival. Auxiliary heating may also be required.

RULES OF THUMB

1. To keep the sunspace and adjoining area at an average temperature of 65 - 70°F, the ratio of floor area to double glazed window area can be determined by the following table:

TABLE 3-9 SIZING GLAZING AREA FOR ATTACHED SOLAR GREENHOUSES

Glazing area per sq ft of floor area	Building material between sunspace and living space
0.78 - 1.3 sq ft	masonry wall
0.57 - 1.05 sq ft	water wall

2. If a thermal wall is the chief heat transfer mechanism between the sunspace and the living space, the wall thickness is sized according to the following table:

TABLE 3-10 SUNSPACE WALL THICKNESS

MATERIAL	THICKNESS
Brick	10" - 14"
Concrete	12" - 18"
Water	8" or more or 0.67 cubic feet per sq ft of south glazing

OTHER CONSIDERATIONS

If the sunspace is to be used as an attached greenhouse for plants, the following suggestions should be considered:

1. As many surfaces as possible should be painted white in order to maximize light reflected onto plants. Any thermal walls may be painted red or blue.

2. As morning light is more beneficial to plants, east glazing is preferable to west glazing.

3. Ventilation will provide needed carbon dioxide to plants.

4. Proper ventilation can also control humidity levels. 60% relative humidity is ideal; insects and pests thrive in an environment with relative humidity above 75%.

5. Ventilating fans should be sized at 5 cfm per square foot of south glazing.

6. Plants usually cannot tolerate more than a 10 - 15°F fluctuation. Night shutters and auxiliary heat may be required.

7. Rockbed or water container storage will maximize solar heat gain and plant production.

CONTINUOUS THERMAL ENVELOPE

Also called the "double shell", the continuous thermal envelope (CTE) is the latest arrival on the passive solar energy scene. It was popularized by Tom Smith of Lake Tahoe, California, and has had a wide following among builders and the public, however, little actual testing of the system has been reported. The only known test room is located on the Omaha campus of the University of Nebraska whose Passive Solar Research Group has also monitored the Smith House and the Dennis Demmel double shell house in Hartington, Nebraska.

In a double shell system, sunlight enters the greenhouse and heats the air which rises to the cavity space in the roof area. As heat transfers to both the interior living space and the outside, the column of air begins to cool and slowly falls down the cavity on the north side of the structure. Any excess energy is transferred to the earth beneath the home. The cooled air re-enters the south-facing greenhouse to replace heated air and the process is repeated (FIG 3-16). In the evening, the reverse process occcurs as heat is lost through the south glazing causing the air in the greenhouse to cool and fall into the crawl space. Warm air from the roof cavity is drawn down into the greenhouse, which in turn pulls air up the cavity in the north wall. Some heat from the earth storage is transferred to the air column in the north wall. This causes a reverse siphoning effect to occur (FIG 3-17).

