THE VIABILITY OF THE WOOD PLENUM COMPARED TO THERMAL MASS

by

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During the major part of this past decade, we have seen tremendous pressures on the price of energy. This has produced some of the most serious inquiry we have ever seen in creative applications, attempting to reduce energy consumption of all kinds. All of this searching and thinking would have made sense decades ago out of principle. However, it was not enough that we understood on an intellectual basis that our supplies of crude oil and other fossil fuels were finite. It was only after we as individuals had to face cost increases in amounts that would have been considered unbelievably staggering as recent as 1970, that action has centered around the housing industry and the fact that millions of Americans now spend between $1-2,000 per year to heat and cool their homes. Out of the solutions that have been offered to deal with the problem, we will consider today the viability of the wood plenum compared to thermal mass.

Among the reasons why we feel the wood plenum to be superior is the fact that it is better able to control and stabilize all types of available heat energy. Thermal mass is undeniably able to store heat energy and to radiate such energy within living spaces. However, when used in configurations to take advantage of that characteristic, thermal mass structures are much like a loaded, moving truck without a steering wheel. It has a capability, but is basically out of control most of the time. As supporting evidence for our contentions, we will use two of our buildings, whose performance records speak for themselves.

A commercial building we have built houses a cheese and health food business. Since it was built on a level lot (sloping lots are nice but not absolutely necessary), some fill was brought in to earth cover and landscape. We landscape covered the west, north and east sides using a slope of about two to one covered with bluegrass sod. The roof is covered with 18" tapered to 12" of earth and sod. The roof has two exhaust fan openings and other vents required for plumbing. A large double door opening, which is used as their service door, is on the east side with the earth held back by two retaining walls. This building is 36' x 32' (1152 sq. ft.), with a large open porch and roof on the south front which shades the entrance door and all the windows. This eliminates any passive solar gain for the building, which would be derived from any glass areas.

The construction schedule for this building illustrates what can be done in a relatively short period of time, if the building schedule is not dependent on "curing time" for some or all components of the building. Ground breaking was September 1, 1979 and they opened for business on October 1, 1979; with the building and landscaping completed.

The "Mouse House" (its business name) had electric heat installed in the ceiling when the building was built. Aside from initial testing, the heating system has yet to be used, after two complete Minnesota winters. They have had no expenses for providing heat. The use of four refrigeration units to keep the merchandise fresh, along with the fluorescent lights, have provided more than enough heat to maintain 68-72 degrees.

Following is a brief description of each of the four refrigeration units, all of which have the compressors mounted in the unit:

1. One regular household refrigerator, about 16 cubic foot
2. One open top chest type cooler, approximately 30" x 80"
3. One open front cooler, approximately 55" x 72"
4. One wall type freezer unit, approximately 55" x 72"

The owners are presently considering relocating three of the compressor units in order to duct out the heat during the summer and leave it in for the winter. The "Mouse House" was among the award winners of the State of Minnesota Department of Energy. 1979 Energy Savers Award of Excellence. This was quite an achievement for a small, privately owned business in a small rural town.

Part of the explanation for this building's performance can be attributed to the inherent benefits of earth sheltered construction. Another substantial reason is the fact that the structure is built entirely of wood and thus has a substantial stud cavity able to be filled with fiberglass insulation. A "thermal mass" structure is typically rather difficult to insulate beyond R-12 or 15.
Our average sidewall below grade has an R value of about 31.

Another building we would point to is a basic two bedroom home 26' x 40' (1040 sq. ft.) located in Redwood Falls, Minnesota. This building was constructed on a level lot and landscaped and earth covered by bringing in the dirt. The structure has been used as an office since it was built in the fall of 1979. It has a south front exposure with one 6' wood patio door, one 3' walk door with side light, and one small picture window having dirt bermed to the bottom of the window. The east end wall has two standard size bedroom windows with the dirt bermed to the bottom of the windows. The north and west walls are fully covered with earth. The roof has 18" sloped to 12" of earth cover and had four plastic bubble skylights, (approximately 33" x 38") until January

of this year. We replaced them with clerestory windows for the skylight area to gain greater overall benefits. Inspite of the fact that we did realize some heat gain in the winter, the losses

were higher. There was also unacceptable heat gain in the summer. The current situation is very comfortable and we are now satisfied with it.

