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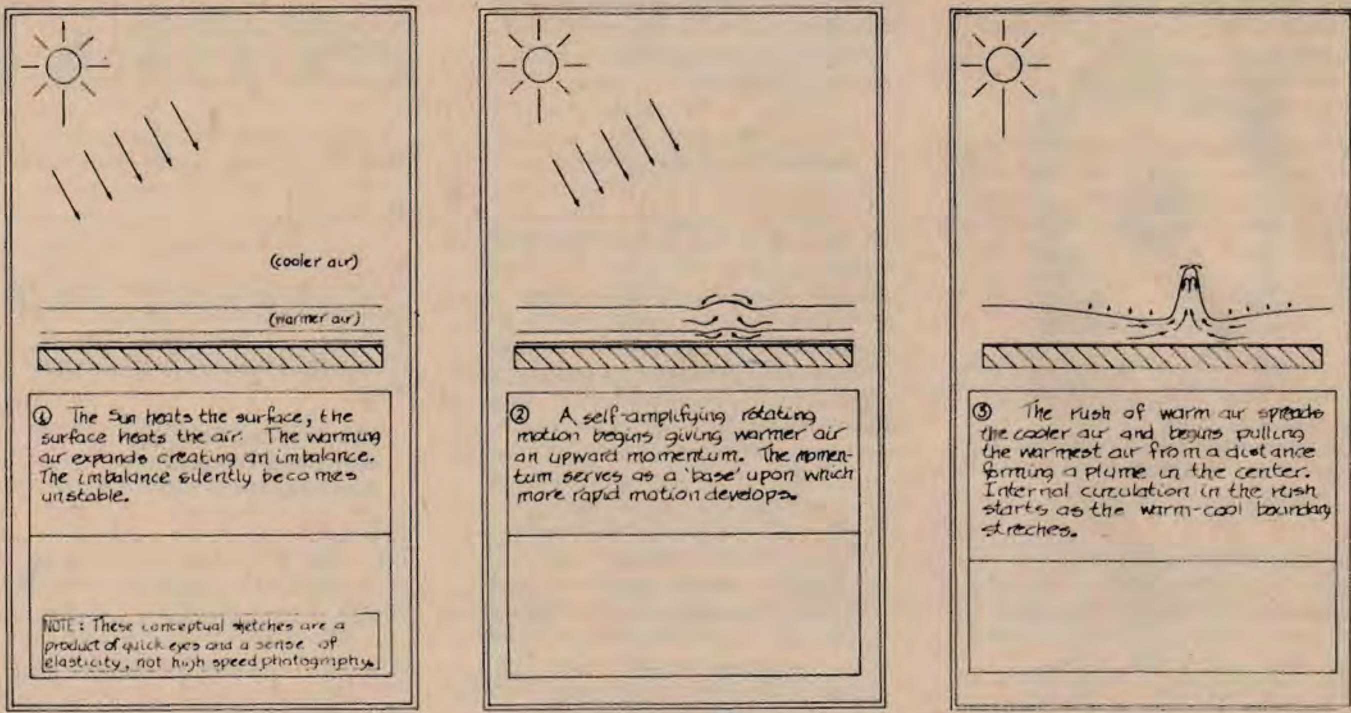


The Air Currents of Two Classic Passive Solar Homes

Natural climatic behavior, while increasingly recognized as both highly ordered processes and a powerful tool for building climate conditioning, is so complex, silent, invisible and foreign to our traditional awareness that quality understanding might seem beyond reach. In my view, high quality understanding of the intricate cyclic interactions of conduction, radiation, convection and material properties, in response to the daily sun cycle, is available through direct observation of these natural cycles. 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.

Two solar homes I've observed, Karen Terry's house and First Village Unit No. 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. They also can serve as a measurable expression of the thermal harmonies between the building and the environment. The drawings which follow 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 No. 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.

