SNEAKY INVISIBLE THINGS

CURRENTS OF TWO CLASSIC PASSIVE SOLAR HOMES

APPENDIX: A DISCRETE CURRENT TEST CELL

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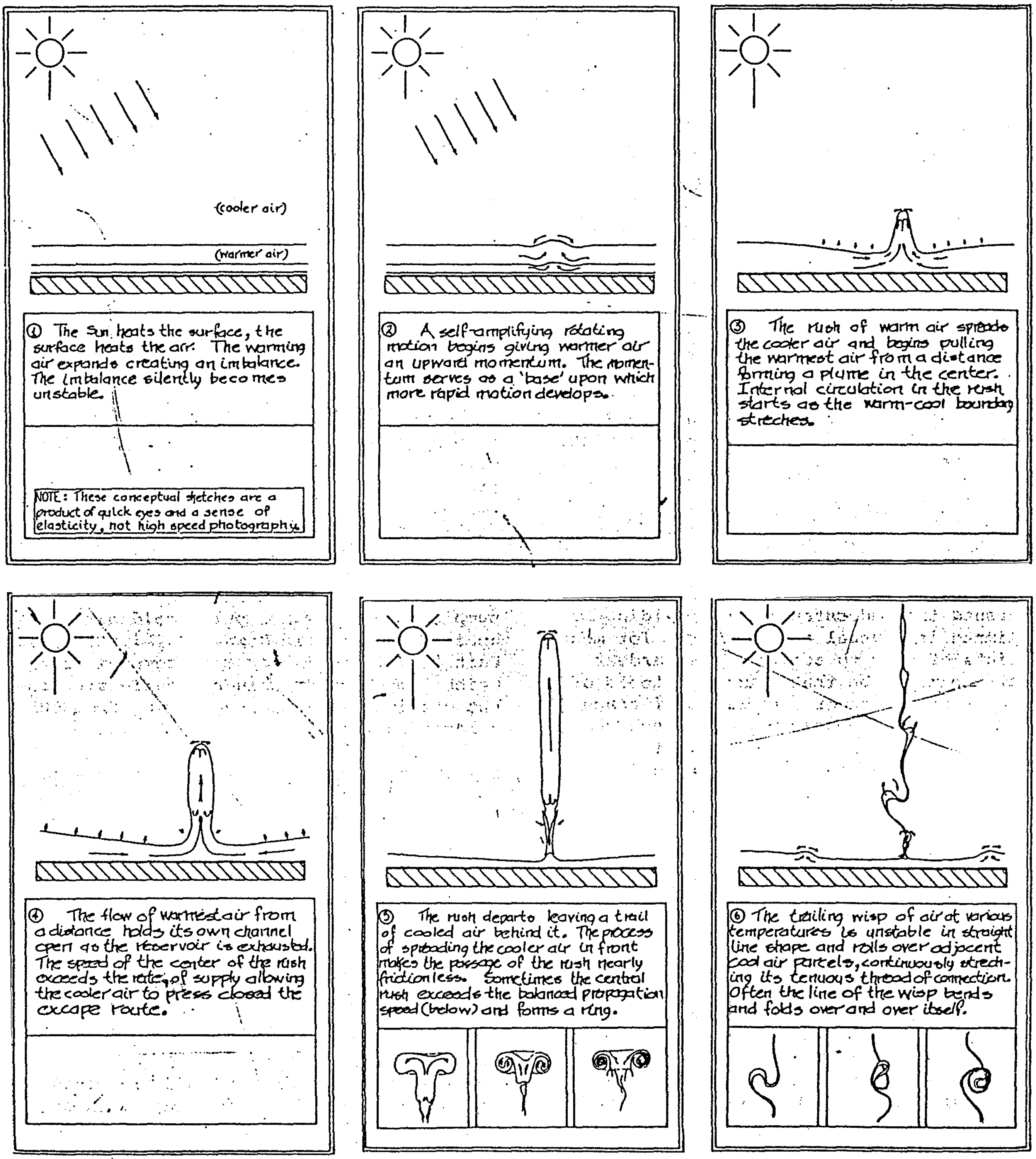
ABSTRACT: Air currents are usually considered to be too unpredictable to be individually described or engineered. Karen Terry's house and First Village Unit #1 display individual current patterns of such beauty, clarity and consistent order as to suggest some straight-forward means by which the repetitive patterns of discrete currents can be engineered and how they can serve as a measurable expression of the thermal harmonies between the building and the environment. Design with these patterns has resulted in a 65-75% normal winter efficiency for a flat plate collector.

