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VENTILATION

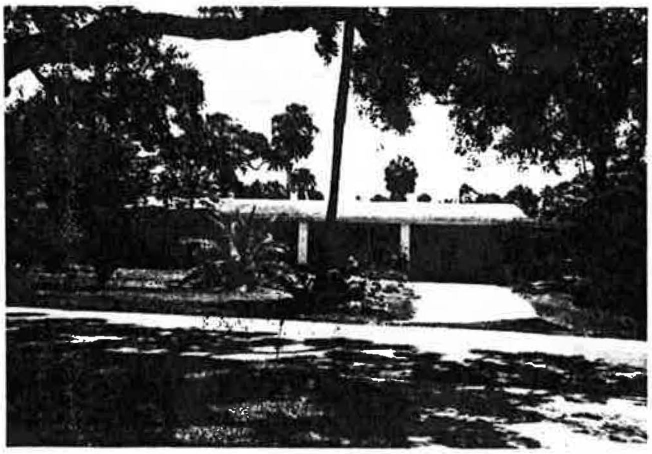
Florida Cooling, the Natural Way

by Danny Parker

During a hot and sticky Florida summer, a whole-house fan can augment nature's own cooling effects and bring down air conditioning loads.

Is it possible to comfortably survive Florida's sweltering summers without air conditioning? The dry bulb temperature on hot August days hovers in the 90s, with the wet bulb temperature not far behind. As the saying goes, "Everybody complains about the weather, but no one does anything about it." Well, something *was* done when air conditioner technology made mechanical cooling affordable to most. With the availability of cooling appliances, the percentage of air conditioned homes has soared from a mere 18% in 1960 to 94% in 1990.

Today 98% of new Florida homeowners report some use of air conditioners between May and September of each year. The other 2% are hardy, foolish, or both. For better or worse, the author is among this group. At our house, we prefer open windows with lots of ventilation. We enjoy the fresh air, and an open house reduces the sharp contrast between the inside and outdoors that air conditioning brings. The way we see it, the outdoor world is one of the finer things that Florida has to offer. Why be cut off from it?



Danny Parker

Enhanced natural cooling methods make the author's Florida home liveable in hot summer weather.

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Monitoring a Florida House

The instrumentation we installed was capable of making 18 measurements. Site weather data included temperature, relative humidity, wind speed, and insolation. Temperature, humidity, and power consumption measurements were taken on the interior of the building. We measured the following:

Temperature

1. Outside air temperature
2. Interior living room (main zone) air temperature
3. Kitchen air temperature
4. Supply-register temperature
5. Slab-floor temperature
6. Attic-air temperature
7. Garage temperature
8. Refrigerator-fresh-food compartment temperature
9. Freezer-compartment temperature
10. Ground temperature (1 ft depth)
11. Pool temperature (2.5 ft depth)

Single-ended voltage measurements

1. Pyranometer (rooftop)
2. Ambient relative humidity
3. Interior relative humidity

Pulse Counts Measurements

1. Wind speed (10 ft height)
2. Air conditioning/heat pump/strip heat watt hours
3. Refrigerator watt hours
4. Refrigerator door opening

We used type-T copper-constant thermocouples to record temperatures. The exterior temperature measurement thermocouple was shielded from radiation. Humidity was measured by using bulk-polymer resistive type hygrometers, insolation by using a silicon-cell pyranometer with a current output, wind speed by a cupped anemometer which provided pulses to the data logger, and electrical consumption by using two 30-amp pulse-initiating power meters.

A Campbell C21X data logger provided the data collection for the research effort. All the installed instruments were scanned every five seconds with integrated averages and totals transmitted to final storage every fifteen minutes. The data were removed periodically using an on-site personal computer with a direct link to the data logger. The data were then read into a statistical package for plotting and analysis.

Moreover, the longer the natural ventilation season can be extended, the lower the overall air conditioning electrical consumption will be. Previously we studied 384 single-family homes in Central Florida and found each month from May through September that each household claiming to use natural ventilation rather than air conditioning averaged savings of 777 kilowatt hours (kWh).[1] This suggests that a considerable amount electricity can be saved if the natural ventilation season can be extended and we air condition only during the hottest periods. The fact that society survived without air conditioning before 1950 indicates that alternatives must exist. The trick is to arrive at some acceptable level of comfort and convenience.

