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James A. Ray

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James A. Ray
Ener-Tech, Inc.
1924 Burlewood Dr.
St. Louis, MO 63141

ABSTRACT

The double envelope concept of house construction has received recent interest due to claims of performance not backed by analytical or operational data along with questions in code compliance and building costs associated with the construction. This paper provides a compilation of information from around the country including problems and successes and initial review of technical data associated with instrumented projects. Specific information from the Midwest is based on three houses in the St. Louis area which include designs for passive cooling and heating with alternative energy sources for backup.

1. INTRODUCTION

The design of energy conservation houses has evolved through a process of improved insulation and weatherstripping, active solar systems, passive solar design, hybrid solar designs, and earth contact. Although effective results have evolved; the costs, complexities and limited introduction into the mass housing market has led to generally slow progress. The latest passive solar designs have provided the building community with an effective method, but they generally still have been limited by architectural types, large glazing areas, and severe restrictions on site developement. The newest series, which includes double envelope and superinsulated designs, key toward freedom of architectural design, reduction in the need for solar input due to reduced loads and have provided the builder with a cost effective, mass reproducible, frame constructed house. The double envelope concept uses the principles of the superinsulated design, but provides means for earth coupling which can aid in both heating and cooling and retains a multifunctional solar gain area. References 1-6 provide background information on both double envelope and superinsulated designs.

2. DOUBLE ENVELOPE CONCEPT

2.1 GENERAL

The initial passive design technique was tied toward trying to obtain as much solar radiation as possible when available with mass storage to carry over through cloudy days. Passive cooling was limited to shade and ventilation with evaporative and radiation cooling in low humidity/clear sky areas. Increased insulation and sealing standards were found to be more cost effective to limit the amount of solar gain necessary and its associated storage. The ultimate is defined as a superinsulated house which has some solar gain with no direct storage and no or limited auxiliary heating requirements. Visual appearance and lack of cooling has been the main negatives of this approach due to the minimum number and size of windows to reduce the heat loss. The double envelope concept utilizes a flow path around the inner living area along with a south face solar gain area. The isolation effect from the outside ambient along with the mass storage in the building materials and sub-grade earth is the principle of the concept. Figures 1 and 2 indicate the general concept of the double envelope design.

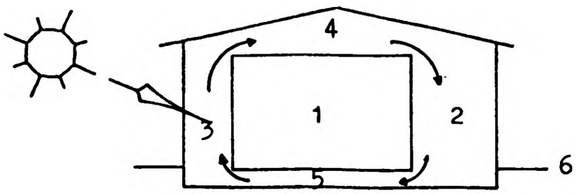

Figure 1
Flow Around Inner Region

1 - Inner Region
2 - Flow Area in North Wall Area
3 - Solar Gain Area
4 - Flow Area in Attic Area
5 - Flow Area in Sub-Grade Area
6 - Ground Level

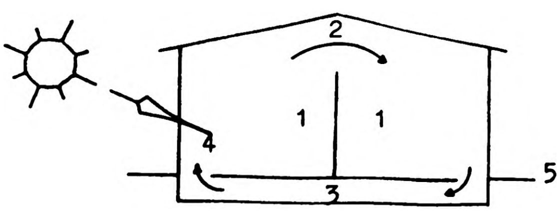

Figure 2
Flow Around Living Area

1 - Living Space
2 - Flow Around Living Space
3 - Flow Area in Sub-Grade Area
4 - Solar Gain Area
5 - Ground Level

2.2 ADVANTAGES OF THE CONCEPT

The double envelope concept stresses a south sunspace, solarium, and/or greenhouse as the solar gain area. This aspect provides an aesthetic and desired feature to the house independent of its solar function. If plants are utilized in the sunspace, some benefit on air quality is achieved. If the loop is in a ceiling/wall plenum, the mean radiant temperature of the surface is much more desirable than a standard frame wall. The coupling with the earth provides for both temperature and humidity control due to the earth and concrete characteristics. For cooling, the earth coupling along with methods to positive ventilate the house by exhausting at the top of the loop provide enhanced characteristics. The concept can be adapted to almost any architectural design using any face for the south solar gain area. The concept seasonally adjusts itself due to its close tie to the earth. This, some benefits of earth contact can be used without going underground. The loop concept by normal functional mode of operation prevents over-heating during the peak solar gain periods in the winter heating season. The use of the greenhouse concept allows year round usage without the requirement for auxiliary heat.