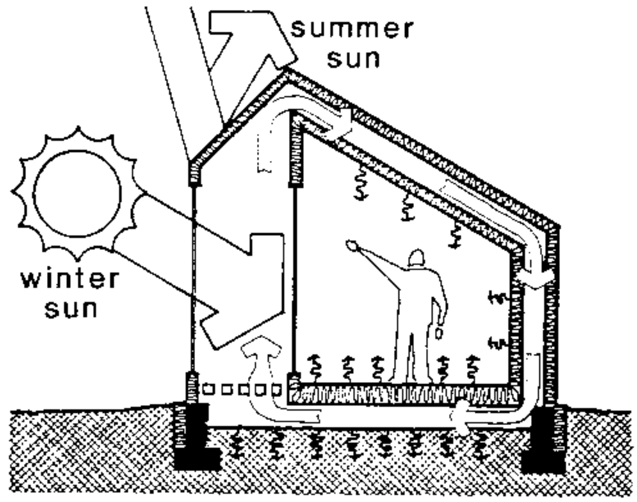
DOUBLE SHELL "CTE" CHARACTERISTICS

ADVANTAGES

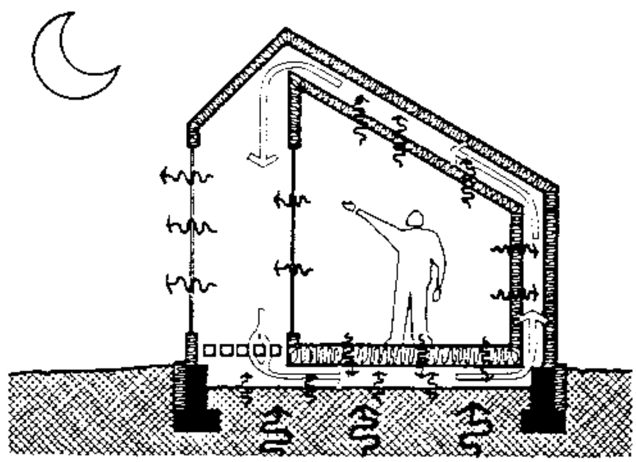
1. Though recommended, night shutters are not required.

2. Thermal mass is not required except in the crawl space.

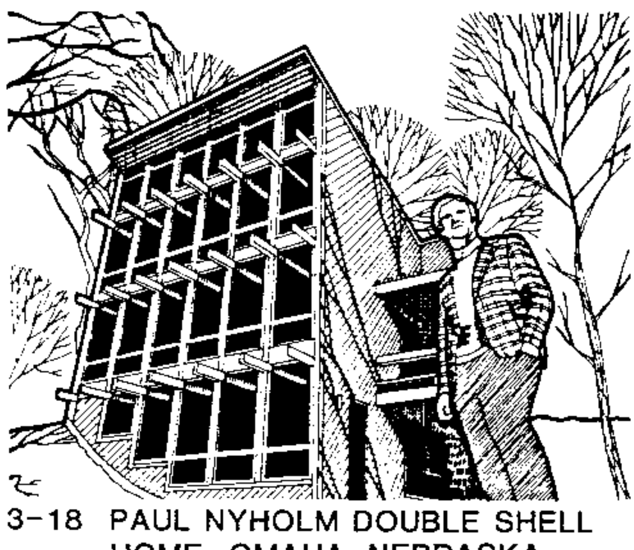
3. The design is adaptable, and numerous variations can be made from the original plans (FIG 3-18).



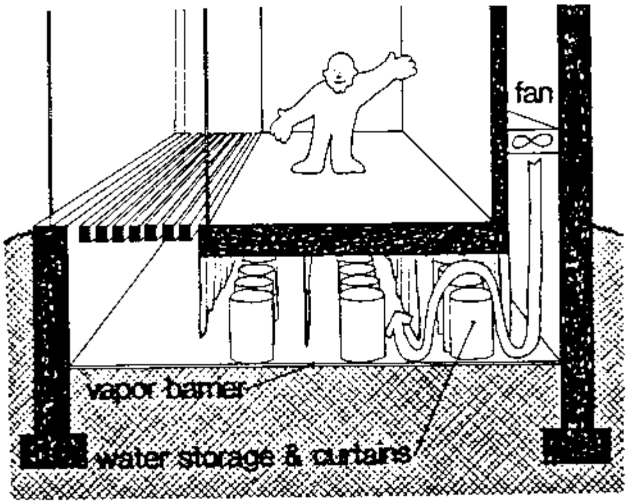
3-16 DOUBLE SHELL: DAYTIME OPERATION



3-17 DOUBLE SHELL: NIGHTTIME OPERATION



3-18 PAUL NYHOLM DOUBLE SHELL HOME OMAHA, NEBRASKA



3-19 DOUBLE SHELL: STORAGE DETAIL

4. Unlike a typical sunspace, the greenhouse in a double shell may not overheat because the heat is distributed during the warm air movement through the convective loop cycle.