Monitoring, like Charity, Begins at Home

Over the last year I studied my own home to learn about important influences on residential cooling energy use. Monitoring began in June 1990 and has continued up to the present. With the help of colleagues Subrato Chandra, Philip Fairey, and Ted Stedman from Florida Solar Energy Center and funding from the Department of Energy, we examined a variety of energy-saving schemes in a hot climate including repair of air conditioning air distribution systems, replacement of an inefficient refrigerator with an efficient model, swimming pool thermal performance, and understanding how house characteristics influence natural cooling potential.[2] This article will solely concentrate on the last consideration. The home was monitored for the entire month of June 1990 to examine influences on natural cooling, and then air conditioned in the months of July and August to examine influences on this large electrical end-use.

The building that we examined is typical for Florida: a single-family detached structure with a total floor area of approximately 1,800 ft². The traditional attached Florida room (a 300 ft² area surrounded by jalousie windows) and garage (200 ft²) are not conditioned. The conditioned floor area is approximately 1,300 ft². The house faces north-south and is located two blocks from the Atlantic Ocean in Cocoa Beach, Fla. (See Figure 1.) Each room in the house has a ceiling fan to improve interior comfort on warm days.

The floor consists of slab-on-grade construction without carpeting (terrazzo). Built in 1958, the walls are typical concrete block construction with no insulation. However, approximately ten inches of fiber-glass insulation has been blown into the attic. The attic space is ventilated by soffit vents and two roof-top rotary wind ventilators. The attic space is open to the garage space, which does not have a ceiling and is open directly to the roof decking. The house is partially shaded by a tree on the east face; an outdoor swimming pool is situated on the south side of the building.

Will Winds Cooperate?

Most of the strategies for natural ventilation of homes to reduce air conditioning energy use revolve around maximizing open window area and orienting the building to take advantage of the prevailing breeze, providing cross ventilation.[3] Wingwalls—which protrude from a house next to the windows to divert wind into the house—and other, more elaborate architectural features can enhance ventilation.[4,5] However, in all cases the primary intent is to reduce interior building temperatures by promoting air flow through the building when the ambient air is cooler than that on the interior. Nighttime ventilation is particularly effective in this regard, especially for arid locations, which are cool at night. But one problem in warm, humid climates likes ours is the lack of a suitably high wind speed.[6]

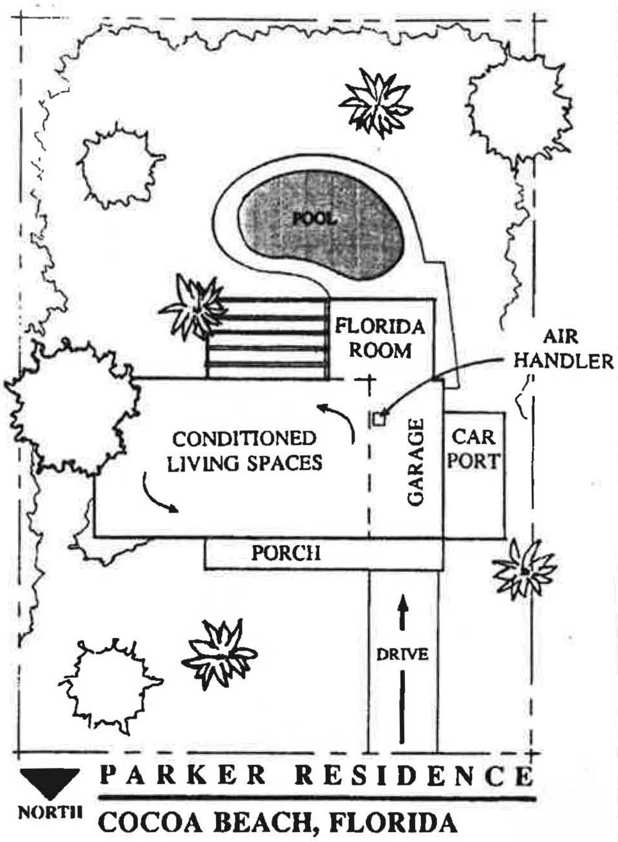

Figure 1. A typical Florida single-family home.