The building uses a counter flow electric furnace for heat and this structure does not have an air conditioner. The furnace is on a separate meter which makes it easy to monitor the KWH used. From the time the furnace was installed in the fall of 1979 until April 17, 1980, the building used 2467 KWH for heating. This electricity, at $.028, amounted to $69.07. From April 17, 1980 until October 1980, the building used 184 KWH for cooling. At the same $.028, we get $5.15. This amount was used to run the furnace fan to circulate the air through our rock storage area in the plen-wood system under the wood floor. From October 10, 1980 until December 29, 1980. 19 KWH was used by the furnace fan to move some excess passive solar heat into the rock storage below the floor. The cost of 19 KWH at $.04 (showing a cost increase of 43% over the previous year) was $.76. This amount added to the previous sums gives us a total cost of $74.98 for heating and cooling 1040 sq. ft. for the 1980 year in Redwood Falls, Minnesota. The following graph (Figure 1) illustrates the kilowatts used during the month of March, 1981 on a daily basis.

As further evidence of energy efficiencies, the heating elements were not actually connected for the furnace until January 5 of 1981, for the winter recently ended.

For an extended period of time now, we have been collecting performance information on the 1040 sq. ft. building. Once each day, the temperature and humidity readings have been taken and recorded for: outside the building, inside the building, and in the rock storage (under floor plenum) area. Figures 2 and 4 will show how the temperatures for these three areas compared, and Figures 3 and 5 will illustrate the same comparison for humidity levels.

Without question, we feel that the wood plenum performs in a superior manner; and has basic characteristics that do not involve the negative factors found in using thermal mass materials. One such shortcoming of thermal mass materials is the fact that structures using that approach can experience internal air temperature increases of 12 - 20 degrees over a five-hour period, from such sources as passive solar gain. This is brought on of course because thermal mass walls take an extended period of time to absorb short-term excesses of heat energy. The heat energy has nowhere to go, so it stays in the living space. A frustrated homeowner has few choices but to open a window (such as in the winter) and let the heat out. Interior temperatures of 85 degrees can easily be achieved from this situation, temperature levels which really are not even acceptable in the summer when one is used to it and dressed for it. In fact, as a thermal mass wall struggles to absorb such short-term excesses of available heat energy, it is also beginning to radiate heat energy back into the living space, further aggravating the problem.

Structures using thermal mass materials are known to have problems with humidity levels. We have received numerous, unsolicited comments from the public about their own thermal mass structures, ones owned by friends, or ones they have visited. We hear comments about "only" 75% humidity inside, about running 5 dehumidifiers for a year, about condensed water dripping from the core holes of concrete roof plank, about musty closets and drawers, and about sweating walls. This is one of the serious "charateristic" problems that thermal mass materials have when used below grade. Thermal mass materials often continue to cure for a number of years. The moisture given off during this process is part of the continuing problem of humidity. At $.04/KWH, a 420 watt (20 pint/day) dehumidifier running about 75% of the time would use $68.25 of electricity for a year. Running 5 units would cost $341.25 a year.

The most widely used method of insulating thermal mass materials is to fasten high density styrofoam on the exterior. This is often a two-inch thick piece with an R value of 12 at the most. This doesn't begin to approach the R value possible with a glass filled 2 x 10 stud cavity, in excess of R-30.

Thermal mass materials used on the floors are usually less comfortable to walk on than would be the case with a wood floor over a wood plenum. Anyone who has stood on, or walked on, concrete for any length of time knows positively that wood is much more comfortable and doesn't produce the same foot and leg problems.

Thermal mass materials used in floors tend to be colder in the winter and hotter in the summer. Cold floors are among the leading causes for colds and flu among young children - who for several years spend most of their time on the floor. Even conventional wood homes can have air temperatures around 55 degrees near the floor. Thermal mass floors can be even cooler. Floors over a wood plenum average around 65 degrees throughout the year. (See figures 2 and 4).

In addition to cold, thermal mass floors can be very hot. Anyone who has walked barefoot on a sidewalk in the summer knows how easy it can be to get burned feet at times. Once again, small children run the risk of having a problem with thermal mass floor, should they crawl with bare skin onto a hot floor beside a patio door.