INTRODUCTION: The process by which I have pursued the understanding of building climate is unusual and difficult for most points of view to accept. The hardest part seems to be that I use the tools of architectural theory, concepts of space and form, to do basic physics research. Another divergence which I make from customary practice is that before I read the studies of others or attempt to collect a basket full of numbers, I seek to develop an informed intuition by undirected observation of the beauties of natural process. In nature, beauty and simplicity seem to be closely connected. From first attending to the beauty of natural patterns, the steps of developing and refining uncertainty into simplified understanding can directly progress. Proceeding in this direction with the subject of climate dynamics behaviors seems especially appropriate because of their silent and invisible character and extreme complexity. My particular approach has been to take as much data and make as many direct observations as possible and then see if there was anything puzzling or interesting about them. I found lots. Most crucial to being able to make the following descriptions of two homes was the discovery that the highly energetic yet well protected indoor climates of passive solar homes create air currents which tend to be highly distinct and individualistic. In this, passive solar homes seem to be a new feature on earth and provide a first opportunity to observe protected yet uninhibited natural climate behavior. The drawings I present here show reasonable first order approximations of air currents and current patterns. The true behaviors in these homes, though sometimes several orders more complex, are generally as distinct and individual.

In Karen Terry's house I not only found beautiful patterns, I also found a natural pumping process which pulls cold air uphill and warm air down. In First Village Unit #1 I found a much more complex order which, among other things, neatly drew the hottest individual currents away from the coldest surface (contrary to the normal direction of hottest to coldest) by involving them in a figure eight convection loop. To even rudimentarily understand these behaviors it would be of great advantage to do some direct personal observation of air currents. The use of incense smoke, with a little patience, can become a very powerful mapping tool. The resulting understanding, though never definitive, always enriches understanding by allowing an appreciation of a building climate as a total system.

1. <u>A DISCRETE AIR CURRENT</u> To supplement the understanding of those who do pursue the subject by observation and to give those who don't at least a hint as to what

an air current is, I offer figures 1. to 6., conceptual sketches of the first air current. One critical aspect seems to be how currents invent themselves without any obvious suggestion, i.e. turn themselves on at a time when they don't exist. This concept has a variety of very interesting spin-offs. A second crucial aspect is the way air currents travel by means of a continuous unfolding of a central core which rushes to the front, splits itself and the air mass and remains relatively stationery on the outside 'surface' as the rest of the current passes by. This and

