NATURAL ORDERS IN CONVECTION
AND
DIRECT OBSERVATION SKILLS FOR NATURAL CLIMATE DESIGN

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ABSTRACT

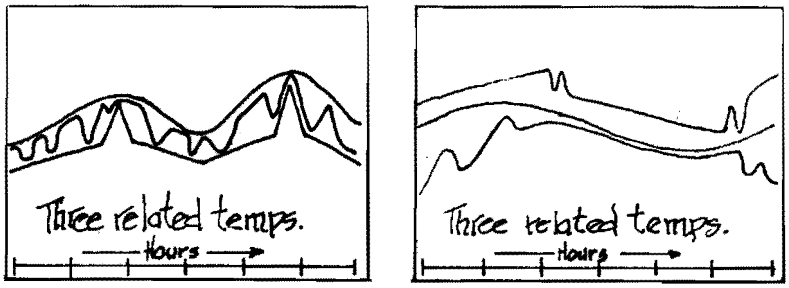
Natural climatic behavior, while increasingly recognized as both highly ordered process and a powerful tool for building climate conditioning, is so complex, silent, invisible and foreign to our traditional awareness that quality understanding might seem beyond reach. In my view, high quality understanding of the intricate cyclic interactions of conduction, radiation, convection and material properties, in response to the daily sun cycle, is availible through direct observation of these natural cycles. Convection is a rich cyclic behavior and a delicate measure of house climate. While not simple, convection is very orderly and readily observable using simple tools.

INTRODUCTION

For about four years I have been doing occasional explorations into the energy dynamics of local climate. In the past year and a half I have studied, in depth, the dynamics of a dozen solar and non-solar homes. In building climate studies, none of the hundreds of environmental conditions are ever constant, and there arises a problem of having to look in all 'directions' at once. This problem of 'looking behind' and looking 'in front' at the same time can, with thorough study, dissolve into the discovery of nature's perpetual habit of reacting to everything at once in the simplest and most direct way possible. Passive solar home climates offer a special opportunity for this kind of study for they are largely closed systems with exceptionally strong, systematic, rapid and, as far as nature goes, simple climatic action.

My pursuit of house climate understanding has involved some largely unorthodox procedure. The heart of my study technique involves the intensive personal observation of single thirty-four hour periods. My equipment includes a 24 channel chart recorder, lots of thermocouples, half a dozen 'hot wire' anemometers, a couple of pyronometers, and then very importantly, incense sticks and a refined attention to skin sensation. Smoke trails have become my best scientific tool.

In studying and interpreting data collected in this way, I have attended more to the formulation of questions rather than answers, more to trends and directions than to amounts. My use of the graphic data has been to study the appearance of familiar curve shapes such as parallel curves, step curves, elastic oscillations, convergence, coupling, bounded instability, anomalies, and very importantly, the first, second and third derivative rates. My use of the personal observations of incense smoke and skin sensation has been primarily to study the organizational qualities of the whole behavior, with special attention to the organization of convection currents.



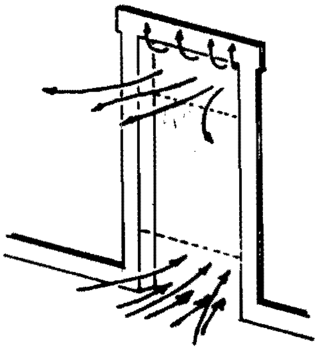
(fig 1)

Though these studies have resulted in diverse, complex and incomplete understanding, I feel that the following tentative conceptual guidelines to understanding convection not only constitute a significant step in theory but, more importantly, are a good and broad foundation for observing house climate.

1. THE IMPORTANCE OF AIR FLOW

Convection is a large heat mover and a very delicate indicator of the balance of remote surface temperatures, building geometries, material properties and outside influences. The complex path of a unit of energy into and then out of a home, usually includes travel by means of air circulation. The thermal action, of solar homes especially, involves repeated internal energy flows between different parts. These radiant, conductive and convective flows are only readily observable by studying convection.