5. Heat to each room can be regulated by windows or vents in the inner shell.

6. The greenhouse serves as a focal point for the home and provides a pleasant sunlit space. Flowers and other plants lend a cheerful touch to the space and their fragrance can permeate the entire home.

DISADVANTAGES

1. Temperature stratification in the greenhouse can make upper floors uncomfortable, particularly in the summer and possibly during late spring and early fall.

2. This system may cost more to construct than other passive solar heating techniques because building an inner and outer envelope requires additional materials.

3. In the winter, rooms on the the north side which are not in direct contact with the greenhouse are noticeably colder than other rooms.

4. Firestop dampers and/or fire-resistant sheetrock may be required in the north cavity.

5. Condensation may develop on glazing surfaces and cause rot damage to wood surfaces.

OTHER CONSIDERATIONS

1. Water storage can be located in the crawl space (FIG 3-19).

2. A fan or blower is recommended if temperature stratification is found to be a problem or if thermal storage (other than earth) is utilized in the crawl space.

3. A vapor barrier covering the earth in the crawl space will reduce moisture condensation significantly.

4. Flashing should be placed on the sills to collect condensation which may occur on the greenhouse glass. The flashing can be tilted so that water runs off. Flexible hose at the flashing depression has been successfully utilized in some double shell homes.

5. The sloped roof glazing common to many double shell designs is not recommended for several reasons: 1) it does not appreciably help the driving force of the convection loop, 2) shutters must be used during the cooling season to prevent overheating, and 3) it is more difficult to successfully shade a sloped roof than a vertical surface.

6. The R value of the outer wall should be much higher than that of the inner wall. When additional thermal storage is placed in the crawl space and a fan is used, the ratio of insulation in the outside wall to inside wall should be 3 to 1 or greater.

THERMOSIPHON (NATURAL CONVECTION)

The thermosiphon operates on the same principle as the continuous thermal envelope: warmed air rises and cold air falls. In a U tube collector with thermal storage (FIG 3-20, 3-21), an angled U tube collector is placed below the storage. Sun shining through the glazing causes the absorber plate, consisting of several layers of metal lath, to heat rapidly. This raises the temperature of the air coming in contact with the metal lath causing the air to expand and rise. This rising column of warm air enters the building where, depending on the damper setting, it can either heat thermal storage or enter the living space directly. Cold replacement air is drawn from the rear channel of the collector. When properly designed, the process does not reverse at night, as cold air pools at the bottom of the collector, eliminating the flow until the sun rises the next day (FIG 3-22).

THERMOSIPHON (NATURAL CONVECTION) CHARACTERISTICS

ADVANTAGES

1. Thermosiphon systems can have thermal efficiencies equaling those of active flat plate collectors.

2. The principle can be used in retrofitting an existing home. Systems can range from simple window boxes to entire wall systems.

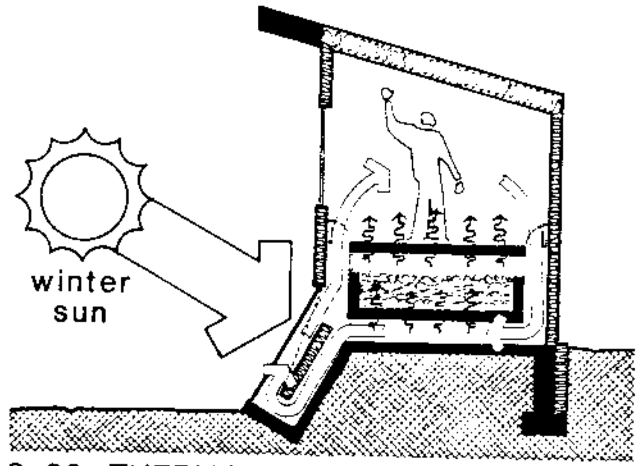
3. Unlike active systems, fans are not required for operation.