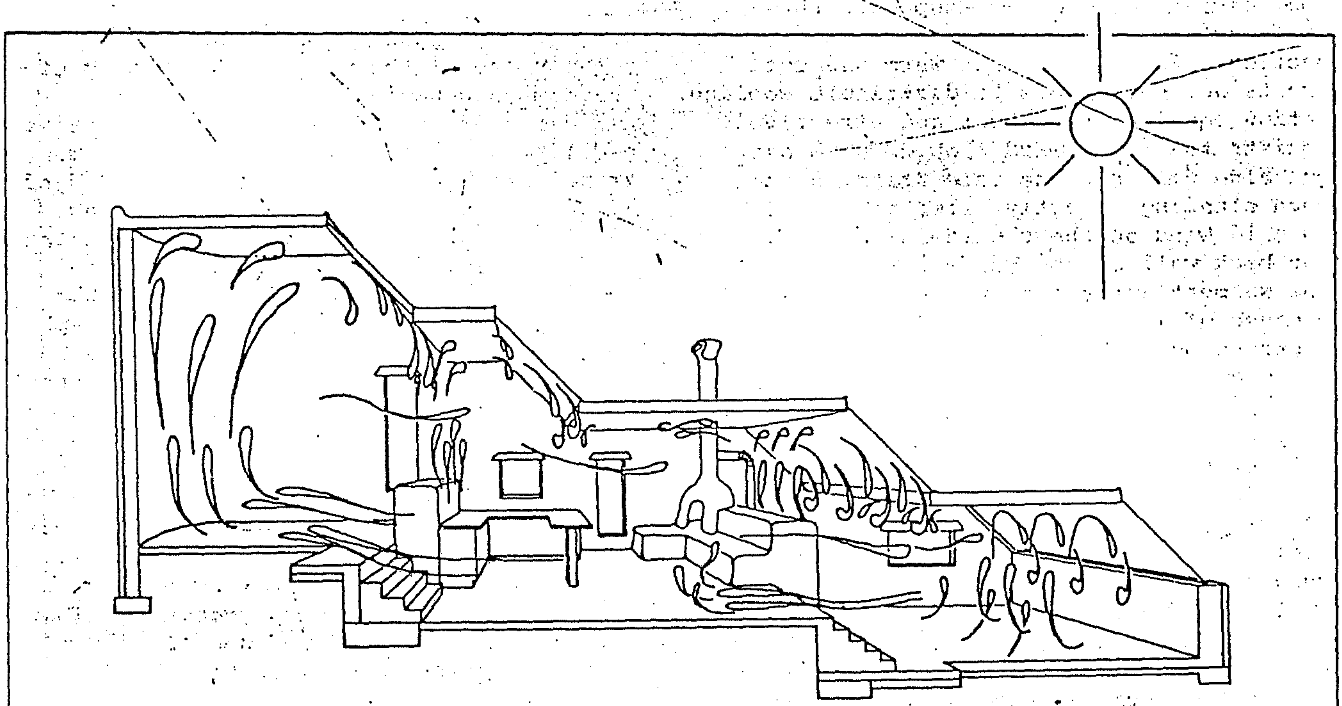


other sorts of similar orderly behaviors are generally characteristic of passive thermal air currents as contrasted to the familiar disorderly behavior of forced non-thermal air currents. The easiest place to observe simplified versions of these orderly flows is in doorways and along floors of any building where there is very commonly found a smooth and well defined river of cool air flowing steadily in one direction or another.

2. <u>KAREN TERRY'S HOUSE</u> (Santa Fe, N.M., designed by David Wright, fig. 7) Karen Terry's house is a direct gain solar house. It is composed of two parallel north-south insulated adobe walls which step up a south facing slope, spanned on top by alternating flat roof and tilted glazing and joined below by three floor levels. The floors and the bancos between floor levels are high thermal mass elements. The house works quite well, being comfortable throughout at most times and requiring use of the heating stove on only ten to fifteen days a year. No operable insulation is used.

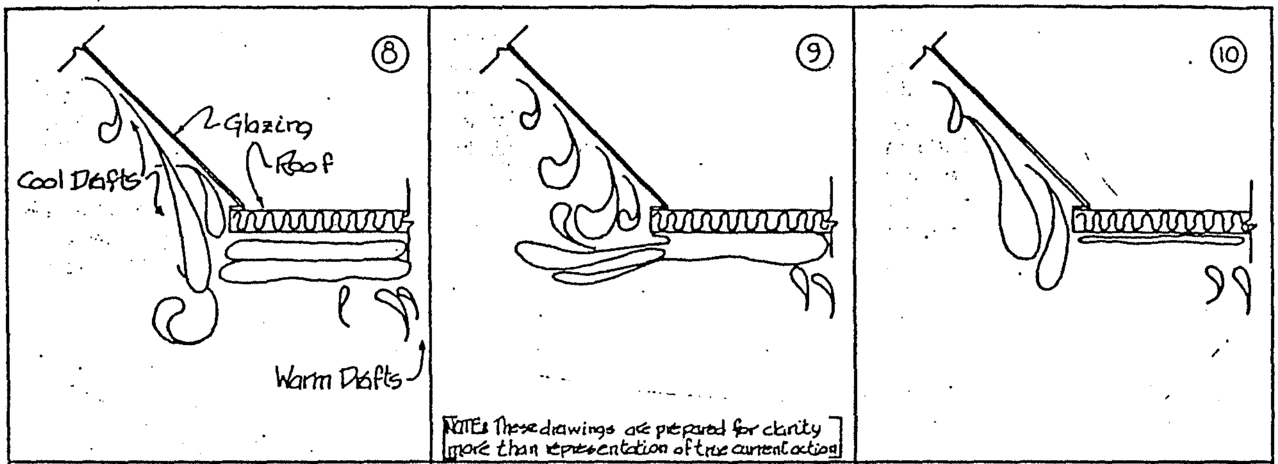
The first hint that something unusual is happening in the climate of the house is that the top to bottom temperature stratification is much lower than might be expected in a twenty-five foot high room with lots of windows, even considering the thermal mass. The second hint comes from noticing that in winter, both day and night, the cool air streams along the floor are gentle and tend to go northward, effectively up-hill. The keys to discovering the overall pattern of flows lies in the interaction of cool rushes which descend from the overhead glazing with the warm rushes which rise from warm mass below, the effect of the strong warm sheet of air which rushes up the broad smooth back wall of the house and then in that these current patterns operate continuously, both day and night, so long as the mass surfaces are warmer than the air and the air is warmer than the windows.