The wind speed data collected at the house site for June of 1990 showed that even with a coastal location, the windspeeds are inadequate to provide interior cross-ventilation. Wind speeds were highest during the afternoon, dropping to the lowest velocities during the evening. The average site-measured windspeed is less than 2 miles per hour for the hours from 7 p.m. to 9 a.m. Unfortunately, if natural ventilation is to succeed, a house needs the most ventilation during the evening hours when the wind speed is lowest.

How Building Mass Affects Ventilation

The construction of the monitored house—concrete block with stucco finish with a slab-on-grade foundation—should moderate the swing in daily internal air temperatures. Computer simulations already suggest that buildings with a higher thermal mass will benefit considerably more from enhanced natural ventilation, that is, utilizing whole-house fans, than will lighter buildings.[7]

Figure 2 shows the average interior, slab, and ambient temperatures for the entire natural ventilation period in

June. The data show that on average the outside—or ambient—air temperature becomes lower than the living room temperature at about 4 p.m. Also, substantial differences

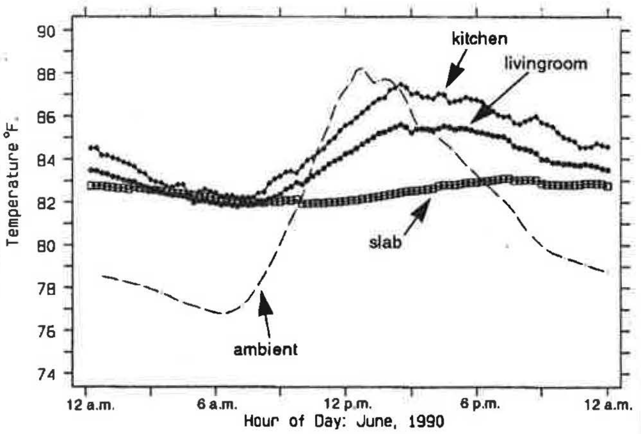

Figure 2.
Avg. Living Room and Kitchen Temps: Natural Ventilation

exist throughout the evening. During this time ambient temperatures are much more comfortable. As shown, the house interior is usually warmer than the outside for most of the evening hours, while the interior is lower than the exterior during the hot mid-day period. The higher interior temperature during the evening hours is caused both by the thermal storage within the building as well as the release of heat from occupants and operating appliances. Unfortunately the period of time when we would most like

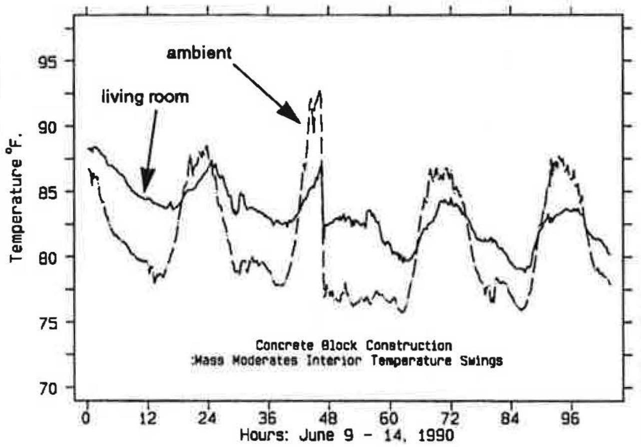

Figure 3.
Ambient and Main Zone Temperatures While Venting

to ventilate the building naturally (when the outside is cooler than the inside), the wind speed is at its lowest. Clearly, some method of inducing building ventilation will be required if the occupants are to remain comfortable.

When the house is naturally ventilated over a four-day period, the moderating influence of the building mass is clear. (See Figure 3.) The ambient temperature both rises higher during the day and at night falls lower than the internal temperature, which varies considerably less. However, the data also show a problem of massive houses cooled through ventilation. Outside nighttime temperatures are always closer to comfort conditions than the interior conditions even with windows open. Two important reasons for this nocturnal difference are: 1) the delayed solar heat flux through the walls of the building, and 2) the very low wind speeds typical on hot summer days. In other words, a homeowner can't rely on the wind to cool the house at night, especially since it radiates stored heat.