4. The cost of construction can be modest.

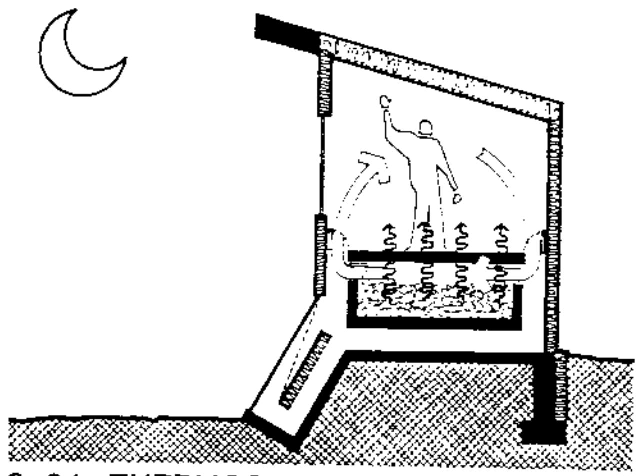
DISADVANTAGES

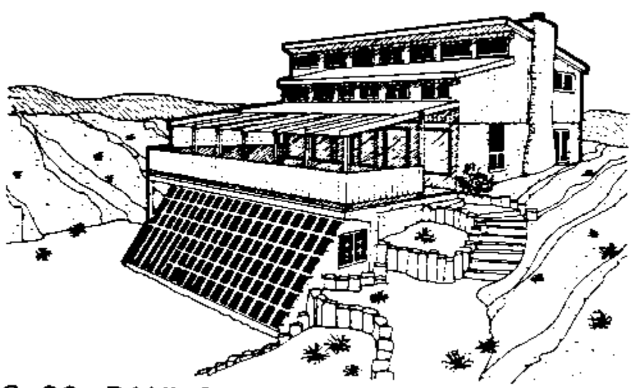
1. Natural convection systems will reverse siphon if not properly designed.

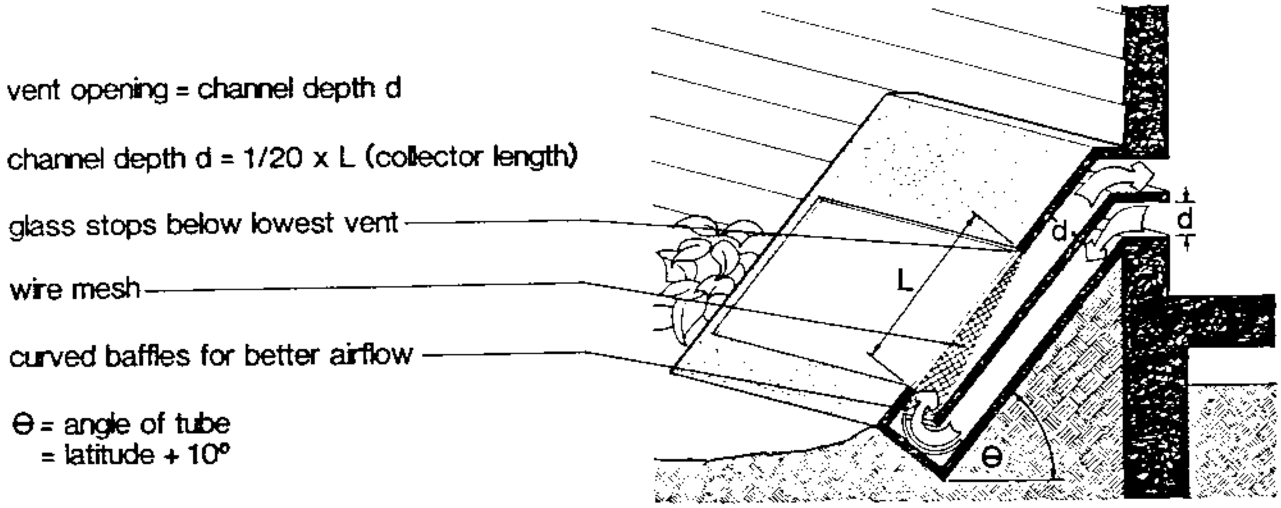
2. Vents and dampers may be required, particularly if the angled U collector is not used.