The warm air which rises in central areas from heated mass would normally rise to the ceiling and then along the ceiling to stratify at the top of the building. The down-draft from the windows falls across the full width of the building forming a momentum curtain which effectively blocks the normal passage of warm air from under the lower adjacent roof level. This blocking is made more effective by the



Karen Terry's House
(fig. 7)

Air Current Pulses - Karen Terry's House - Night-time, Winter Cooling Conditions
Pulse Periods ~ 10 to 15 min.; fairly regular, Effected temps. show sine wave like variations



Reserves of warm air build up in a warm air pool behind a strong cool air curtain.	The warm air pool overflows, blocking & slowing the cool curtain, forcing a buildup of cool air reserves.	As the warm pool is exhausted, the built up cool air re-establishes the cool air curtain.

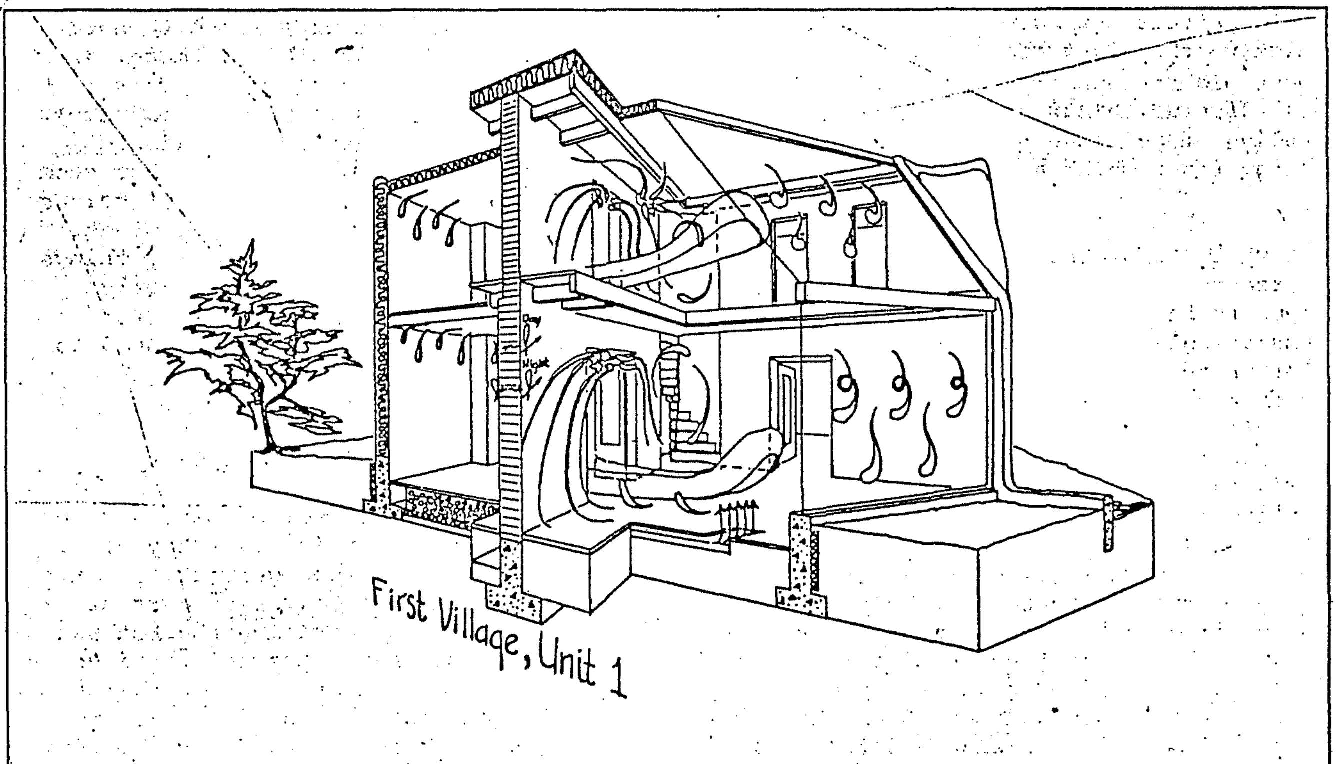
next lower window section which draws from the blocked warm air flow both to supply the down-draft and by pulling along some by the turbulent drag of the down-draft. Thus each window section supports the draft action of each successive window section. The conflict of warm and cool drafts not only tends to distribute cooling action equally throughout and effectively resists the net upward flow of warm air but also diffuses the cold draft so that when standing directly under the windows no cold wind on the shoulders is felt. The back wall of the house is generally the warmest surface in the house and because of its uninterrupted expanse, forms a strong pull on the air mass, drawing large amounts of lower air upward vigorously supplying the down draft on the first set of windows. It seems, for a variety of not altogether too conclusive reasons, that this is the action which tips the balance and causes a gentle net uphill flow of cooler air. The total net effect, though much heat is lost by supplying the coldest surfaces with the warmest air, is a gentle feeling living space free of strong drafts and a top level to bottom level night time temperature stratification of around five degrees where I would have guessed there would be a fifteen to twenty degree difference.