Many thermal mass materials emit a certain odor in a closed space below grade, which reminds one of being in a basement. That odor in the basement of a conventional home (especially one that is finished off) is barely acceptable. For an entire house to have that odor and be liveable, the occupant would need to have an almost constant sinus condition and a stuffed up nose.

Finishing off the interior of structures built with thermal mass materials is often difficult and frustrating, more particularly in the case of poured concrete and concrete block. It takes a substantial amount of time and effort to fur out the walls such

that the interior can be finished off to more resemble a normal home. Not finishing it off, of course, produces a rather drab and noisy environment. The impression given is much like that of being in a bunker or in a hallway under a stadium.

Installing the plumbing and elctrical systems in buildings using thermal mass materials is rather involved. All of the electrical outlets, sanitary pipe, sanitary vents, fresh water runs, etc. must be put in exactly the right place the first time. After the pour is made, any mistakes, problems, misunderstandings, change orders, or materials failures become a major project to correct (4). It obviously requires a jackhammer and results in a patch job that is almost impossible to make look like a new surface.

Fresh water copper lines in constant contact with most thermal mass materials would result in condensation on the surface of the pipe and corrosion. The end result is a leaky water line which may accelerate the deterioration of adjacent water lines or elctrical service, before the leak comes through the surface of the wall. At that point, we are back to jackhammers again.

Structures built of wood with a wood plenum enjoy a number of performance and characteristic advantages over thermal mass materials.

Temperature increases of 12-20 degrees in living spaces do not happen because any surplus heat energy can be automatically stored below the floor. This heat energy then becomes available for use later. It does not have to be exhausted from the structure for the sake of comfort, nor endured until it goes away. Since the entire under area of the floor contains 2 inches of 1 inch diameter rock, it stores excess energy in greater amounts than is possible with an area of thermal mass floor being struck by sunlight (by a patio door, for example). The storage rate or heat transfer rate into the rocks may be faster due to the greater surface area of the rocks because of their spherical shape.

Wood homes with wood plenum do not have any accompanying odors or basement smells. They are merely comfortable living environments with characteristics typical of the conventional, reasonably ventilated home.

Earth sheltered wood homes with wood plenum do not experience the levels of humidity found in thermal mass structures, (See Figures 3 and 5) below grade. This produces a warm, dry environment where one is not afraid to open a closet or a drawer. If one wants blue suede shoes, they really should go out and buy some ---- rather than growing their own in the closet.

Wood buildings with wood plenums and a stud cavity are far easier to insulate to high levels than are thermal mass structures. Of course part of the secret of building any energy efficient building is minimizing the temperature difference of the inside and outside of the structure --- which automatically decreases the heating and cooling loads.

Finishing off a wood building with a wood plenum is far easier. The materials, equipment, and procedures have been developed for conventional homes and are widely available. Since our structures are all wood, nails and fasteners can be used virtually anywhere, without any special preparations or handicap. Since conventional interior finishing materials are used, the buildings appear to be conventional and familiar when viewed from the inside. One exception to conventional characteristics is the fact that our buildings are delightfully quiet.

Since our plumbing and wiring are not buried in concrete, changes or repairs are relatively easy to accomplish.

An additional benefit of using a wood plenum is the ability to distribute the heat energy available from a wood stove or fireplace, and to store the rest. We have all been in rooms where a stove or fireplace is roaring away and the room is uncomfortably hot. Most of the time, the remainder of the house is chilly, because there is no effective way to stabilize or distribute the unwanted heat energy. Structures using thermal mass materials will absorb some of the heat energy in such a situation, producing a radiant source of heat to further aggravate the already uncomfortably overheated room.

As further support for our position, the University of Pittsburgh conducted a study on the effect of the thermal mass on the heating and cooling loads in residences. This study was done in 1977. The study involved one frame house and one identically-sized masonry house in: Tampa, Atlanta, Chicago, and Phoenix. The construction was typical of that used in Southeastern U.S.(3).

The conclusions reached based on this study are as follows:

1. The use of better thermal quality, lower U-value, of the wall construction reduces annual energy and peak loads for cooling and heating.
2. The thermal mass of the wall does not significantly affect the combined heating and cooling energy requirements of good thermal quality residential construction.
3. The effect of the thermal mass of the wall is amplified for higher U-value construction and in locations having a wide range in daily temperatures(3).