What A Whole-House Fan Can Do

All these results indicate that a whole-house fan—which increases air flow to the interior at night—would make occupants of high-mass Florida homes significantly more comfortable during periods while the air conditioner is turned off. Such a strategy would help remove the accumulated heat within the concrete walls while maintaining comfort conditions at an acceptable level. Presumably,

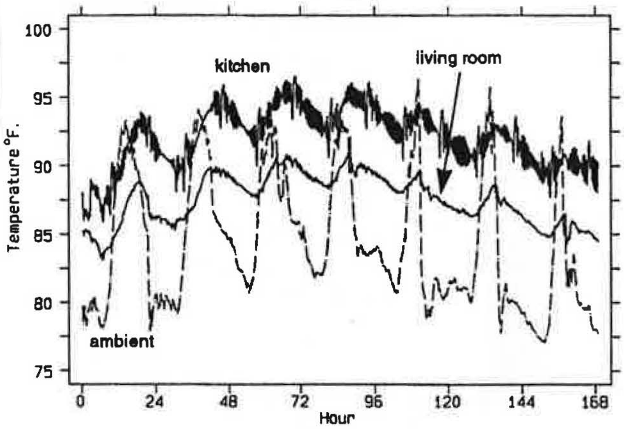

Figure 4a.
July 6–12, 1991: No Whole House Fan

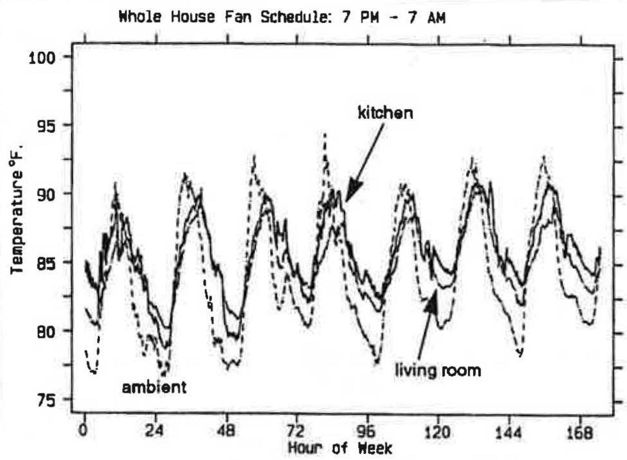

Figure 4b.
August 3–9, 1991: Whole House Fan

How Much Does A Whole-House Fan Save with an Air Conditioner?

Using an air conditioner with a whole-house fan can provide reasonable levels of comfort on the hottest days. The sensible mode of operation is to run the air conditioner during the daytime hours and then the whole-house fan for nighttime cooling when exterior temperatures have become more acceptable. Most studies of the potential energy savings of such a strategy have been based on hourly building energy simulations carried out in differing geographic locations. They predict savings of up to 56% of annual air conditioning electrical use.[1,2] Savings grow potentially larger when the thermostat setting is set on higher temperatures. The absolute savings (kWh) were greatest for the warmest climates (Southeastern and Southwestern United States), but greatest, in terms of minimizing the cooling hours, in northern regions that experience large swings in day and nighttime temperatures.

More significant than these paper studies, however, are two investigations that measured the performance of a whole-house fan in reducing air conditioning energy consumption.[3] In the first, researchers monitored an unoccupied house of brick construction located in Houston, Texas, in the summer of 1977. They measured the energy consumption of the air conditioner under two test conditions. In the first, the whole-house fan was not used and a central air conditioning system was operated whenever the temperature rose above 75°F. In the second condition, the whole-house fan was turned on whenever the outside air temperature was less than 82°F and greater than 75°F. These conditions were usually met only during the summer evening hours.

On days when the daily average temperature was below 75°F, the whole-house fan was able to satisfy all the cooling requirements. Savings in air conditioning consumption from use of the whole-house fan varied between 65% (19 kWh/day) at 76°F to 10% (5 kWh/day) at a daily average temperature of 84°F. (See Figure 7.) (The latter temperature represents the hottest daily average temperature in many locations in the U.S.)

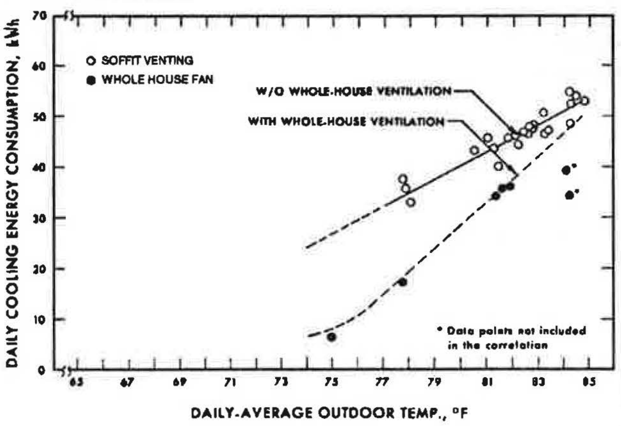

Figure 7.
Daily cooling energy use as a function of daily temperature and whole house fan use.