3-20 THERMOSIPHON: DAYTIME OPERATION


3-21 THERMOSIPHON: NIGHTTIME OPERATION


3-22 PAUL DAVIS THERMOSIPHON HOME: ALBUQUERQUE, NEW MEXICO



3-23 THERMOSIPHON U TUBE DETAIL

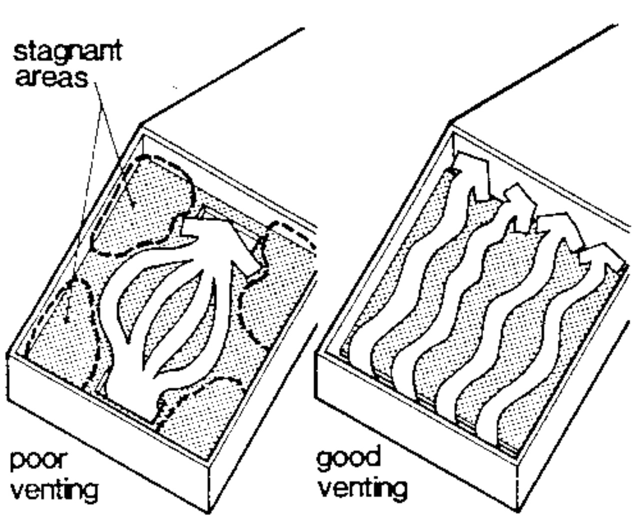
3. Site considerations may not permit incorporating storage with the angled U collector.

RULES OF THUMB

1. The ratio of glass area to floor area is 0.2 to 0.4. For a well-insulated home, this ratio should not be less than 0.08. If there is thermal storage as well, the ratio can be much higher.

2. Other sizing parameters:

   Collector Tilt: the angle from the horizontal should be latitude +10 degrees.



3-24 VENTING STRATEGY FOR THERMOSIPHONS

Channel Depth: the depth of the air flow channels should be 1/20 of the collector length. Thus, a 6' long collector should have channels which are 3"-4" deep (FIG 3-23).

Vertical U Tube Length: if the collector is placed vertically, the tube should be at least 4' long.

OTHER CONSIDERATIONS

1. The glazing must not be placed above the level of the lowest vent. If it is, an extra head of cold air will exist at night to push the cold air back through the system, thus cooling the house.

2. All natural convection systems must be designed with easy air movement in mind. Any impediment to flow will hamper overall thermal performance. To facilitate air movement, the following suggestions should be observed:

   A. Curved baffles should be used in place of square corners (FIG 3-23).

   B. The width of the vent opening should be equal to the width of the collector (Fig 3-24).

C. Vents must be as deep as those in the flow channels of the collector.

3. As air is not a good conductor of heat, it is desirable to maximize the heated surface area exposed to flowing air.

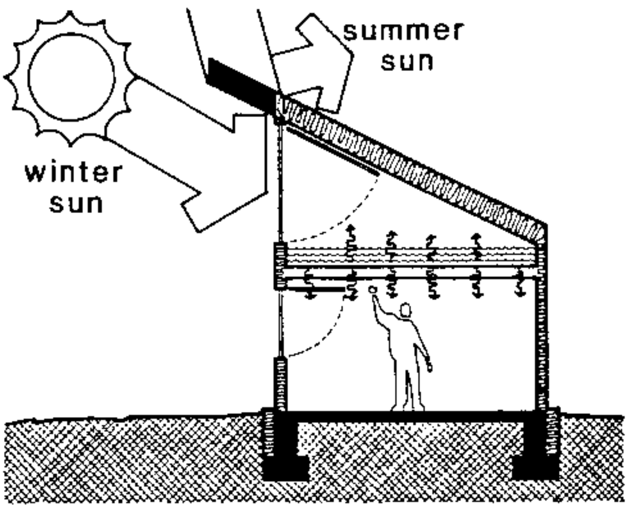
4. Aluminum or steel absorbers should be covered with high temperature black paint (or a selective surfacecoating) in order to survive in a higher temperature environment.