In constructing the study, it was necessary to substantially compromise the insulating capabilities of frame construction, in order to bring it down to the low insulating levels of thermal mass materials. This was done, of course, to achieve control of the study and to isolate the thermal mass of the materials being considered. The conclusions state that indeed there are some very marginal differences between the heating and cooling loads considered on a termal mass comparison alone. Unfortunately, thermal mass alone will not deliver a homeowner from high home operating costs. The difficulties in insulating thermal mass materials produces walls with R values of about 12. The stud

cavities, which are usually a part of buildings with a wood plenum, can be insulated (as in our case) to have R values in excess of 30. Those benefits alone far outweigh the meager gains shown by thermal mass materials, as is summarized by the report itself, "the thermal environmental systems for providing comfort conditions in a residence depend upon the interaction of the complete enclosure."

All of the work is definitely not done. Contributions are yet to be made by architects, engineers, and other creative people in achieving: workable relationships of living spaces to one another, creative natural lighting concepts, and exterior designs which enable such structures to wed comfortable with the earth which envelopes them. Our only limits are what we all fail to consider.

In concluding, we would like to refer to the recent proceedings of the national convention of the American Institute of Architects who met in Minneapolis, in part to discuss the future. At the meeting, a member suggested that the idea of designing buildings around collecting solar energy is too narrow an approach to energy conservation. "A lot of people are tilting at solar windmills," he said. We are inclined to agree with him (1). We feel the answer lies in reducing the appetite of a building for energy, instead of foraging for a cheaper source of energy. Our objective has been profound simplicity. Principles of physics and engineering which are widely known today were not even known to the great minds of science only a short time ago. We have tied those principles together in a synergistic fashion (and in the spirit of the idea "Small is Beautiful") produced a structure which functions beautifully.

To quote from the closing remarks of the convention, "Architects always admire the low-technology buildings. We travel great distances to see simple buildings that work, but we can't seem to take that concern back with us into our drawing rooms (1).

REFERENCES

1. Minneapolis Tribune, Staff Writer John Kostouros, "Panel criticizes Architect's Energy Conservation Efforts," page 88, May 22, 1981.

2. Marshall Municipal Utilities estimates for amount of KWH for constant year use.

3. Effect of the Thermal Mass on the Heating and Cooling Loads in Residences, by Dr. William Rudoy, Professor of Mechanical Engineering, University of Pittsburgh; and Dr. Richard S. Dougall, Associate Professor Mechanical Engineering, University of Pittsburgh; from conference on "Energy Efficiency in Wood Building Construction, Nov. 8-10, 1977, Chicago, Ill.

4. "Installation Comparisons of Electrical and Plumbing Service in Wood and Poured Concrete Structures, " by Douglas Pepper, March 6, 1980.