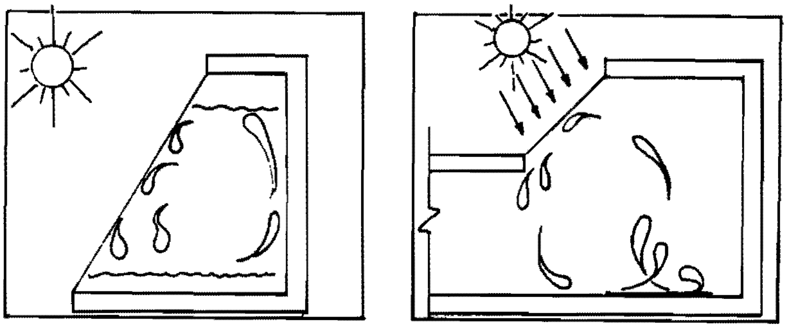
The scales of convection links in the energy flow path can be seen in the following normal case calculation: Through an open doorway to a room, in any house in winter, there might well be found a two foot deep cool air stream at the bottom, and its counterpart warm air stream at the top. A normal temperature difference of 3 F and a normal flow rate of 2 ft. per sec. yields a one way mass flow rate of 3000 lb. of air per hour, and a heat flow rate of 2200 BTU per hour. That is 400 BTU per sq. ft. hour.



(fig 2)

If one observed that this flow was the average of the day, one might conclude that the 15¢ a day in energy flow might be saved by closing the door. However, because in each situation, with the door open and with it closed, different energy flow dynamics are established, it is not likely that you would save the total, or even necessarily half of the open door flow. If you did not thoroughly determine the total daily flow, it is not possible to predict whether there would actually be a net savings or a net loss from closing the door! It is also possible that closing the door would result in a net gain larger than the open door total loss!

In the case of convection on a direct gain mass wall, a significant fraction, say a third, of the incident light energy is immediately carried off by convection. At night a similar fraction of the 'stored' energy is carried off the same surface by convection. It is important to truly understand where this energy goes. Quite often both these day and night currents directly supply the cold window down drafts, thus exaggerating the heat loss. This is not necessary.



(fig 3)

2. PRINCIPLES OF ORDER

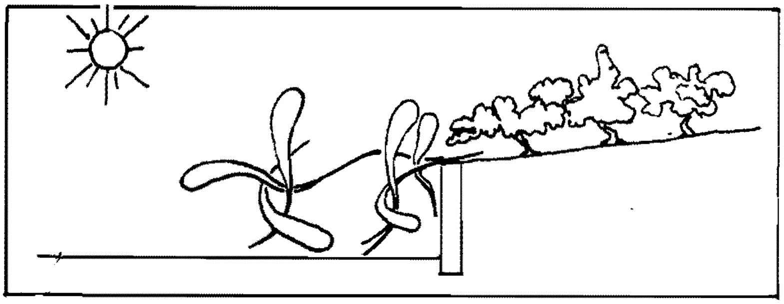
With convection being such a large volume business, one would perhaps expect, but does not usually find, a large amount of turbulence. Convection is a startlingly orderly process. The natural response cycles generate discrete air currents which deftly avoid disturbing each other's paths. When one does block another's path, the other usually waits until the one is finished. The following are eight principles of order which seem to be in operation for thermal air currents.

1. Because thermal air currents are the interaction of fluids of different temperature and density, they don't mix well.

2. Thermal air currents often slide along effortlessly, within very sharply defined mid air boundaries. I am a bit suspicious

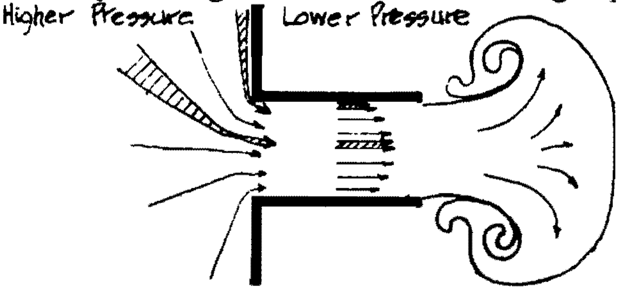
of how a low friction boundary surface can exist in mid air, but I've observed them time and again.

3. There is usually a large still air space between air currents.



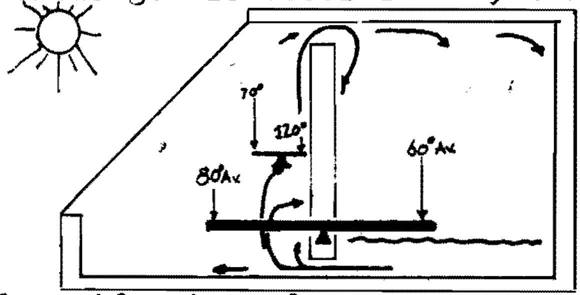
(fig 4)

4. The type of boundary and current form depends heavily upon whether it is a 'pushing' current or being 'pulled' from a distance.