At night there is a pulsating aspect to this flow as described in figures 8, 9, and 10. I know of no particular advantage this behavior results in except in helping make sense of other observations and to give me the opportunity to describe clearly one of the more extraordinary of the common behaviors I have observed. All sorts of air current patterns involve oscillating interactions composed of many transient flows. In general terms I find it intriguing to look for the rotating circle implied by any steady self-regulating cyclic action and for the energy which steadily supports its turning. In this case the circle lies on a piece of graph paper relating the pressure in the warm pool with the pressure in the cool current. Projecting either of these pressures onto a pressure - time graph gives a sine wave. In three dimensions, pressure, pressure and time, the curve is a helix powered by the steady convective cooling of the house. The cooling by convection is steady; the falling of cold and the rising of warm are forced to alternate by the geometry. (Note: The reference here is not necessarily to perfect circles, sine waves nor steady cooling)

3. FIRST VILLAGE UNIT #1 (Santa Fe, N.M., designed by Bill Lumpkins, figure 11)

Unit #1 is a greenhouse - mass wall and fan supplied rock storage type solar house. The two story, south facing (almost) greenhouse is triangular, set between diagonally oriented two story living spaces. It also serves as circulation space to all rooms. The living space exterior walls are very well insulated (7½") and cement plastered both inside and out. There are many nice things one can say about this extraordinary building, there's the playfulness with which it was made and its playfulness with the sun. The thing I find most significant, however, is the way in which architect Lumpkins re-interprets the normally drab meaning of hallway to become the central inviting gesture to both people and the climate. For me this focuses directly on one of the great architectural opportunities brought by the advent of passive solar design. The climate dynamics of the house are highly ordered but also highly complex. There are several discrete individual behaviors nested within each other, each taking up where some other has left off. My description is limited to one series of such events having to do with the way this house handles energy after primary gain, its odd habit of sending the warmest air currents into the safest places. This, combined with the factors which produce remarkably uniform night-time temperatures, seem to be the essential bonus factors which make this house so climaticly successful; only two rooms received backup heating last winter.

