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FINAL TECHNICAL REPORT (AT)

Thermal-envelop stone house, solar

Grant # DE-FG4480R410314

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A Summary:

The purpose of this project^e is to create a comfortable, low-cost heating system for a single-family house, without dependence on non-renewable energy sources. I have attempted to combine a simple solar air-heating collector with the thermal envelop concept (for thermal air circulation) and massive interior stone walls for heat storage. All building materials, with the exception of the solar glazing material and certain other solar components, are inexpensive and locally produced. Examples are: rough-cut hardwood lumber, sandstone (free for the gathering), galvanized roofing for absorberplate, concrete, concrete block, and cellulose insulation. The collector has operated with a relatively high degree of efficiency, though three 0.6 amp duct fans had to be installed in order to increase air circulation. The interior stonework has provided more than adequate heat storage, along with even heat radiation throughout cloudy periods. My main problem has been heat loss around the foundation.

B Project Description / Procedure: (See grant proposal for blue prints and full technical description)

No major difficulties were encountered in completing this project as planned, and the building schedule has been kept essentially on time. The domestic hot water system has encountered some minor problems and is still under construction. Various aspects of construction and performance are listed below for further comment.

1. Wall Construction: (See drawings E & F)

The problem was to create walls which would store thermal energy, allow passage of solar heated air, and radiate heat into the living space of the house, while remaining structurally strong and visually aesthetic. As described in the grant proposal, this was solved in two ways. On the north wall, a stone veneered

column was constructed, and a 4" air space allowed before application of insulation and exterior siding. This provides even exposure of the entire surface of the column to solar heated air, where heat is stored and gradually radiated into the living space. Wire mesh embedded in this wall extends into the air space and aids heat transfer from the air into the wall. On the south wall, five concrete block columns were constructed, the blocks stacked directly one on top of the other. These were used instead of the metal ducts in the drawing, as air can easily pass through their hollow cores. A stone veneer was then layed around the outside of each column. This type of construction was easier, stronger, and less expensive than the method used on the north wall. It is also better suited for wall construction between windows, which are numerous on the south side. Heat transfer and distribution may not, however, be as complete with this method.

I have been extremely pleased with the form - veneer method of wall construction which I developed on an earlier project and used here. A wooden form was used on the unexposed side (outside) of the wall, and a stone veneer layed on the inside. Every few courses of stone, concrete was poured between the veneer and the form. Vertical re-bars were spaced about every three feet. The resulting two story wall is extremely strong and visually pleasant.

2. Collector: (See drawing D)

The collector design is simple, inexpensive, easy to construct, and apparently efficient. It consists of three layers: a reflective surface, an absorber plate, and glazing. A 3" air space is allowed between the reflective surface and absorber for air circulation, and a 1" dead air space is provided between the absorber and glazing. The reflective surface is constructed ^{with} 4' x 8' sheets of "Thermoply" sheathing, and the absorber is of galvanized, corrugated metal roofing, laid horizontally and painted with black absorber paint. The glazing is Kalwall's Sunlite Premium II fiberglass reinforced polymer. The entire collector is bolted,

rather than nailed, to the south roof, with wooden spacers between the various layers. It can be removed, layer by layer, and re-assembled according to new design requirements. The size of the air spaces may be changed, more air baffles may be installed, and another layer of glazing may be added.

The construction of this collector was greatly simplified by the use of a 45° roof angle. Measuring rafters, cutting notches, and calculating distances is much easier this way, as is working on the surface itself. But testing results indicate that this collector began to reach its performance peak in February, when the sun was higher in the sky, and therefore did not do as well as a steeper angle would have in January, when the heating load is greater. A steeper roof angle is even more effective in more northerly latitudes.

3. Circulation: (See drawing A)

I had hoped when I designed this house that air would circulate through the collector and walls of its own accord. I found, however, that this natural convection was insufficient to adequately heat the house, and therefore decided to install three small (0.6 amp) circulating fans in the air ducts in the north roof. A differential controller automatically switches the fans off and on. These fans were designed into the system for testing and experimental purposes, but are now a permanent fixture. Though this involves use of electricity, the amount is minimal, approximately 100 KWHrs./ year. Air circulation is tremendously enhanced by the fans, as is heat transfer as a whole. The main problem seems to be that air travels too quickly through the collector, which was designed for a thermal-siphon, or self-circulating system. Heat transfer from the absorber plate to the circulating air could be increased by future collector modification.