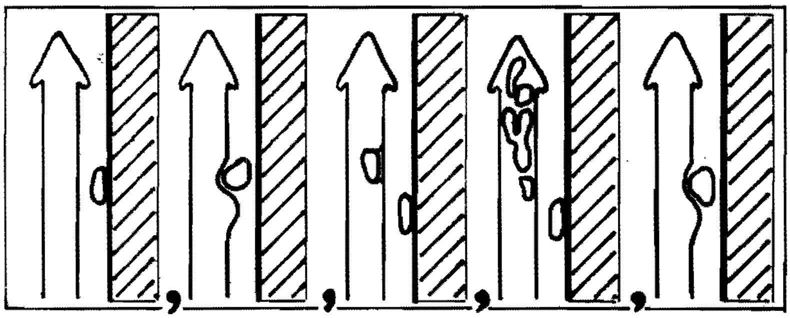
(fig 5)

5. All air currents are both locally and distantly determined. For example, the average temperature difference between two rooms may determine the amount of air flow, but which of the available currents will be exchanged is determined by other interactions.



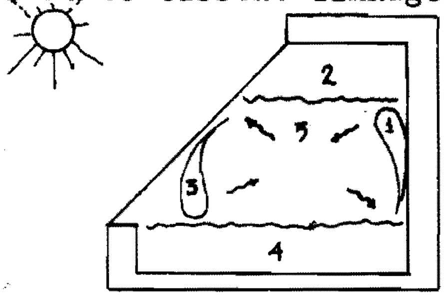
(fig 6)

6. The observable uniformity of many currents, both large and small, is of a uniform velocity and direction rather than temperature. Currents act like tracks for parcels of air of different temp.-density. Parcels of cooler air, moving in a current across a warm wall, for example, exchange momentum with still parcels of warmer air adjacent to the wall. This exchange takes place in a very wide range of times from very quick to a second. This still air layer I call a voluntary air layer. The small parcels of warm air introduced to the stream path mix with each other as the cooler parcels are deposited into the voluntary layer for warming. This completes a direct current to current grafting in a continuous stream. The voluntary layer ranges in thickness from very thin to feet thick and from single layered to many or continuously layered.



(fig 7)

7. Every major air current is a member of a five part life cycle: the rising current, the top reservoir, the falling current, the bottom reservoir and the quiet air within which the others adjust themselves. One of the tools of climate design might be to arrange materials in such a way as to eliminate certain reservoirs by creating direct current-to-current linkages as described in #6.



(fig 8)

8. The properties of solid materials which effect convection are clearly unclear. The interaction of geometry and air current momentum, the enhancing and inhibiting effects of surface texture, the effect of relative temperatures in a convection environment and even the correlation with material properties of heat capacity and conductivity are all undescribed. There is limited evidence that a material's heat capacity is a more significant factor in stimulating air movement and heat transfer, than its heat conductivity.

3. CONVECTION OBSERVATION TECHNIQUE

The use of incense smoke to visualize climate dynamics is a very powerful tool if benefited by a little expertise and an informed intuition. I can't convey any amount of informed intuition, that is always something you make for yourself. The following suggestions might help a bit with the expertise.

1. Carefully watch the difference between smoke rising from its own heat and smoke which has cooled and is passively following an air current. Learn how to shake off a bit of smoke to leave it hanging. Smoke often lies between currents, not necessarily in them. Smoke has a sketchy visual appearance whereas the currents are always volumes. Look for what the smoke can tell you about what you can't see.

2. Wait five seconds after your own movements and a minute after changing openings so that the natural motions may establish themselves. Stand at the side of where you expect to find a current. Notice that floor currents will often part and rejoin in passing around your legs without apparent disturbance. Note the air between currents which doesn't move.

3. Scan across openings. Draw a horizontal line of smoke across an open doorway and watch how the line bends. Scan vertically across an open doorway by starting at the bottom and raising the smoke source at the same rate which the smoke is rising from its own heat.

4. Look especially for currents near floors, walls and ceilings. Note the difference between deep slow currents and thin fast ones. Note where the layers of air in a stratified room come from.

5. Scan across a current in several places from its origin to its destination. Notice if the edge is sharply defined or not.

6. Expect current patterns to change on second, minute, hour, day and season time scales.

7. Check out a room with a fireplace and check out a stairwell.

8. Measure the temperature, speed and area of opposing sides of currents (top & bottom of doors). Heat content of air is in the neighbothood of .02 BTU per ft.^{3}•°F.

