

SIGNING OFF ON THE LOGAN HOUSE

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ABSTRACT

The Logan House in Tampa, Florida serves as a model for designing for passive cooling. Completed in 1981 the “cracker” style house features a raised floor, extensive window openings, and a belvedere with clerestory windows set at the peak of a steeply pitched roof over a central living space. This paper is the third in a series that were published after we began studying patterns of air movement in the building in 1998. We conducted onsite measurements with anemometers and later tested the potential for stack ventilation with different window configurations in the belvedere. Using a fine-bubble technique developed by researchers, we built scale models and videotaped the qualitative effects of micro bubbles moving through the central belvedere. According to the results of this experiment, the designed configuration is, much less successful than the existing condition and the proposed system is the most successful.

1. BACKGROUND

The Logan House in Tampa, Florida serves – literally – as a textbook model of design for passive cooling in a challenging, hot-humid climate. Designed by Dwight Holmes of Rowe Holmes Associates, the cracker style Logan House features a raised floor, extensive and distributed window openings, and a belvedere with clerestory windows set over an open, central living space. Cross ventilation and stack ventilation potential are both explicitly communicated by the design. The design, in fact, is so supportive of an understanding of cross- and stack-ventilation that a section through the building (Figure 1) has been used to illustrate these principles in a widely used book on architectural design strategies. (1)

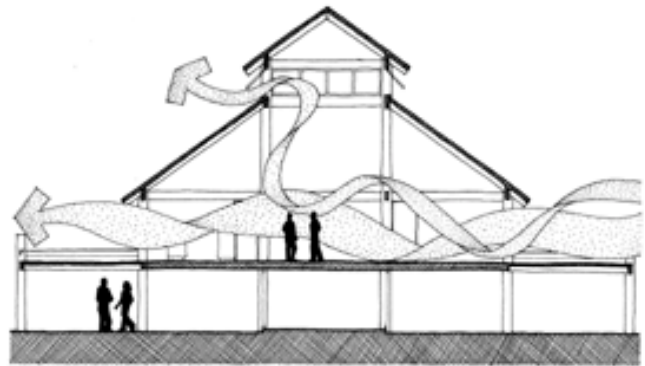


Fig. 1. Using the Logan House to illustrate cross- and stack-ventilation airflow patterns and principles. (1) Reproduced with the permission of John Wiley and Sons.

The Vital Signs curriculum project is a model for the use of existing buildings to inform design practices and design education. (2) Vital Signs provides a structure (protocols, examples, and resources) from which case studies of existing building performance may be developed and disseminated. The Vital Signs approach has been widely used in a number of architectural education programs and has led to a better understanding of a number of interesting and intriguing buildings.

Linking the seeming simplicity of the “magic” (or “smart”) arrows showing air flow in Figure 1 with the investigative methods of Vital Signs was an irresistible challenge. Does the air actually move as illustrated; if it does, does it provide comfort; are the occupants of the Logan House satisfied with its performance? Armed with a wonderful problem, cooperative owners, and a structure for analysis, a series of investigations of the Logan House was begun in 1998. The bottom line for these investigations was an answer to the

questions: “How does the Logan House work from a natural ventilation perspective?” and “How well does the natural ventilation system work relative to thermal comfort?” We found the answers to these fundamental questions to be complex; enough so to require several site visits and warrant multiple papers.

2. PREVIOUS FINDINGS

An initial paper, “The Logan House: Measuring Air Movement,” described how students at Florida A&M University carried out a study of air movement and comfort conditions within the house. (3) The students hypothesized (perhaps based upon a sense of large-scale airflows) that the temperature distribution throughout the house was uniform, both horizontally and vertically. To test this hypothesis, they installed an instrumentation pole, with attached Hobo temperature and humidity loggers, in the house’s central belvedere space to measure thermal conditions at a range of heights.

These measurements (driven by class scheduling) were carried out during cool weather in March 1998 and provided only limited insight into summer performance potentials. On the other hand, the visit stirred ongoing curiosity about the Logan House and its ventilation system that continues today. The visit also clearly illustrated the need to actually visit buildings – several key design changes were made during construction that could have an impact on ventilation performance that are not seen in published accounts of the Logan House. As a direct result of this first visit, a wind tunnel model of the house was constructed and tested to investigate patterns of airflow.

A second paper resulting from this ongoing curiosity, “The Logan House: Stack Effect Effectiveness,” described the collaborative effort of students from three universities who instrumented the Logan House during hot weather (in June 1999) to map thermal conditions throughout the house. (4) A primary question to be answered during that visit was: “Does thermal stratification actually occur, hence reinforcing the stack effect?” Measurements taken in the Logan House during the spring of 1998 suggested that some stratification did occur. Results from the summer 1999 visit, however, showed substantial vertical temperature variation in the area of the belvedere. Although intriguing, these two visits and related analyses generated more questions about the performance of the Logan House than answers. Measuring natural ventilation performance in an occupied building is a complex phenomenon.

