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ENVELOPE HOUSE

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The envelope house is a passive solar design that uses the sun's energy and natural air flow for heat distribution. Sometimes referred to as the double envelope house, the design became increasingly popular in the late 1970s. One of the early proponents of the envelope home claimed that the design could provide 100 percent of the home's space heating requirements in any climate. The envelope home design immediately generated nationwide interest, even though most envelope homes required some supplemental heat during the winter. Many design professionals were critical of the design, however, claiming that the envelope home would not meet its designers' expectations. While the debate over performance continues, a number of envelope homes have been built in both Western and Eastern Washington.

DESIGN OF THE ENVELOPE HOUSE

The envelope house design differs significantly from other passive solar designs in that the envelope home does not directly use the sun's energy for heating interior living spaces. Instead, the home is constructed to provide a continuous loop of solar heated air around the living space of the home (see Figure 1).

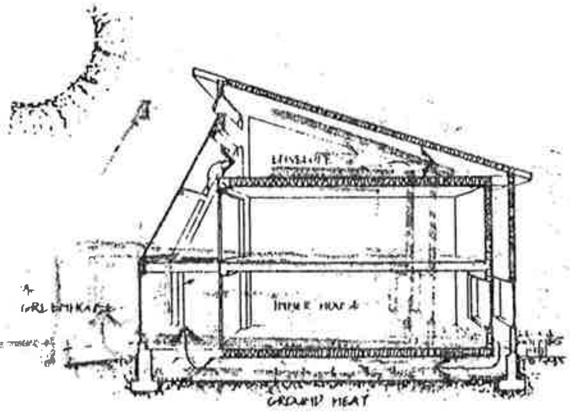

Figure 1 -- Daytime Heating

The envelope home typically uses a full south-facing greenhouse to collect solar energy. As air is heated within this greenhouse space, it rises to the top of the greenhouse and enters through large vent areas into an attic space or plenum in the ceiling of the home. Both sides of this ceiling plenum are insulated. This warm air travels across the ceiling plenum until it reaches the north wall. The north wall of the home is built with a double wall construction which creates a cavity or air space within the wall. Again, both sides of the north wall are insulated. When the air flow from the ceiling plenum reaches the north wall it cools somewhat and thereby becomes more dense. Gravity pulls the air down through the north wall cavity into a crawl space or basement area of the home. As the air circulates through this underfloor area, it transfers its remaining heat to the storage material located in the underfloor space. Rocks, water, earth, or an earth-gravel mixture have all been used as heat storage materials. The envelope loop is completed by allowing the air in the underfloor area to circulate back into the greenhouse. According to the design's originators, providing for a continuous loop of conditioned air around the home creates a moderated environment for the interior living spaces. Interior walls are exposed, therefore, to temperatures substantially warmer than outdoor air temperatures.

In theory, this daytime air flow pattern would be reversed during the nighttime hours (see Figure 2). The heat storage material in the underfloor area would give up heat to the loop which would circulate up through the north wall, across the attic, and down through the greenhouse space. Thus, the envelope loop would have constantly moderated temperatures in both day and night.

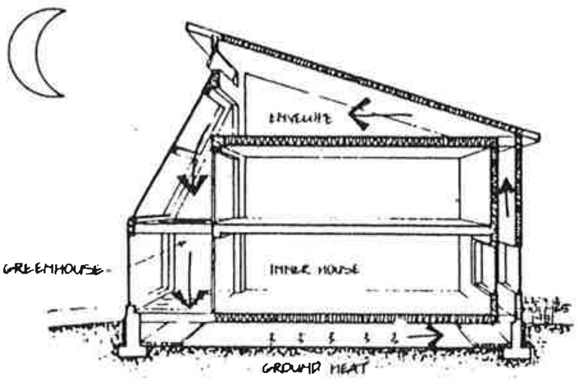

Figure 2 -- Nighttime Heating

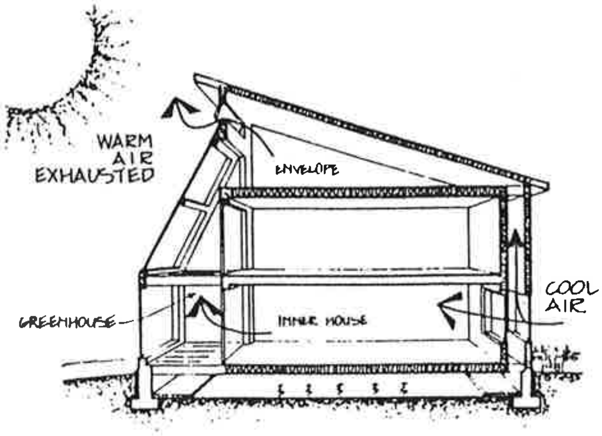

Figure 3 -- Summer Cooling

The summertime cooling operation of the envelope design called for the use of vents in the high point of the greenhouse or gable vents in the attic space (see Figure 3). As the temperature rises in the greenhouse, warm air would exhaust out of of these vents. The venting of warm air would allow cooler air from the home's north side to be pulled through the envelope loop.