2.3 GENERAL PROBLEMS

With all well insulated and sealed houses, ventilation control is a necessity as infiltration no longer serves the purpose. Heat exchangers, earth cooling tubes and other positive forms of energy conserving ventilation must be employed. Due to the passive solar gain design for winter, adequate design considerations must be employed for preventing a summer heat load and possible large losses during the winter nights thru the glazing.

2.4 DOUBLE ENVELOPE PROBLEMS

If the loop is to function purely by convective means, extensive analytical methods must be employed to insure adequate flow. Simple fans can be used to induce flow if necessary. Due to the potential of high humidity situations when coupled with a greenhouse, material selection for the plenum flow area must consider moisture insensitivity. For fire code aspects, a means to fire rate any enclosed plenum with possible fire dampers and smoke detectors should be considered. A summer and winter mode of operation should be included in the design to optimize heating and cooling. Use of north wall windows will require a double window design for the outer and inner walls or a "bridged" structure across the plenum. Typically the outer window in the two window approach will experience fogging during the coldest days due to moist air in the loop.

3. EXAMPLES

The freedom of the envelope concept has evolved into many variations, but the initial impact was a design done by Lee Porter Butler[5] for the Tom Smith[4] residence. After the Smith house was featured in several magazines, including Better Homes and Gardens and Popular Science, the large portion of the first generation of buildings evolved from or copied the Smith design. The St. Louis area has four known envelope houses at the present with two of these basically identical to the Smith design and another one changed primarily for cooling considerations. Figure 3 indicates the most evolved design in that it changed the front second story south glass from a slant installation to vertical and uses north roof peak louvers for summer ventilation. This change is very worthwhile for the St. Louis climate in that cooling bills rival heating bills. Figure 4 indicates a total new design which used multiple methods to emphasize the cooling aspects,[7] including west wall isolation by the garage, mansard roof to provide both 1st and 2nd floor shade control, greenhouse exhausting outside and thru the attic ridge vents during summer operation, ground cooling tubes, louvered shade control device over the slant glass in the greenhouse, isolation and exhausting high humidity areas, stack and cross ventilation design, and airlock entries. These numerous methods for cooling considerations provide the St. Louis design with a different approach to overall double envelope design. Information from three of these houses in addition to nationally available data is used for the following specific paragraphs on design, construction and operation.

4. DESIGN

4.1 GENERAL

Even though the double envelope house is termed a solar house, many of the design features are tied to other specific methods of conserving and utilizing natural energy sources. The double envelope design considers energy for daylighting, heating, cooling, and can include hot water heating. The earth influence is touted in double envelope circles with data just now available to assess the actual contribution. The design process for the double envelope is similar to the superinsulated in that maximum use of energy conserving methods are utilized to reduce the load to be manageable by solar, geothermal and interior generated heat sources. The difference in concept over the superinsulated is the aspect of possible improved air

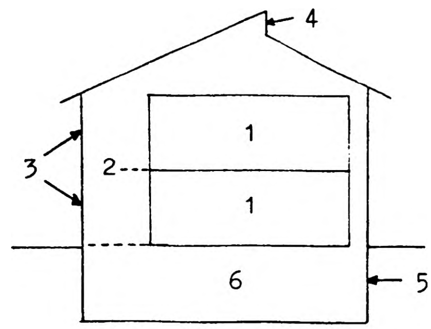

Figure 3
St. Louis Example 1

1 - Inner Region
2 - Sunspace
3 - Glazed Wall
4 - Operable Louvers
5 - Ground Cooling Tube
6 - Basement

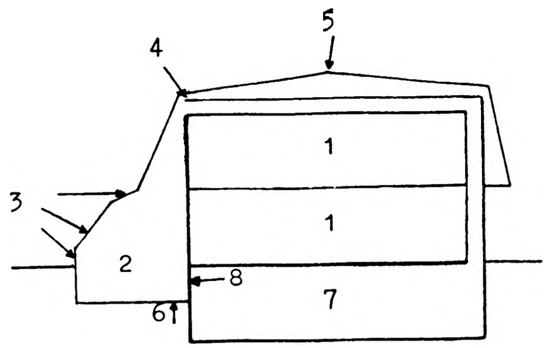

Figure 4
St. Louis Example 2

1 - Inner Region
2 - Greenhouse
3 - Glazed Area
4 - Operable Damper
5 - Ridge Vent
6 - Ground Cooling Tube
7 - Basement
8 - Operable Windows

distribution, humidity control, sunspace/greenhouse living feature without an auxilary heating requirement, potential improved cooling characteristics and an earth coupling feature. Both designs offer a large potential for energy savings and comfortable living conditions.