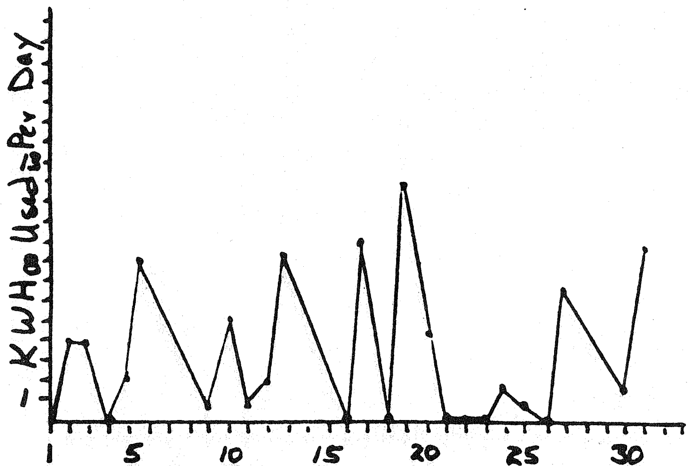
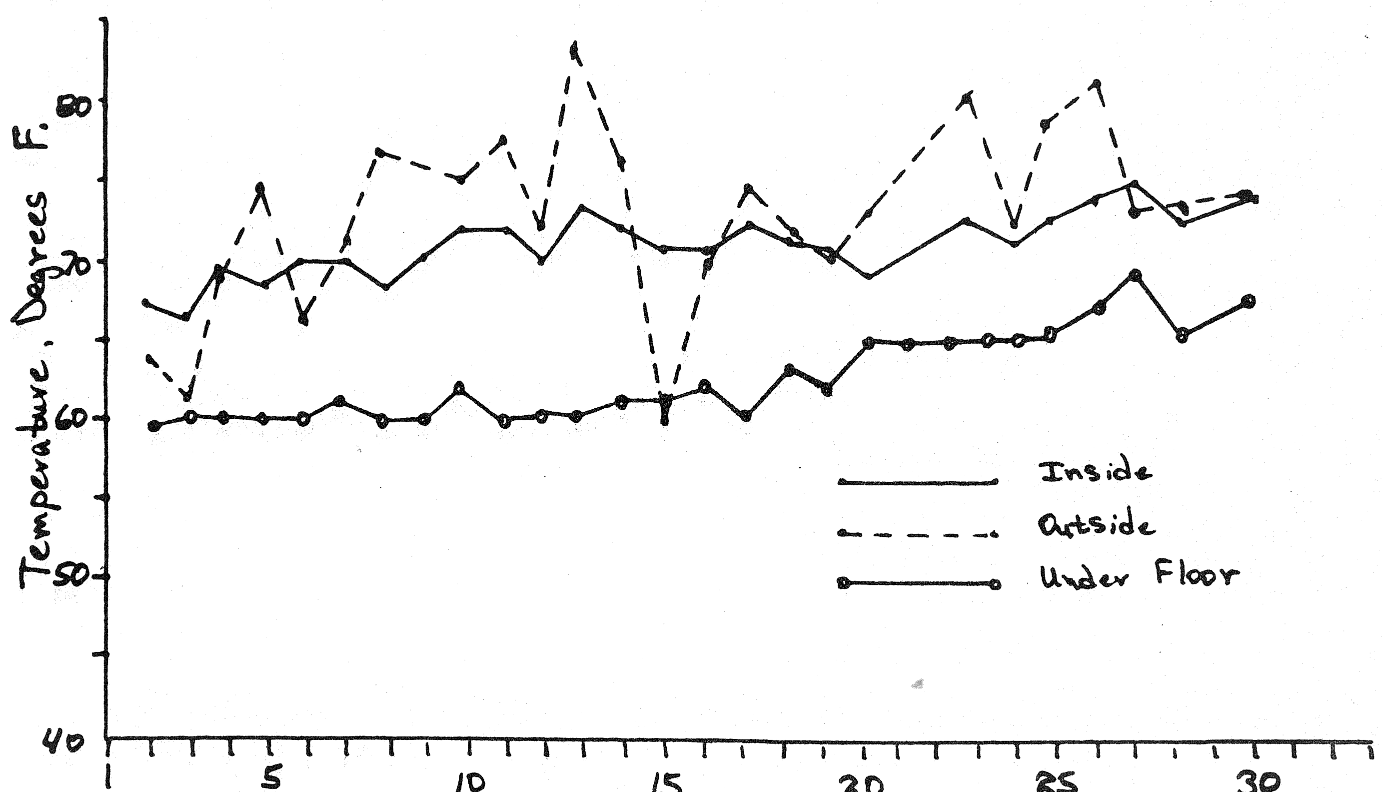


Figure I. Days of March, 1981
1040 Square Feet. 9 a.m. each day
Total KWH for Month = 109

March 1981 - Thermostat setting was 65°.

The effectiveness of a working "Everstrong Marketing Inc." Total Wood Earth Sheltered Structure using its Wood Plenum System is shown in the graph.

The temperature under the floor is the key to how it works. It is very easy to determine how much sun there was on most any given day by the ri[sing] or lowering of the underfloor temperature on the following morning.



Days of June, 1980

Figure II. Temperature Inside, Outside, and Under Floor
Days of June, 1980
Everstrong Marketing, Inc. Office
About 9:00 a.m. Each Day

This paper was published in Earth Shelter Performance and Evaluation, L.L. Boyer, (Ed.), Proceedings of the 2nd National Technical Conference on Earth Sheltered Buildings conducted in Tulsa, Oklahoma, October 16 and 17, 1981, by the Office of Architectural Extension, Oklahoma State University, Stillwater, OK 7407