(Source: I. N. Burch and S. J. Treado, "Ventilating Residences and their Attics for Energy Conservation," NBS Special Publication 548 *Summer Attic and Whole House Ventilation*, NBS, Washington D.C., p. 83.)

In the second study, researchers monitored two side-by-side, unoccupied frame houses in Gainesville, Fla., in the summer of 1982.[4] Both houses were air conditioned although one was equipped with a whole-house fan and a control that automatically disengaged the air conditioners, opened the windows, and powered the fan when the ambient temperature dropped below 82°F. This house with the whole-house fan experienced 22% electricity savings. The automatic control operated the fan most evenings, with this strategy reducing daily air conditioning use by up to 44% on milder summer days.

Beware The Latent Load

A word of caution: Air conditioning reductions in very humid climates may be lower than the numbers described above. The nightly temperatures may only drop below 82°F for a short period of time during summer evening hours and occupants would have to open windows and operate the fans to realize savings. More importantly, nighttime ventilation when the humidity is high may increase the latent cooling load on the air conditioner when the air conditioner is turned on the following morning. This is due to moisture adsorption into building materials during the ventilation period.

A series of summertime experiments were performed on a Central Florida townhouse that was air conditioned during the day and ventilated at night.[5] The researchers in this case found that the condensate removed by the air conditioner increased from 6.8 to 26.2 liters per day when the house was bare and unfurnished to when it had carpeting, drapes, and other moisture-adsorbing materials located on the interior. Air conditioning energy use was increased by 10–20% because of the increased latent load. This does not mean, however, that use of such a strategy would obviate savings from whole-house ventilation. It does suggest that a house with fewer furnishings (specifically carpet) would incur less daytime interior humidity and the consequent latent load on the air conditioner.

Endnotes

1. T. Kusuda and J.W. Bean, *Savings in Electric Cooling Energy by the Use of a Whole-House Fan*, NBS Technical Note 1138, National Bureau of Standards, Washington, DC, May 1981.
2. M. Olszewski and H.A. McLain, *Using Whole-House Fan to Decrease Air Conditioning Energy Use*, ORNL/CON-115, Oak Ridge National Laboratory, Oak Ridge, TN, September 1983.
3. D.M. Burch and S.J. Treado, "Ventilating Residences and their Attics for Energy Conservation," *Summer Attic and Whole-House Ventilation*, NBS Special Publication 548, National Bureau of Standards, Washington, DC, 1979.
4. Ingley, H.A., R.W. Dixon, and D.E. Buffington, *Residential Conservation Demonstration Program*, prepared for the Florida Public Service Commission, University of Florida, Gainesville, FL, 1983.
5. C.J. Cromer and J.B. Cummings, *Thermal Performance Field Monitoring of Various Conservation Construction Techniques*, FSEC-CR-172-87, Florida Solar Energy Center, Cape Canaveral, FL, May 1987.

such forced ventilation would also extend the morning comfort conditions by storing night "coolth" within the massive construction of the house.

We installed such a fan in the central hallway of the home in July of 1991. The fan is a 24" model with a ⅓ horsepower motor, designed to draw 3,100 cubic feet per minute (cfm) against a static pressure drop of 1 inch of water. (We measured the actual efficiency of the fan using an Alnor Balometer.) As installed with the automatic louvers, the whole-house fan produced an average air-flow of 1,150 cfm at the low-speed setting and 2,060 cfm at the high-speed setting. Since the fan motor draws 265 watts at low

Table 1. How Induced Ventilation Affects Living Room and Kitchen Temperatures

7 p.m.–7 a.m., Summer 1991

Temperature	Average	Standard Deviation	Minimum	Maximum
No Whole House Fan: July 6–12, 1991				
Ambient (°F)	80	2.6	76	88
Kitchen (°F)	90	2.4	85	96
Living Room (°F)	86	1.9	82	90
ΔT Kitchen (°F)	10	1.8	4	16
ΔT Living Room (°F)	6	1.4	1	8
With Whole House Fan: August 3–9, 1991				
Ambient (°F)	81	2.4	76	87
Kitchen (°F)	85	2.6	79	91
Living Room (°F)	84	2.2	80	90
ΔT Kitchen (°F)	4	1.3	1	7
ΔT Living Room (°F)	3	0.8	1	6