9. Look for gurgling type action of air as it 'bubbles' through warmer or cooler bodies which results from crossed flows or inversions. All pockets tend to be visited by intermittent puffs or currents. Note what geometries constitute a pocket.

10. Try to find the diffenence between 'push' and 'pull' currents, how a push current tends to billow out at a point and how a pull current can leave 'cracks' in the main air mass for very discrete air currents to slip into.

Then there are some suggestions for your mental process for making the observations really meaningful.

1. Develop your understanding of the basics of physics: density, momentum, balance bounce,etc.

2. Try to develop an awareness and a habit of viewing whole cycles: ones of the moment, the day, the year, seed-organism-seed, idea-thought-idea,etc.

3. Look for what never changes as a basis for understanding and responding to what does.

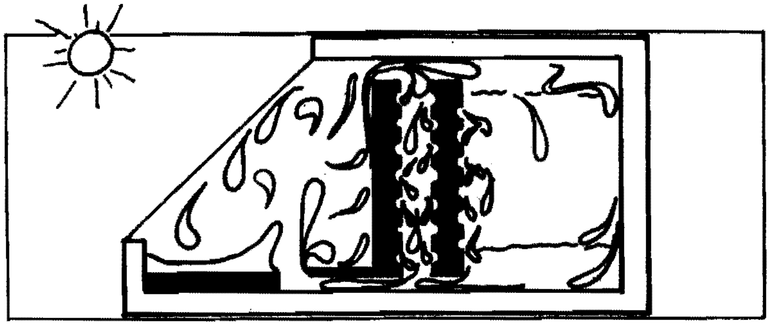
4. Ask questions, develop and then refine uncertainty, draw few if any conclusions. Value uncertainty

5. Don't expect any of the above fourteen comments to be very meaningful until after you're a good observer.

4. DESIGN WITH AIR CURRENTS

The above discussion has stemmed from my delight with the intricate order and beauty of things. This is not sufficient to make things work, though it may be one of the essential factors in letting things work. One of the basic problems in design is that it is hard enough to relate pencil lines to building materials which are visible and expected to stay put. Relating pencil lines to invisible things which change continuously is another matter entirely. While difficult to recognize, I think there is an inherent difference between arbitrary wiggling and genuinely thoughtful guesses. One of the differences is that natural air flow tends to be a sequence of straight lines and non-circular curves. All curves should contain a sense of elasticity. Drawings of air currents will often have crossing paths and use the same path for intermittent currents in different directions. In the last analysis, however, a well informed imagination is the only good key.

The following is a conceptual sketch of imaginery **morning** air currents in an interesting imaginery material configuration. The concept incorporates two general principles, which, while unconfirmed, I think deserve serious inquiry, partly because they contradict aspects of present practice. The first is to supply the cold window drafts with the coolest air available. The second is to place a room between convective gain mass and exterior walls, i.e.,not to put mass in place of low mass insulation. One of several types of further sophistication of this climate structure concept would be to use a selective surface covering for the direct gain wall. If the back of the covering is emissive, both conductive and convective gain should be enhanced at the expense of heating the glazing by radiation.



(fig 9)

5. PRESENT RESEARCH

There is a very long list of studies and learning tools which ought to be pursued. The capital intensiveness of high technology research and development seems to be seriously inhibiting our ability to learn of and adopt the power of natural process.

CONCLUSION

Though the above is certainly not the stuff of a conclusive study, I would like to go out on a limb and suggest that the luxurious house climates of 100% passive solar architecture need not be difficult in most climate zones. In order to approach this ideal there needs to develop some clear way of working with complex dynamic interactions which are not as yet well understood. I do not think this will be easy, especially in view of our overall cultural dependence upon pat answers for all issues. In addition, we may have to wait quite a while for some group of experts to analyticly understand the dynamics of building climates. Rules of thumb, reams of personal testaments and self declared expertise may have to suffice for a bit longer.

One of the steps I feel is necessary to widespread ease of dealing with dynamics is the development of widespread demonstration capability, so that the public, builders and architects can develop their own personal understanding of the many times of day and the responses of climate designs to them. One of the major barriers to such a program is the funding dilemma of having to quantify the value of observing the puzzles of the unknown. The apparently generally held impression that there isn't much out there to observe seems to be the most significant barrier. Assuming that these and other problems could be overcome, I think that the federally funded community center program could be used to very great advantage in providing accessible places where both expert and novice could share observations of natural process.