I have also thought of installing some small photo-voltaic cells above the main roof collector for the purpose of solar-generating the current to run the circulating fans. No battery or switching systems would be necessary, as the fans would need to run only when the sun is out. It is my belief that fans and small

massive ductwork needed for a fully self-circulating system.

Another note on air circulation concerns the dampers at the lower end of the roof collector. When closed at night, this very effectively prevents cold air from falling down from the collector through the south wall, and into the greenhouse. They are easy to open and close, but they require the presense of a human operator. Should one be away from home during the evening, heat is lost, or should one forget to open them in the morning, air will not circulate. Automatic dampers, though expensive, would greatly facilitate the operation of the system.

4. Roof Vent: (Drawing B)

Though tedious to build, the roof vent has proven effective, and is without doubt essential to this type of system. The problem is to provide airtight, insulated air passages in the wintertime, while allowing maximum collector ventilation in the summertime. This was attained through use of two pieces (inner and outer) of flexible duct board with a piece of fiberglass insulation in between. In the winter time this "sandwich" is pushed up against the outer screening of the vent in each space between roof rafters, effectively sealing and insulating the space. It is simply pulled out and stored in the summer. It took about ten minutes to do this at the end of this winter's heating season, and will take about a half hour to reinstall this fall. The roof vent system successfully serves as a conduit between the collector and the north roof ducts, and also does an excellent job keeping the house cool in the summer.

5. Greenhouse:

The greenhouse is up against the south wall of the house and sunken about $3\frac{1}{2}$ ' below grade. It is insulated underneath and on all sides, and double glazed. A permanent deep soil bed provides adequate room for plants, as well as thermal mass. The greenhouse is part of the envelop system, adding collector space during the day, and drawing heat from the foundation of the house at night.

There is no auxilliary heating system and some plants were kept alive all winter.

While an exccellent facility for raising plants all year round, this greenhouse has not performed adequately as an addition to the solar heating system. One problem is that it was not completed until November, and alot of cold was "trapped" into the bed and foundation. This should be no problem in the future. The other problem is that too much heat is lost through the upper portion of the greenhouse roof, even though it is double-glazed. I hope to provide hinged insulated panels that can swing up and insulate the upper portion of the glazing during very cold weather (and in summer).

C Testing and Test Results: (see included diagram and table)

Heat flow is measured in this system with the use of a Helioscope electronic digital thermometer and seventeen remote sensors placed throughout the house. Temperature readings (in degrees F) were taken and recorded several times a day throughout the winter, and on certain days they were taken at regular half-hour intervals. Various experiments were run with fans off, at half speed, dampers installed temporarily in various palces, etc., by which the system performance was measured and modifications concieved. The raw data of a full cycle of the system performance is included in the table below. The experiment was run on a mostly sunny day (March 1), with a light wind from the southwest. For the sake of the readings, no auxilliary heating was used on this day.

These test results are both encouraging and disappointing. Disappointing in that the house did not adequately heat itself on a relatively mild, sunny day, but encouraging in that sufficient heat was collected and circulated, that the house can, and hopefully will, heat itself after some modifications.

D Problems and Possible Solutions:

It is obvious that a great deal of heat is lost out through the gravel bed and foundation of the house. This is due to inadequate insulation, and especially, waterproffing, of the foundation perimeter. Some parts of the footing will have to be re-excavated and re-insulated, and a vapor barrier applied to carry moisture away from the house, I plan to keep the soil dry around the entire house for at least 8' tp 10' in any direction. This should both insulate and add to the thermal mass of the system. Electronic temperature sensors will be placed in the soil on either side of the vapor/insulation barrier in order to take comparative readings of its effectiveness. I will begin to operate the system in the late summer in order to start off with heat stored in the ground over the summer. (Because the thermal envelop is separate from the living space of the house, the system can be run in warm weather with the windows open. This will heat the gravel bed and foundation without overheating the walls.)