4.2 LOOP

Although the airflow path can be passed thru living space or other defined space areas, a large majority utilize a flow area within a ceiling/wall area. Design considerations for this "plenum" sizing, air flow smoothing, moisture insensitivity, fire rating, and structural regards must be determined. Typically, most first generation air spaces have been on the order of 12 inches in width. Other smaller dimensions have been used with no notable differences in performance. Air flow smoothing has been shown to be a desired trait but not absolute due to the low associated velocities. Moisture insensitive requirements are associated with greenhouse moist air being cooled in the plenum or moisture migration with the lack of vapor barriers. Fire protection means have received the most attention in regard to code acceptance of a vertical enclosed shaft (plenum). Structural design criteria is primarily tied to providing the easiest and most economical method for the plenum construction.

4.3 GREENHOUSE/SUNSPACE

The amount of glazing is sized typically on a basis of standard passive solar technique. Large glazing areas must be considered as large energy loss areas also due to daytime and nighttime conduction losses. The amount of glazing and/or movable insulation should be considered as means to optimize these features. For greenhouse consideration, additional direct solar gain storage should be adapted for better temperature control for the plants.

4.4 EARTH COUPLING

The loop thru a crawl space area or basement requires no special consideration except external insulations on the foundation wall is required. The insulation should be protected above grade by use of flashing, plaster cement mixture or asbestos board. A non-moisture sensitive insulation product should be used or special attention to drainage to prevent water soaked insulation and subsequent reduced insulation value.

5. CONSTRUCTION

Construction practices for a double envelope house are basically the same as any extra tight, super energy conservation design. The feature that is unique to the double envelope is the plenum construction. The wall plenum is typically fire rated with 5/8" fire code drywall applied to both inner and outer surfaces. In some cases, the second floor joists which penetrate the plenum space are also wrapped in drywall. All joints must be taped for code compliance. The inner wall may be a built up stud wall which would require working in the plenum to secure the drywall and tape joints. A standard drywall steel stud system is available which allows blind installations with all placement from the room side. The ceiling plenum may be air space between rafters or roof trusses or may be made up with a suspended or joist supported drywall.

6. OPERATION

6.1 TEMPERATURES

Due to the superinsulating features, the double envelope houses exhibit very stable operation with fairly rapid response to any internal heat source. The operational results from a Jan/Feb winter condition with outside ambients reaching 0°F, indicate to greenhouse operates over a range of 45-85°F, the inner region 55-75°F (noon to midnight above 65°F) and the near earth 45-55°F. Although small temperature changes actually occur with the earth, the mass factor of the earth provides a large storage potential for maintaining the greenhouse temperature above 45°F.

6.2 AIRFLOW

The convective loop process is a reality, but the flowrates are generally small. Velocities on the order of 30-50 fpm occur during the day and 10-20 fpm at night.

6.3 LOOP ISOLATION

Estimates of the energy stored in the house materials as a percentage of the solar gain is on the order of 40%. The airspace temperatures along with this mass storage in the loop criteria provide for improving the effective temperature the inner region reacts to in a heat loss mode. Evidence of the effect of the loop per se has been verified by back-to-back checks with the loop operating and closed off. The results indicate a positive effect with the loop open in lieu of closed. Estimates of the amount of energy stored in the earth portion of the loop indicate on the order of 20%.

7. CONCLUSION

The double envelope houses are providing a specific method of conserving and utilizing auxiliary energy sources in which experience data is supporting the design as very effective. Additional data and improved design/construction methods are still necessary to determine the future success of this concept.

8. REFERENCES

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9. BIOGRAPHY

James A. Ray, P.E., BSME Univ of TN, MSME Univ of MO-Rolla, 13 years professional experience, Vice-President Ener-Tech, Inc, consulting engineering firm specializing in solar and energy conservation design. Design projects have included new/retrofit residential/commercial energy conservation buildings including such concepts as passive solar(one residential design received a HUD Cycle 5 Design Award), earth contact, double envelope, superinsulated, alternative energy backup systems, passive cooling techniques and active solar systems. Instructor, St. Louis Community College, lecturer/speaker, along with numerous professional association memberships.