CRITICISM OF THE ENVELOPE DESIGN

While few designers and engineers doubted the summertime performance of the envelope house, a number of design professionals expressed reservations on the home's operation during the heating season. One of the most common criticisms concerned the daytime air flow patterns within the envelope loop. Critics have contended that there would be insufficient energy to drive a uniform air flow through the envelope loop under most conditions. Gravity-forced convection currents typically have very low air flow rates, particularly when floor and ceiling joists extending into the loop create air turbulence. Critics claim, therefore, that the daytime convective heating loop described in the theory of the design would happen only infrequently.

Similarly, a number of people have been skeptical of the nighttime operation of the envelope design. Many critics have doubted that the stored heat in the underfloor area could create a uniform nighttime air flow. Again, insufficient energy would be available to drive air up the north wall and across the attic space.

In addition, envelope home critics have claimed that the design makes inefficient use of solar energy. Critics first note that it requires a loss of heat from the north wall cavity to drive the convective loop during the day. Existing envelope homes with temperature monitors have recorded a 15°F to 25°F drop in air temperature between the top of the greenhouse and the bottom of the north wall air cavity. The envelope design sacrifices this solar-heated air to drive the convective loop instead of storing it in a heat storage system. Other critics cite the design's inefficient use of solar energy by describing an operational paradox. It seems that the air flow through the envelope loop would be greatest when high temperatures are recorded in the greenhouse. However, high greenhouse temperatures also increase the rate of heat loss from the greenhouse structure itself, thus reducing system efficiencies.

Other criticisms have centered on the ability of the envelope home to store significant amounts of heat in the underfloor area. Initially, critics contended that there would not be much energy left in the air as it circulated through the underfloor area. Therefore, only a small quantity of heat could be stored. Additionally, the point is made that the underfloor air would stratify leaving the cooler air in contact with the storage medium.

Design professionals have leveled a number of seemingly valid objections to the envelope home design. Questions concerning air flow patterns, design efficiencies, and heat storage in the envelope house raise serious doubts on the practicality of the design. Notwithstanding this rather long list of criticisms, however, the actual performance of existing envelope homes has generally been quite good. Owners have reported their homes as comfortable, aesthetically pleasing, and only needing a small amount of auxiliary heat to maintain warm temperatures. Monitoring of existing envelope homes has indicated that the annual heating load for the home has rivalled heavily insulated (sometimes called "superinsulated") homes in similar climates.

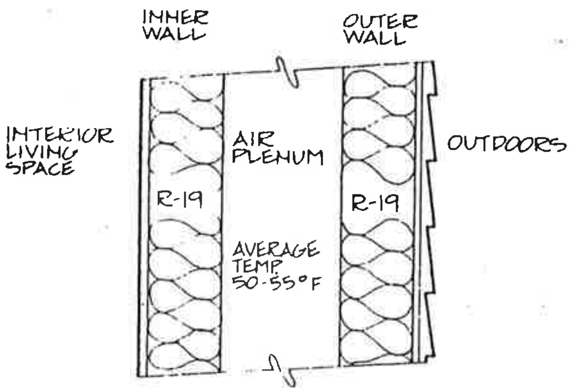

Figure 4 -- Wall Profile

Recent research into the operation of the envelope design has yielded a number of factors which help explain its performance. Initially, it seems that the envelope design provides an excellent insulating capability due to its unique construction. The inner wall, which is insulated, is separated from the insulated outer wall by the envelope loop (see Figure 4). Temperatures within the loop are typically moderate. This double wall construction provides an insulating value that rivals that of a super-insulated home. The result is a low rate of heat loss and warmer wall surface temperatures that increase occupant comfort.

Another aspect of envelope home construction that helps explain its performance is its level of air tightness. The envelope design overcomes much of the effect of cold air infiltration that occurs with a conventionally constructed home. In the envelope home, cold air that infiltrates the outer wall mixes with the air circulating through the double loop. Therefore, direct cold air infiltration into living spaces will be reduced. In addition, the inside wall is not exposed to the wind, thereby reducing wind-driven cold air surges experienced in many conventionally constructed homes. The air infiltration into living spaces that does occur in envelope homes will have been warmed by air temperatures within the envelope loop.

Finally, performance of the envelope home can also be explained by the effects of ground source heat on temperatures within the envelope loop. Because the underfloor heat storage system is in contact with the earth, it is possible that envelope loop air is tempered by heat from the ground. During the night, as temperatures drop within the loop, heat from the ground is given up into the loop. Temperatures within the loop tend to stabilize within a few degrees of ground water temperatures. In the Puget Sound area, this might typically be in the range of 53°F to 55°F. The release of ground source heat into the loop probably does not create an air flow completely around the envelope loop. It is more probable that the ground source heat flows to the north wall space and the greenhouse area or both. Thus, during the nighttime hours, the spaces within the north wall and the greenhouse area are tempered with ground source heat.