When sunlight enters the house it falls on a wide variety of surfaces. There are many high and low mass areas which receive direct gain for either long or short periods, heating themselves and the air adjacent to them. The heated air adjacent to the vertical mass wall rises in smooth uniform sheets I call slip streams. Before these streams slip off the wall and become turbulent they are drawn off sideways to the tops of open doorways. This smooth lateral motion seems to be allowed, in part, by a nearly motionless air mass trapped by the deck or roof structure above the section of wall which blocks the path to the glass and by the fact that the down draft for the windows is very amply supplied from cooler central greenhouse air. This aspect of alternate supply is among the



(fig. 11)

most crucial factors in attempting to design for air currents. The opportunity is for choosing the coolest of warm air to send to the coldest surface. This allows the cold surface (the glazing) to get colder both by slowing the rate of convection motion and lowering the supply temperature.

After the sheet of warm air from the walls has entered a room by the top of a doorway it is drawn off to replace cooler air anywhere in the room. The cooler air forms a pool, usually one to three feet deep, inside the room which drains through the doorway into the center of the greenhouse. This cooler air is still warmer than the glazing and often serves as the supply for the cold window draft. The cold draft from the windows either turbulently mixes with warmer greenhouse air or falls to the floor of the greenhouse supplying the up-drafts of sunlit objects or the slip rising on the lower walls. The energetic slip stream on the walls not only serves to transfer heat preferentially to the rooms but also serves to more rapidly cool the mass wall so that less heat is re-radiated to the glass and less convection travels from the wall to the glass when the doors are closed in the evening. The total net effect of this figure eight cycle is that the rooms are heated more quickly, the glass heated more slowly and the rapid actions are concentrated near the edges of things giving the house a feeling of gentleness despite the massive energy flows which are taking place.

GENTLENESS There are a wide variety of reasons why an impression of gentleness seems to be a measure of quality in passive solar design. It usually means that there are sequences of direct exchanges which keep the faster currents near surfaces and often that there are few direct exchanges between very warm and very cool surfaces. It means that convective skin cooling is minimized and makes the positive health and odor effects of lower air temperatures more comfortable. At night it often means that heat is being transferred largely by radiant means rather than by normally dominant convective flow. In contrast to the dead quiet sensory deprivation of some homes designed on the basis of efficiency alone I find gentleness in a passive solar home to be an aspect of sure-footed responsiveness to nature and a measure of its sensual life giving environment.

CONCLUSION The patterns I've been able to observe reinforce, for me, the notion that there is a better way to approach the understanding of climate dynamics than the basket of numbers approach. This is especially true for the vast majority of designers, builders, and building occupants who really need to understand their own impact on their environment without spending endless hours laboriously stirring a caldron of fantastic formulas delicately spiced with finagle factors. That I seem to have used my method to make a selective surface, modified flat plate collector with normal winter efficiencies around 70% without the aid of a single calculation suggests to me that others might do so as well.

In the course of my studies I've found several areas of basic physics which appear to have gone unstudied. Among these is study of what happens when an object at one uniform temperature and thermal mass is placed in a room at another temperature and thermal mass. I can't find anywhere the formula which correlates natural convective heat transfer with heat capacity. All I can find are formulas relating convection to constant surface temperatures. This implies infinite thermal mass, a condition which never exists. This is but one example of studies which seem highly appropriate to understanding climate dynamics behavior in buildings, but seem to have gone unstudied because of science's dependence on holding things constant. Somehow nature makes very orderly things without holding anything arbitrarily constant. I think that in order to understand building climates we need to make the attempt to do the same.

APPENDIX: RESULTS OF A TEST CELL FOR DISCRETE CURRENTS

The creation and control of slip streams for solar collectors involves key elements in the relation between geometry and air current orders. The discrete current collector works by inviting the hot air currents to propagate themselves directly to the storage without mixing with the collector air mass on the way. Figures 12, 13 and 14 show recorded performance of a test cell. The efficiencies listed here are calculated including a few