A Discrete Air Current

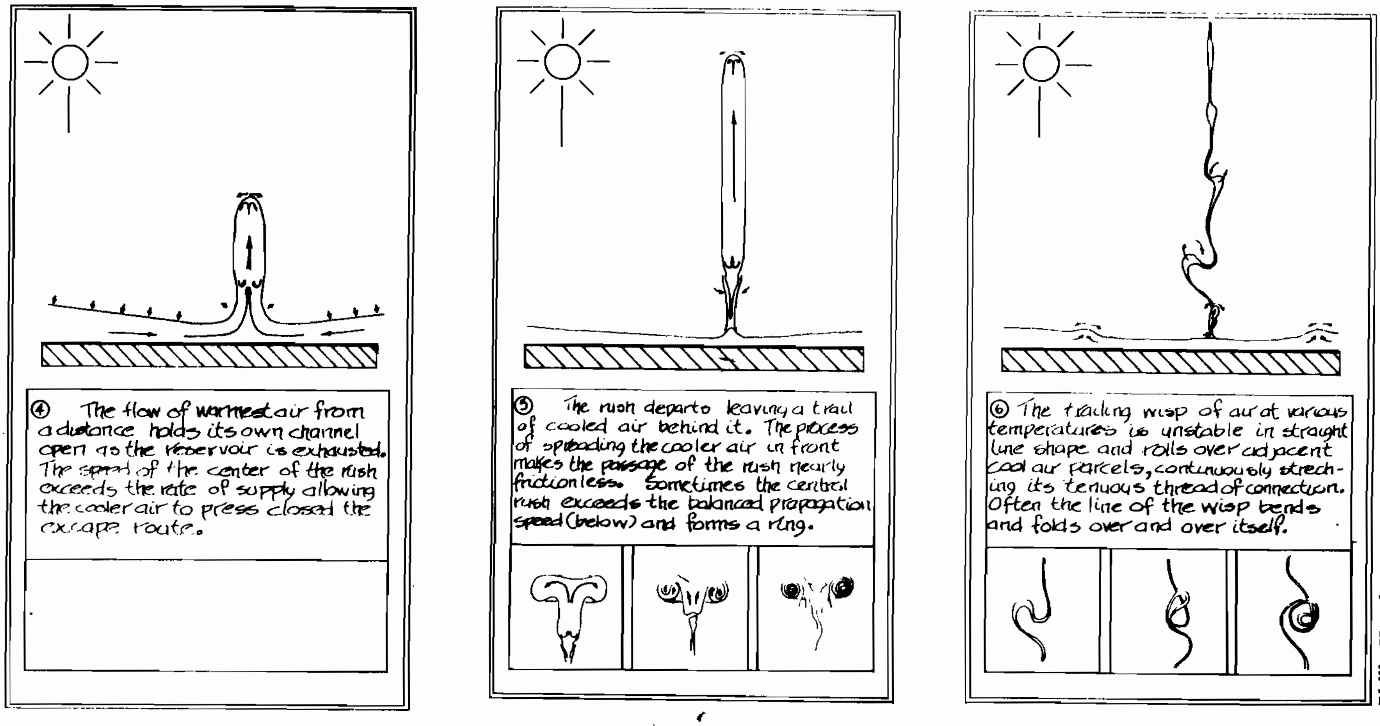
One critical aspect seems to be how currents invent themselves without any obvious suggestion, i.e. turn themselves on at a time when they don't exist. This concept has a variety of very interesting spin-offs. The following sketches show major stages in the self-invention of an air current (1 through 6). 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 contasted with 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. Such observation is necessary for those who wish to attempt design with air currents.

Karen Terry's House

(Santa Fe, NM, 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 bankos 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.



Philip Henshaw

Things always seem to move forward in bumps and lurches. A new insight, then lots of fiddling, refining, fussing and side-sliding until someone gets another good idea. Here's a big jump for passive solar design—a beginning of understanding the principles of natural air movement in buildings in ways that it can be designed to do magic—pumping cold air uphill or shuffling precious warm air off to a secure hiding place until it is needed. Figured out by a handful of incense sticks and a heart full of curiosity—no ERDA grant involved. When you add up how little is gotten from pouring all our energy research money into corporate and academic ratholes to rediscover the solar wheel, it seems we might be much wiser to give rewards to the people who have achieved *the most rather than grants to those who propose the most. Phil Henshaw's my nominee for this year's reward. —TB*