Table 2. Living Room and Kitchen Temperatures With Air Conditioning versus Natural Cooling

Temperature	Average	Standard Deviation	Minimum	Maximum
Air Conditioning				
Kitchen (°F)	84	1.9	78	94
Living Room (°F)	82	1.8	76	87
Ventilating				
Kitchen (°F)	86	3.2	78	95
Living Room (°F)	86	3.1	78	92

speed and 350 watts at high speed, the results indicate a greater efficiency in air movement at the high-speed setting, which is where we set it.

The breeze caused by the whole-house fan was quite noticeable near windows. Under ambient conditions of almost still air, the air velocities were measured using a Kurz Series 1040 hot-wire anemometer. The air velocities produced in the center of the kitchen without the fan, with the fan at the low-speed, and at high-speed settings averaged 12, 54, and 75 feet per minute (fpm), respectively. The analogous values for the center of the living room were 7, 44, and 55 fpm. Velocities measured by open windows were more than twice any of those values. Past research shows that higher air velocities can have a very beneficial effect on human comfort at high temperature and humidity conditions.[8]

We monitored the home for several weeks to find periods with similar ambient temperature conditions. We selected two very hot weeks in July and August 1991 during which we relied on natural ventilation. During the second week we turned on the whole fan at 7 p.m. when the ambient temperature generally drops lower than that on the building interior. We shut it off at 7 a.m. when the ambient temperature starts to rise above the inside temperature. (See Figure 4.) The windows were opened in the house so that the kitchen was strongly ventilated by fan operation.

The effect of fan use on interior temperature conditions is striking. Before the fan was employed, the kitchen and living room temperatures generally floated well above the ambient air temperature during all but the hottest part of the day. Use of the fan dropped nighttime temperatures such that they were much closer to the more comfortable ambient conditions. (See Table 1.) Our results show an improvement in the evening interior comfort conditions of 3–6 °F with the largest change occurring in the kitchen. Moreover, the data reveal that the total daily average interior temperature dropped by over 2.5 °F due to heat from the thermal mass of the building being removed, providing cooler morning temperatures on the inside.

While some may want their air conditioning at all costs, for those who are looking for alternatives to 24-hour air conditioning, these findings represent a substantial improvement in the comfort conditions over natural, non-induced ventilation. And more importantly, the electricity consumption associated with the twelve hours of fan use at low speed was measured at 3.2 kilowatt-hours (kWh) per day. This is less than one tenth of the daily air conditioning electricity consumption from the previous July, which averaged 36 kWh!

Cool Cooking in the Kitchen

Based on the measurements, the kitchen is far warmer than the living room, whether the occupants are using the air conditioner, or relying on natural ventilation to reduce air conditioning loads. (SeeTable 2.) Figure 5 shows a comparison of the average kitchen and living room temperatures for the early summer when natural ventilation without a fan was used to meet cooling loads.

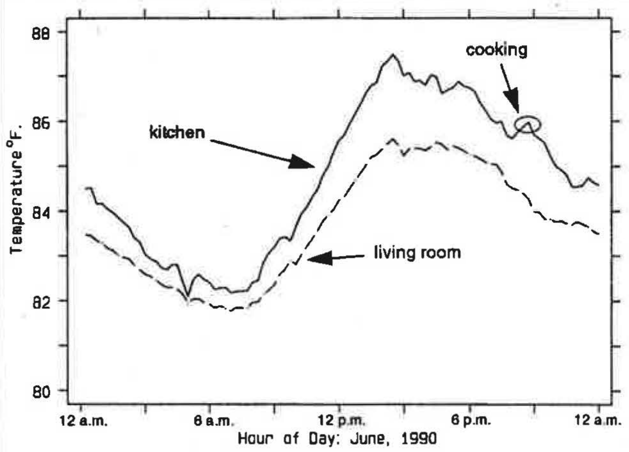

Figure 5.
Avg. Main Zone and Kitchen Temps: Natural Ventilation

The plots show two trends with which almost every Florida cook will agree:

1) Kitchens are warmer than most other rooms.