It seems that the contribution of ground·source heat to the envelope home's performance may be more significant than the home's solar features. Designers are reacting to this information by paying greater attention to underfloor heat storage. Many recent envelope homes have used 6 to 8 inches of dirt, cleaned of any organic material, as the heat storage medium. A polyethylene vapor barrier is typically placed under this dirt storage system and the sides insulated for better heat retention.

SPECIAL CONSTRUCTION DETAILS OF THE ENVELOPE HOUSE

Because the design of the envelope home differs significantly from conventional homes, a number of construction details should be mentioned. The double wall construction on the home's north side represents the most radical departure from conventional construction. The exterior wall is typically set on the foundation with the inner wall as non-load bearing. A plenum of 8 to 18 inches is created by this double wall construction. The walls themselves are conventionally constructed, however, of 2 x 4 or 2 x 6 framing. In Western Washington, vapor barriers are often installed on the warm side of both walls, that is, the room side of the inner wall and the loop side of the outer wall. Some building departments, however, will require vapor barriers on both sides of the plenum chamber. Windows on the north wall are often framed into both the inner and outer walls. By using double glazed units, four panes of glass separate the interior living space from the outside. In some designs, the north wall windows are placed in the exterior wall only, by boxing out the inner wall with a window seat.

The east and west walls of the home are of conventional wood frame construction but should be heavily insulated (at least to R-19). The south side greenhouse structure is constructed with a large area of double glazing for solar collection. Window area between the home and the greenhouse should be double glazed.

One of the most significant problems in the construction of the envelope design is the question of fire prevention in the north wall air space. If a fire were to start within the envelope loop, it might spread rapidly throughout the home. Most local building codes will require some provision for fire safety within the north wall cavity. Existing envelope designs have used one or more of three methods to ensure fire safety. First, it is possible to install an automated sprinkler system within the north wall loop. In case of fire, the sprinklers would operate to put out the fire. Accidental operation of the sprinkler system, however, could cause significant water damage within the north wall. A second fire prevention method is to line the north wall cavity with 5/8" plasterboard. The plasterboard is fire resistant and provides a one-hour fire protection for the north wall. Both sides of the north wall must be lined as well as the floor and ceiling joists which extend into the loop. Installing the plasterboard is time consuming and therefore increases construction costs. A third method of fire prevention is the installation of fire dampers on each floor level. Wood dampers of 1½ inches can be held open at each floor level within the north wall by a fuseable link. The fuseable link is a solder connection which will drop the damper closed to create a firestop when critical temperatures occur within the loop. Dampers are accessed by service panels in the north wall. Since requirements for fire safety vary considerably between areas, local building departments should be consulted.

NEW IDEAS FOR THE ENVELOPE HOUSE

Continued research into the envelope home has yielded a number of suggested changes in the design to both hold down cost and increase performance. Some envelope homes may use a fan to assist the flow of air around the loop during sunny periods. Other designers are modifying air flow through the underfloor space to increase thermal contact between the air and the heat storage medium. To lower construction costs, some designers have suggested building a single heavily insulated north wall with air ducts to provide for loop circulation. Finally, some designs are attempting to make better use of solar energy by incorporating conventional passive solar strategies into the home such as a trombe wall or direct gain. Each of these design changes are an attempt to preserve the basic concept of the envelope, but also increase the total efficiency of the home.

ECONOMICS OF THE ENVELOPE HOUSE

While the envelope home typically requires little auxiliary heat during the winter, the construction cost of the home can exceed the cost of conventional construction or other passive solar home designs. Increased material costs for constructing the double wall on the north side and the two roofs can drive up total home cost significantly. In addition, providing for fire protection in the envelope design can also increase costs. On average, the envelope design can add 10 percent or more additional cost over conventional construction. If the greenhouse area is considered as living space, the square foot construction cost of the envelope home is somewhat reduced. In most instances, however, this still results in higher construction costs than in a conventionally designed home.

WHERE CAN I GET MORE INFORMATION?

In the Puget Sound area, the Washington Energy Extension Service offers free programs on envelope homes and passive solar design. To find out when and where the next program will be, call 344-7984 and ask for tape #1000 -- a week by week listing of Washington Energy Extension Service programs. In addition to these programs, the Washington Energy Extension Service maintains resource libraries for public use which contain numerous publications pertaining to solar energy. To find out more about the resource libraries, call 344-7984 and ask for tape #1007.

SUGGESTED READING:

Solar Age. "Shakedown for the Envelope House", Vic Reno. November 1980.

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The Double Shell Solar House. Don Booth (ed.). Community Builders, Canterbury, NH, 1980.