Another possible problem is heat loss through the collector at night. Dampers prevent this from happening at the bottom of the collector, but relatively high nighttime collector air readings at the top of the collector (where the sensor is) indicates a possible heat loss. For instance, at 5:00 am, the collector air was 53.5° , when the outside air was at 42.5° . This may be due to air stratification within the collector itself, which is not serious, or it may be due to convection currents within the north wall, whereby heat from the wall is carried up to the collector and lost. First, I will place a sensor at the bottom of the collector to see if the problem is ^twithin the collector itself, and if not, I will attempt to install automatic dampers next to the fans in order to prevent convection currents

The other main source of heat loss at the foundation level is through the greenhouse, as discussed earlier.

F Conclusions:

This project has been completed and tested as designed, but is not in its final form. The solar heating system provided nearly all of our heating needs towards the end of the heating season, but was inadequate during the winter. It helped heat the house, but would have to bear more of the load in order to be cost effective. I believe that the system can be improved tremendously with some additional input, but only the test results from next winter will tell for sure. I plan to make modifications this summer and resume testing next winter. I also hope to computerize my test data in order to make quantitative analyses of the system's performance. More than enough heat is generated by the collector, and it is moving to the right places; it is just a matter of keeping it.

The design could be improved markedly, based on construction experience and test results. Improvements could be made in collector efficiency, air flow, ductwork, and foundation insulation. The basic building materials: stone, concrete, concrete block, corrugated metal, and rough-cut lumber have more than proven their worth in creating low cost, esthetic, solar-heated housing. In this sense, this house can be considered a primitive prototype of one thing that can be done in this region to deal with the energy situation.

Plus:
on 8:50 am

Wind: medium, gust
Some fall in morning
some light to 6.0
in afternoon

Plus full:
(15 fire)

Temperature Portion Data

3/1/82
(6.00) am

pm

Date	9:00	9:30	10:00	10:30	11:00	11:30	12:00	12:30	1:00	1:30	1:45	2:00	2:30	3:00	3:30	4:00
1 Outside Air	59	60.5	69	79	88.5	95	100	102.5	104	100	99	97	96	98.5	86	86.5
2 Inside Air	87.5	76.5	94	112.5	124.5	137.5	147.5	148.5	145.5	141	136	128.5	123	109	103.5	92
3 North Wall	61.5	65	76.5	85.5	92	97	99	101	103.5	101	99	98.5	97	94.5	82	88.5
4 North Wall	63.5	67	66	68.5	71	73.5	75.5	77	78.5		79		74.5	77.5	79	78.5
5 North Wall	60	62	74.5	81.5	88	92.5	95.5	96.5	95		96		93.5	92	88.5	87
6 North Wall	57.5	59	59.5	60	61.5	62.5	63.5	64.5	65.5		66		67	67	67	67
7 Under Floor	56	57	61.5	64.5	66.5	68.5	71.5	73	74.5		75.5		75.5	75.5	74.5	72.5
8 Under Floor	52	52	52	52	52.5	52.5	53.5	53	53.5		53.5		54	54.5	54.5	55
9 Under Floor	53	54	59.5	66	71.5	75.5	76	77	79		80.5		76.5	79	78.5	75
10 South Wall	54.5	55	55.5	58.5	58	58.5	60.5	61.5	63		65		66	66.5	67	67
11 South Wall	57	57.5	59	60	61	62.5	64	64.5	65.5		66		67	67.5	67	66
12 South Wall	59	59.5	59.5	59.5	59.5	59.5	59.5	59.5	59.5		59		59	59	59	59.5
13 Ceiling	58.5	61	64.5	72	80.5	87.5	94.5	96.5	96		96		95	94	99	99
14 Inside up	59	57.5	60	60	60	60.5	62.5	61	61.5		62		62.5	63	63	62.5
15 Inside down	57	57.5	57.5	58	58.5	59	59	59.5	60		60		60.5	61	60.5	60.5
16 Outside Wall	51	51	51	51	51	51	51	51	51.5		51.5		52	52	52.5	53
17 Outside	60	61	61.5	62.5	63	64	64.5	64.5	66		66		66.5	66.5	67	67
18 Outside	60	61	61.5	62.5	63	64	64.5	64.5	66		66		66.5	66.5	67	67
19 Outside	60	61	61.5	62.5	63	64	64.5	64.5	66		66		66.5	66.5	67	67
20 Outside	60	61	61.5	62.5	63	64	64.5	64.5	66		66		66.5	66.5	67	67