5. Glass should be used for glazing. Fiberglass and plastic glazing materials should be avoided.

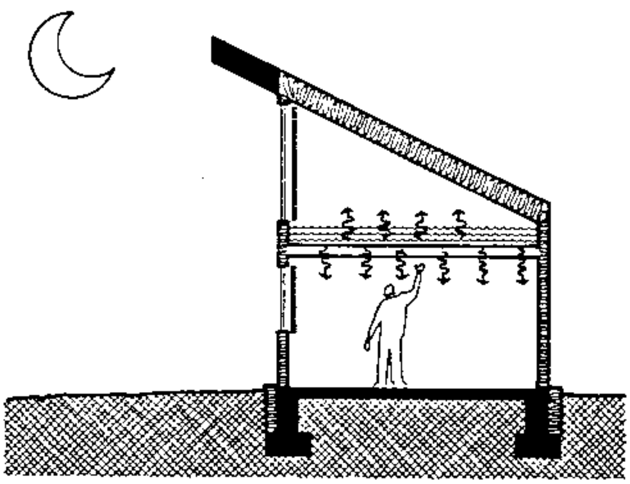
6. The thermal performance of a natural convection system is based on two measures: 1) the temperature difference between inlet and outlet of the collector, and 2) the flowrate. A high outlet temperature indicates the collector is too hot and is losing much of its gain back to the outside. During the noon hours on a sunny day a U tube collector can have a flowrate of 4 to 5 cubic feet per square foot of collector per minute.

TABLE 3-9 THERMOSIPHON PERFORMANCE CRITERIA

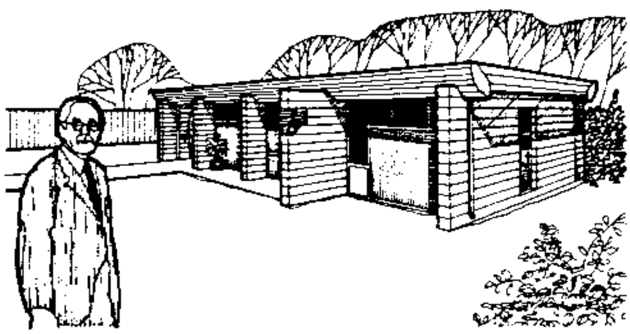
Inlet/outlet temperature difference °F	Comments
20 - 40	high efficiency and very good air flowrate
40 - 55	good efficiency and good air flowrate
55 - 70	reasonable efficiency and acceptable air flowrate
70 - 85	slow flow and collector temperatures are too high
85 or more	mistakes in design and/or construction



3-25 ROOF POND: DAYTIME OPERATION



3-26 ROOF POND: NIGHTTIME OPERATION



3-27 HAROLD HAY DESIGNED ROOF POND HOUSE

ROOF PONDS

In a roof pond system, water is stored in a membrane liner located in the structure's roof. During the day, the shutters are opened to permit sunlight to penetrate the roof space and heat the water (FIG 3-25). At night, the shutters are closed, and heat from the roof pond transfers into the home (FIG 3-26). During the summer, the process is reversed: the shutters are closed during the day, and the water absorbs heat from the house; at night, the shutters are opened to allow heat to be radiated to the night sky. The roof pond concept has not been tested in Nebraska.

ADVANTAGES

1. Roof ponds have been demonstrated to provide high solar heating fractions in the southwestern United States (FIG 3-27).

2. Roof ponds can provide passive cooling via night sky radiation in summer.

DISADVANTAGES

1. As additional loads must be supported by the building, it is recommended that the services of a structural engineer be obtained.

2. The roof pond has only been tested in warm climates. Due to problems caused by freezing, extensive modifications in the design may be required in the midwest.

RULE OF THUMB

1. For a south sloping collector with night shutter, the ratio of roof pond area to floor space area should be 0.40 to 0.60.