SNEAKY INVISIBLE THINGS

Philip E. Henshaw

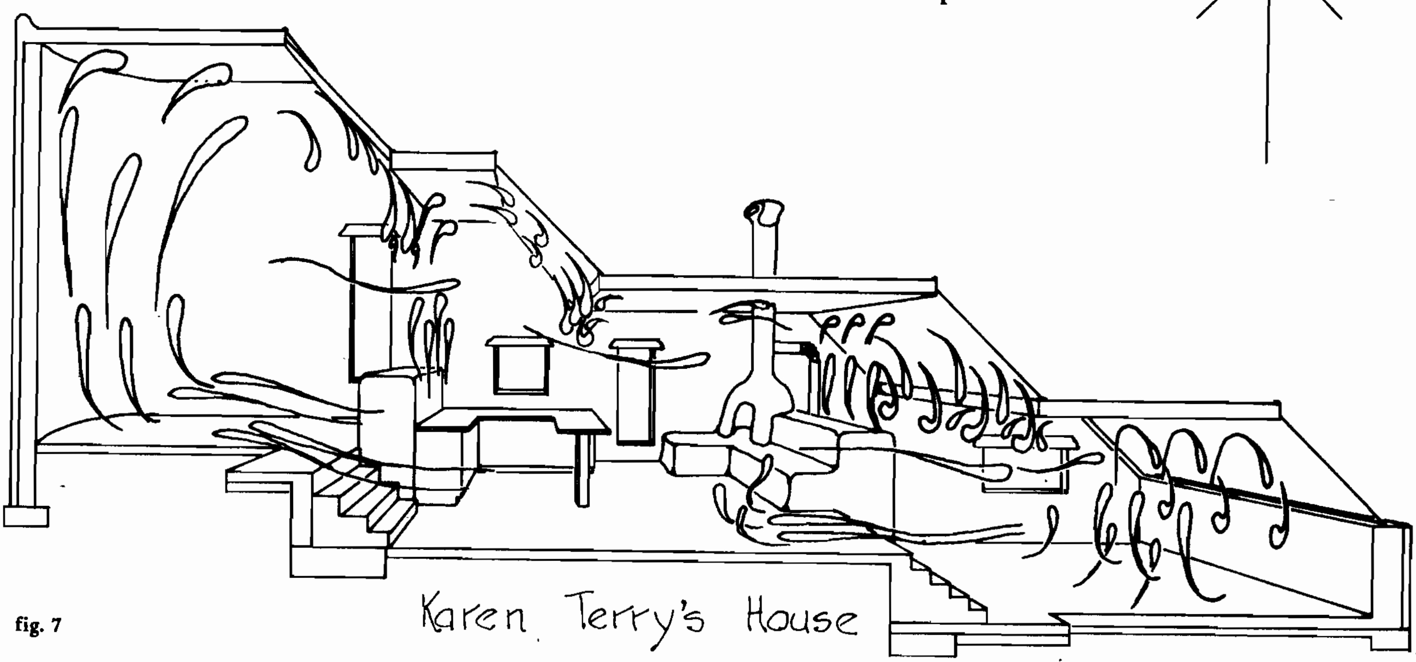


fig. 7

Philip Henshaw

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 next lower window section, which draws from the blocked warm air flow both to supply the down-draft and by pulling along some of 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 nighttime 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.