2) Kitchen temperatures can reach intolerable levels when cooking is taking place.

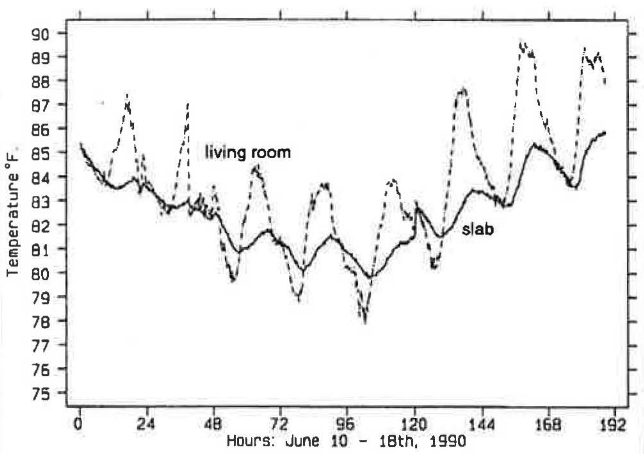

Figure 6.
Slab and Main Zone Temperatures while Venting

The range and oven are big heat-producing culprits. The waste heat given off by the inefficient 19 ft^3 refrigerator located in the space makes a big difference, too. Summer electrical consumption of the unit averaged 287 watts from June to September of 1990, or 6.9 kWh per day! (A much more efficient unit was installed in August 1991. Measurements will continue to determine whether temperature reductions occur in the kitchen.)

Using whole-house fans to exhaust warm air from the kitchen can substantially improve kitchen comfort in the summer, our data show. (Another option would be exhaust vent fans activated by range-top operation.)

Floor Slab Cooling

The monitored house is somewhat unique in that the floor is not carpeted and has a terrazzo surface. Before 1970 this was the dominant type of floor surface in Florida. Although most homes in Florida are now carpeted, research indicates that exposed floor slabs may offer some cooling season benefits for Florida homes.[9]

Figure 2 indicates the moderating influence of the ground as a heat-sink during periods of natural ventilation. The ground temperature at a depth of 2.5 ft varies only slightly through the daily cycle over the entire summer—in contrast to the large amplitude of the swing in daily air temperature. Figure 6 shows the distribution of living room and floor slab temperatures over a hot, week-long period of natural ventilation in June. The daily cycle of heat storage within the floor slab is quite obvious in the plot as the slab slowly warms during the evening hours, absorbing heat from the room interior. This indicates that the slab mass is providing a significant moderating influence on the house internal temperatures when ventilating. The slab temperature was lower than the air temperature throughout the summer, even during periods of air conditioning during the summer of 1990. (None of our readings showed temperature stratification which might have indicated why the slab was cooler than the air.)

The floor slab surface in the living room is cooler under both conditions of natural ventilation and air conditioning. (See Table 3.) Assuming 1,000 ft^2 of exposed terrazzo and assuming ASHRAE's surface heat transfer coefficient (1.63 Btu/hr-ft^2-°F), the slab should cool at a rate of approximately 2,300 Btu/hr when ventilating and half this figure when air conditioning at an average 81°F interior temperature. Floor slabs in Florida do not transfer heat for cooling set points between approximately 77 °F and 80 °F.

Table 3. Main Zone and Floor Slab Temperatures With Air Conditioning versus Natural Ventilation

Temperature	Average	Standard Deviation	Minimum	Maximum
Air Conditioning				
Main Zone (°F)	82	1.8	76	87
Slab (°F)	81	1.2	78	84
Ventilating				
Main Zone (°F)	85	3.1	78	92
Slab (°F)	84	2.3	79	89

Natural Cooling Comfort

Is it possible to survive summer without air conditioning? The answer, of course, depends on the climate and one's tolerance to heat and especially to humidity. In dry moderate climates such a central California, humidity is low and nighttime temperatures drop, making the strategies outlined here adequate to keep most homeowners comfortable through the summer season without air conditioning. In Florida, however, with its very high humidity,

So How Do I Install a Whole-House Fan?