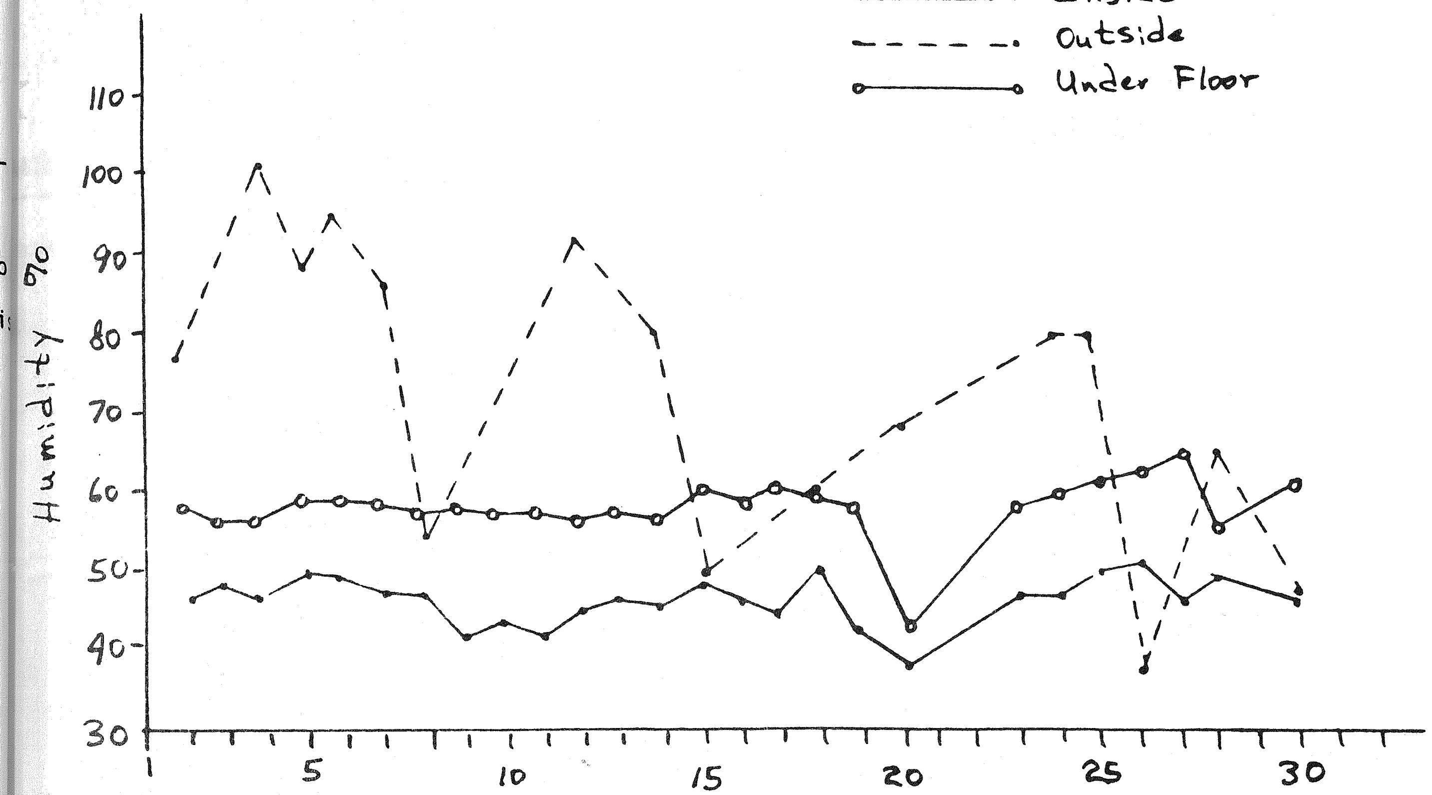


Figure III. Days of June, 1980
Humidity Inside, Outside, and Under Floor
Everstrong Marketing, Inc. Office
About 9:00 a.m. Each Day