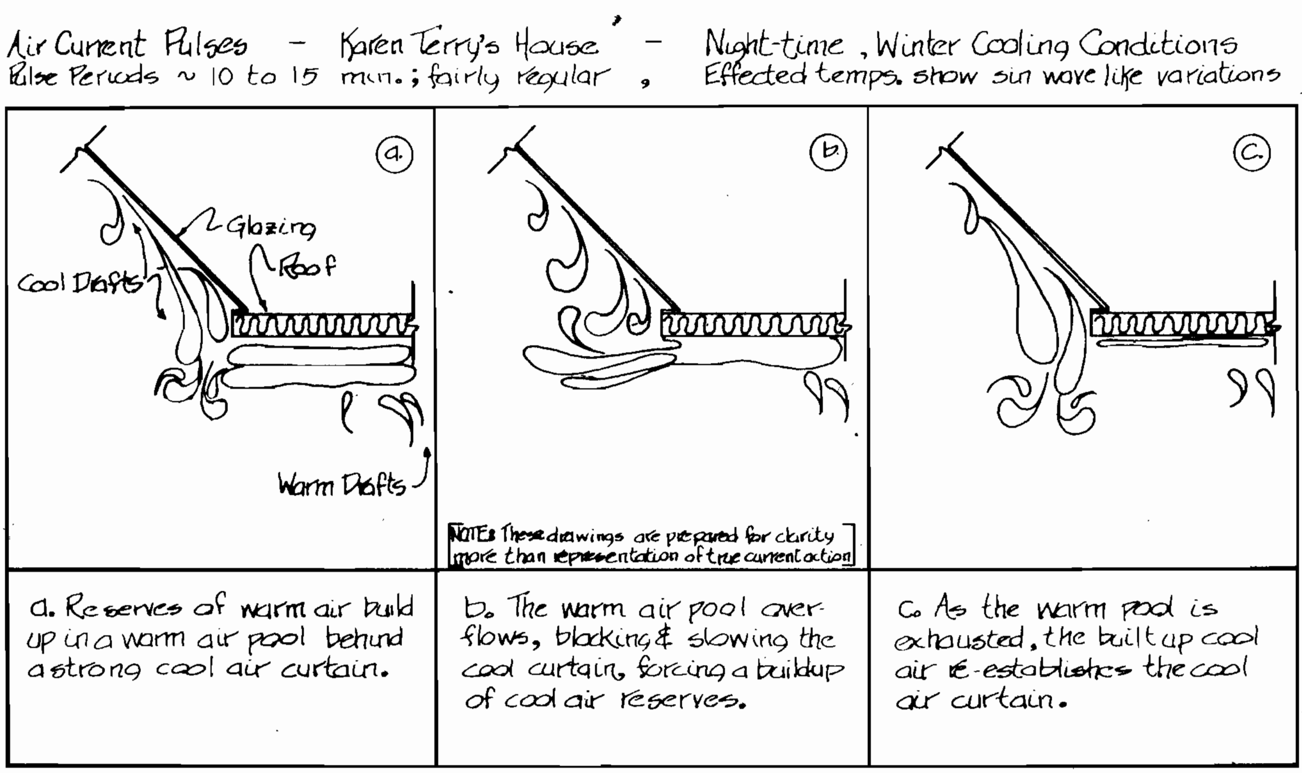
All sorts of air current patterns involve oscillating interactions composed of many transient flows. In general terms I find it intriguing to look for the rotating circle implied by any steady self-regulating cyclic action and for the energy which steadily supports its turning. In this case the circle 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 the sine wave (rising, falling, rising, falling, etc.). 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.)

First Village Unit No. 1

(Santa Fe, NM, designed by Bill Lumpkins, fig. 12)

Unit No. 1 is a greenhouse—mass wall and fan-supplied rock storage type solar house. The two-story, south facing 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 (7-1/2") 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 not its essentially 100 percent passive heating and cooling behavior, but 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 nighttime temperatures seems to be the essential bonus factors which make this house so climatically successful; only two rooms received backup heating last winter.



Philip Henshaw

fig. 8, 9, 10

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 top 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 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 updrafts of sunlit objects or the slip streams 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's something which is found in the experience of good passive solar homes and nowhere else. 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, gentleness in a passive solar home seems 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 prevalent basket of numbers approach. This especially 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 cauldron of fantastic formulas delicately spiced with finagle factors. That method may, with sufficient expertise, tell what you've done, but it doesn't tell you what to do. All you need is to become a good listener.

From my listening I've learned that passive solar design is still very far from being sophisticated. Not only do most designs fail to work as well as expected, but the ones that work better than expected remain a mystery. When you look into it, you find that many of the formulas we use are genuinely foolish. One case in point is the controversy around Lee Butler's EKOSE'A houses. I can't tell you how many people have "proved" that people in his houses aren't comfortable when they say they are. I haven't had a chance to personally observe the dynamics of one of his houses, however when someone tells me they're sweating and my equation tells me they are in the later stages of frostbite, there's little question of which to believe.

There's a lot of learning to do. That the very small handful of people who have developed real skill in creating naturally luxurious building climates also are the same very small handful of people who have been devoted observers of nature is no coincidence.

Philip Henshaw can be contacted at Box 18123, Denver, CO 80218.

A slightly different version of "Sneaky Invisible Things" is being published in the Proceedings of the 1979 AS of ISES National Passive Solar Convention. For details, contact AS of ISES, c/o American Technical University, P.O. Box 1416, Killeen, TX 76541.

Next month Phil will outline principles and techniques for observing and designing with air currents in your own home.

fig. 12