Space does not permit us to describe the necessary details associated with sizing, selection, and installation of whole house fans. Based on the experiences of our intrepid team, we do offer a few unique insights:

- **Look before you cut.** Scout the location of ducts and wiring above the ceiling of the location where you are planning to install the fan. Be also aware of the challenge that various locations may present in terms of fishing a wire down a wall for the associated controls.
- **Protect your lungs.** Plan on wearing a mask with filter if you will be dealing with an attic containing blown-in fiber glass.
- **Protect your sanity.** Avoid the 120 °F attic temperatures we braved in the interest of mid-summer science. Put the fan in during the winter or spring when attic conditions are reasonable.

A number of good publications already exist to guide those in need of more information:

- Donald W. Abrams, "Whole House Fans for Low Cost Cooling," *Solar Age*, April, 1983, p. 14.
- *Consumer Reports*, "Whole House Fans," Vol. 46, No. 6, June, 1981, p. 348.
- Gary Cook, "Whole House Fans: Benefits and Description," Florida Energy Extension Service, EES-32, University of Florida, Gainesville, FL.
- Phil McCafferty, "Even with Air Conditioning You Need a Whole House Fan," *Popular Science*, April, 1987, p. 76.
- Alex Wilson, "Putting In a Whole House Fan," *Homeowner*, June, 1991, p. 60.

most people opt for air conditioning for at least part of the summer. Even here, though, it's possible to greatly reduce the need for mechanical cooling by improving the ability for natural ventilation to meet cooling needs. Based on our monitoring, we can draw some conclusions about the natural cooling potential of homes:

- Building layout and orientation should be planned to promote maximum ventilation from prevailing local breezes. Awning casement windows are best since they allow the full window area to be opened.
- In most locations, the local wind velocities will not be great enough to provide continuous comfort using natural ventilation. Fans will be necessary to augment comfort.
- Massive buildings offer improved interior comfort only if the building can be strongly ventilated by mechanical means at night or if breezes are adequate during the evening hours.
- Nighttime use of whole-house fans offers significant potential for enhancing natural ventilation when evening wind velocities are low. Interior temperature reductions of 3–6 °F are possible, even during the hottest weather.
- Ventilation of homes using whole-house fans is best accomplished by drawing air out of the warm kitchen.
- A non-carpeted tile or terrazzo floor offers cooling effects—and therefore comfort—when ventilating during summer months. ■

Endnotes

1. R.K. Vieria and D.S. Parker, *Energy Use in Attached and Detached Residenial Devlopments*, FSEC-CR-381-91, Florida Solar Energy Center, Cape Canaveral, FL, Jan. 1991, p. B-8.
2. D. Parker, *Monitored Energy Use Characteristics of a Florida Residence*, FSEC-RR-23-91, Florida Solar Energy Center, Cape Canaveral, FL, April 1991.
3. A. Bowen, P. Fairey, and S. Chandra, *Passive Cooling by Natural Ventilation: World Literature Review and Annotated Bibliography*, Florida Solar Energy Center, Cape Canaveral, FL, 1981.
4. S. Chandra, M. Houston. P. Fairey, and A. Kerestecioglu, "Wingwalls to Improve Natural Ventilation: Full Scale Results and Design Strategies," *Proceedings of the 8th National Passive Solar Conference*, American Solar Energy Society, Boulder, CO, 1983.
5. B. Givoni, "Ventilation Problems in Hot Countries," Research Report, Building Research Station, Technion-Israel Institute of Technology, 1968.
6. S.J. Byrne, Y.J. Huang, R.L. Ritschard, and D.M. Foley, *The Impact of Wind-Induced Ventilation on Residential Cooling Load and Human Comfort*, LBL-20919, Lawrence Berkeley Laboratory, Berkeley, CA , 1986.
7. P. Fairey. S. Chandra, and A. Kerestecioglu, "Ventilative Cooling in Southern Residences: A Parametric Analysis," *Proceedings of the 1985 ASHRAE/DOE/BTECC Conference on the Thermal Performance of the Exterior Envelopes of Buildings III*, Clearwater Beach, FL, October 1985.
8. P.O. Fanger, *Thermal Comfort*, Robert E. Krieger Publishing Co., Malabar, FL.
9. P. Fairey, A. Kerestecioglu, R. Vieira, M. Swami, and S. Chandra, *Latent and Sensible Load Distributions in Conventional and Energy-Efficient Residences*, FSEC-CR-153-86, Florida Solar Energy Center, Cape Canaveral, FL, May 1986.