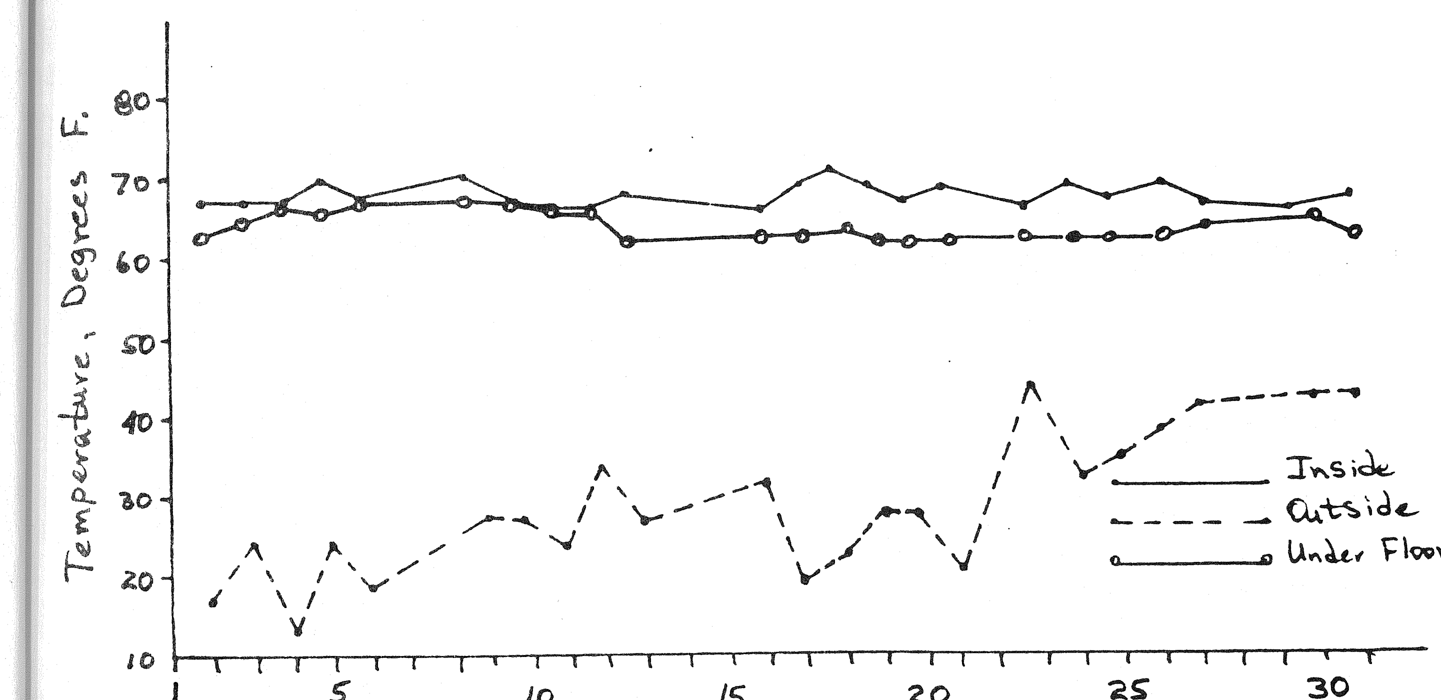


Figure IV. Temperature Inside, Outside, and Under Floor – March, 1981
Everstrong Marketing, Inc. Office About 9:00 a.m. Each Day