3. LOOKING FOR SIGNS

Two primary issues related to natural ventilation performance in the Logan House became clear as a result of earlier investigations. First, airflow from natural ventilation is difficult to measure on site. Such airflow is dynamic over both the short and long term, potentially fleeting in a temporal sense, and quite variable in a spatial sense. The ideal methodology for examining such a phenomenon is long-term (but short-frequency), automated measurements at many locations in and around the house. This methodology is extremely expensive and beyond the combined abilities of the universities involved in the study. The second issue is the apparent importance of many subtle decisions that may affect ventilation performance – and how such decisions (both design and operational) can be captured for study. Included in this category of issues are window swings (in versus out), the pattern and number of windows open at any one time, the use of backup air-conditioning systems, and something as quirky as hurricane preparedness (cupola windows being nailed shut).

Undeterred by the complexities described above, or simply challenged by them, a third visit to the Logan House was made in December 2001. The primary purpose of this visit was to take on-site measurements of air movement, using multiple instruments placed at various locations across the occupied floor space of the house. The December visit date was dictated by travel capabilities of the relatively large number of people required to man the instruments involved. December is not an ideal time to study passive cooling; then again, December in Tampa is not necessarily an underheated time of year. Although the instruments were low cost, the personnel required to operate them was not. This is an inverse cost pattern typically found in Vital Signs (and other) field measurements.

In conjunction with an additional site visit, design analysis methods that might shed light on the subtleties of natural ventilation performance were considered. Wind tunnel measurements were previously undertaken, and although “successful” would require a larger scale model to address unresolved questions regarding window swings and sequencing of openings. In addition, the wind tunnel tests were mainly qualitative – quantitative results would require extensive instrumentation similar to that required for an on-site measurement series. Two alternatives to wind tunnel modeling were considered: mathematical modeling using computational fluid dynamics (CFD) and hydraulic modeling using a fine bubble technique. Numerous inquiries into CFD modeling for this type of problem suggested this was not a viable alternative in terms of software cost and learning curve. The consensus of experts was that the types of questions being asked about the Logan House would

require upper-end software and an experienced modeler. Modeling using a fine-bubble technique was undertaken.

4. CURRENT FINDINGS

4.1 On-Site Air Velocity Measurements

Instantaneous measurements of airflow velocity were made across the plane of the Logan House living area using Testo hot-wire anemometers as shown in Table 2. The method entailed lining up - five researchers (faculty, students, retired faculty, onlookers, and owner) holding anemometers at eye-level and reading out air speeds at 15-second intervals (to a sixth researcher acting as recorder). Readings were taken at a point-in-time, repeating this method 25 times. The people-intensive nature of this process is evident. We might, in fact, have had more people holding more anemometers to gather data over a closer spacing interval.



Fig. 2. From one deck to another, instantaneous velocity measurements were taken using hot-wire anemometers.

4.2 Fine-bubble Technique Modeling

To shed light on the qualitative nature of air movement, specifically stack ventilation from the living area through the windows in the belvedere, we investigated a low-cost technique developed to visualize buoyancy-driven ventilation using electrolytically generated fine hydrogen bubbles.

(6) The advantages of this technique are: relatively inexpensive materials may be used, setup and operations are simple, and unlike other water modeling systems (brine working on density differentials), bubbles behave like bubbles and are upwardly buoyant. The limitation of this technique, as expressed by the developers, occurs when the top opening is lower than the ceiling level, where bubbles will accumulate on the top of the building, giving rise to unrealistic flow fields.

4.2.2 Modeling Supplies

The modeling setup included supplies listed in Table 1, placed on a sturdy lab cart near a sink, near wall outlets, and with ample space for setting up a camera tripod. We constructed an acrylic scale model of the central living space and belvedere. We were curious about the efficiency of the existing window configuration at allowing hot air to exit and decided to test three scenarios: existing configuration (windows hinged at the bottom, swinging in), the as-designed configuration (windows hinged at the top, swinging out—see Figure 1), and a proposed configuration that we hypothesized would best allow air to move and exit through the least tortuous path, be easy to weatherproof, maintain, and operate (hinged at the top, swinging in), Figure 4.

TABLE 1: Fine-bubble Equipment and Supplies

- < 37 gallon fish tank, filled with 25 gallons of water
- < 2.5 kg of Na_2SO_4 , approximate 0.1M solution
- < 20 gauge platinum wire for an anode and cathode, soldered to copper wire leads threaded through a glass tube sealed with epoxy.
- < rubber tubing attached to anode and cathode
- < battery charger, 12 volt DC, 10 amp, clamps
- < acrylic scale models
- < plug strips with surge protector
- < hose as a siphon
- < digital video and still cameras, tripod

After completing the experimental observations and photography, images were taken into a movie editor to capture flow performance at time-intervals. We also compiled list of “next time” items of supplies to have on hand or tips on running the flow demonstration smoothly: use a black, matte-surfaced acrylic for the back of the model to hide reflections and tubing, use a brightly colored acrylic for design changes, electric tape to secure the clamp-on attachment to copper wire leads, additional plug strips, longer leads to anode/cathode, build up model to be situated higher above aquarium floor, and use a heavier acrylic to fabricate model or provide weight to prevent model floating.