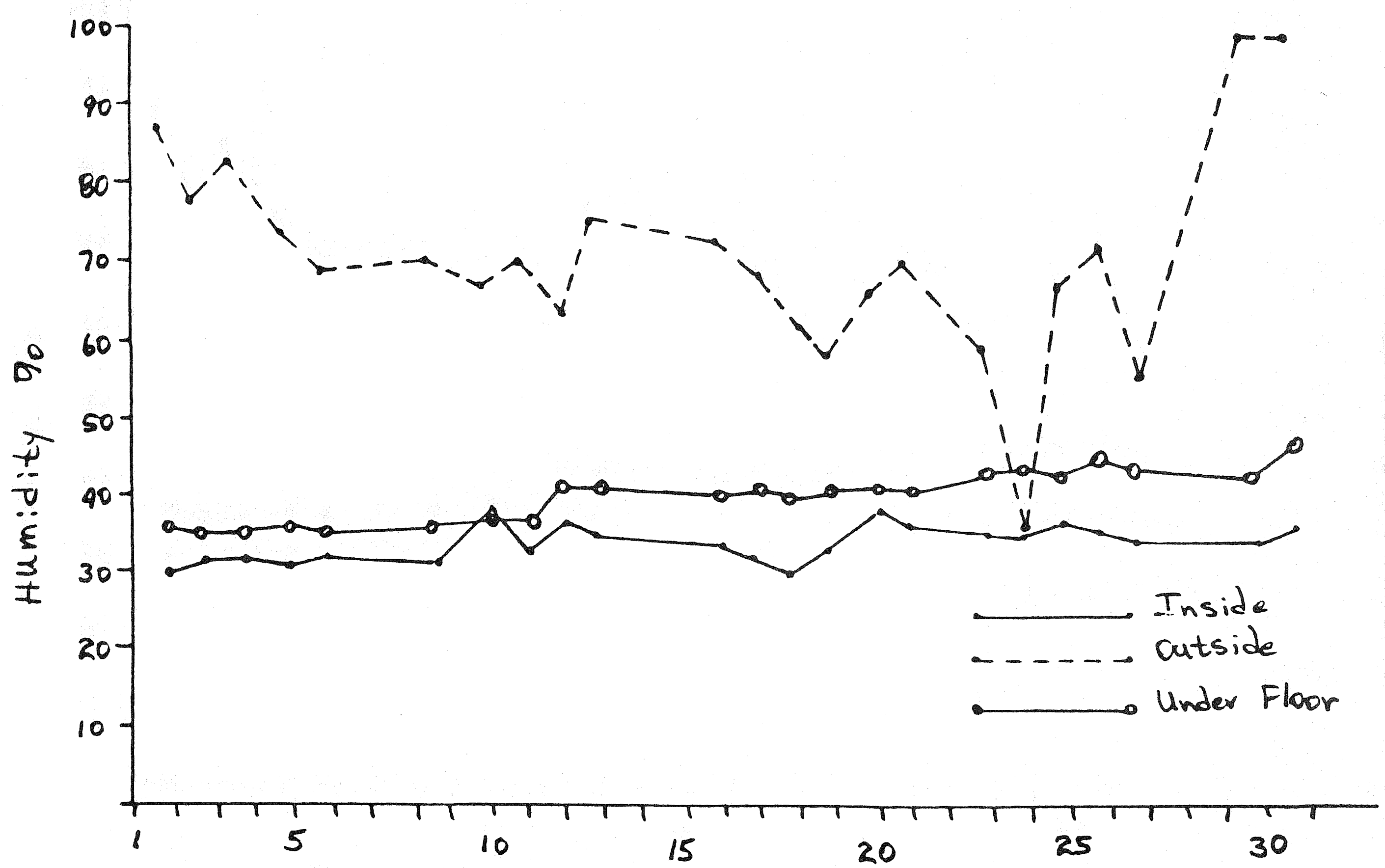


Figure V. Humidity Inside, Outside, and Under Floor
Everstrong Marketing, Inc Office About 9:00 a.m. Each Day
Days of March, 1981

EVERSTRONG MARKETING, INC.

MODEL HOME 1872 SQ.FT. REDWOOD FALLS, MN.

JANUARY, 1982

DATE	INSIDE		OUTSIDE		UNDER FLOOR	
	Temp	Hum	Temp	Hum	Temp	Hum
January 2	48		19		56	
4	46		-8	87 (W.C. -22)		
5			12	87 (W.C. -35)		
6	46		-11		54	
7			-30			
8	70	33	-1	67	57	44
9	69	33	-16	85 (Noon W.C. -60) (3.pm W.C. -85)	57	44
10	67	33	-31	44	57	44
11	70	34	-8	37	58	44
12	70	33	-4	62	57	43
13	70	33	-12	76	57	42
14	68	34	-20	62	57	42
15	68	33	-8	67	57	42
16	70	33	-21	68	57	43
17	71	33	-21	68 (W.C. -57)	57	43
18	70	33	6	52	60	42
19	66	33	14	92	59	42
20	68	33	6	72	58	42
21	70	34	11	92	57	42
22	71	34	11	88 (Blizzard)	57	43
23	70	33	-1	76 (W.C. -42)	57	43
24	69	33	-18	(W.C. -40)	57	42
25	71	33	-9	75	57	42
26	70	32	-18	88	57	42
27	71	32	32	88	57	43
28	70	34	-2	68	57	43
29	70	34	15	72	57	43
30	72	33	9		58	42
31	71	33	-22		57	42

W.C. (Wind Chill)

Source of supplemental heat is a 34" energy efficient fireplace. Electric heat has never been turned on. The house was left from Dec.26, 1981 until Jan.7, 1982 with no source of heat. This house faces Northeast.