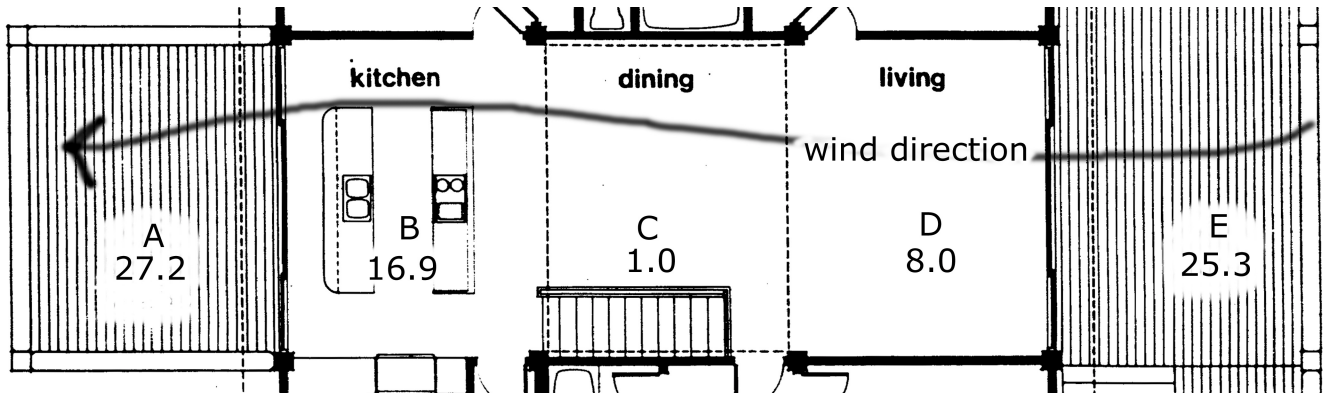


Fig. 3. Averaged, instantaneous measurements of airflow velocity across the living room in ft/min. Measurements taken at 15-second intervals with sliding doors open on each end of the living area.

4.2.3 Results and Analysis

The turbulent nature of wind flow (Table 2) made it difficult to pinpoint and read a precise velocity value. Substantial changes in air velocity readings were seen at the kitchen location, for example, ranging between 0 and 165 ft/min during the elapsed time of the study. All simultaneous readings, however, seemed to relate to each other—strong wind on the windward and leeward sides corresponded to lower velocities on through the space as shown by the averaged measurements in Figure 3. We predicted that air movement would behave more consistently throughout the space, and did not anticipate that the middle of the living area would essentially be a dead zone. Reinforcement of the tenuous, dynamic character of natural airflow was perhaps the most forceful result of this investigation.

TABLE 2: Sample measurements taken with hot wire anemometers in living room at 15-sec. intervals (ft/min).

A	B	C	D	E
9	1	1	23	45
34	29	0	0	12
68	8	0	0	38
16	4	0	0	10
67	33	0	0	68
20	9	0	10	19
56	24	2	8	17

The original working drawings for the Logan House show a mezzanine floor and the belvedere windows hinged at the top and projecting to the exterior, as awnings. The existing configuration employs windows hinged at the bottom that swing into the belvedere. The changed design decision may be due to the lower cost of windows that simply rely on

tension in a chain to stay open, rather than needing a more complex cranking system, as the designed windows would. With the removal of the mezzanine, it became necessary to control the windows from the ground level. This change is intriguing and we sought to determine the difference in air movement between the designed and existing configurations. We also proposed a third, alternate system: windows that were hinged at the top, as intended, but swing into the space, anticipating that the airflow route would follow a less tortuous path.

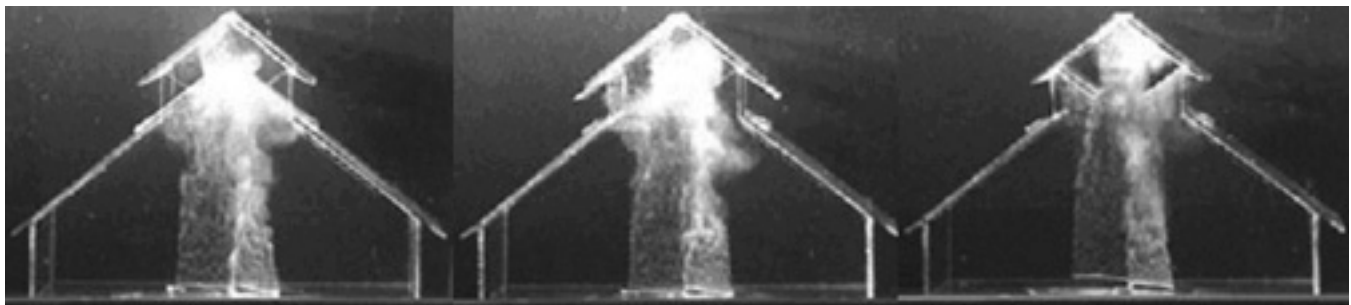
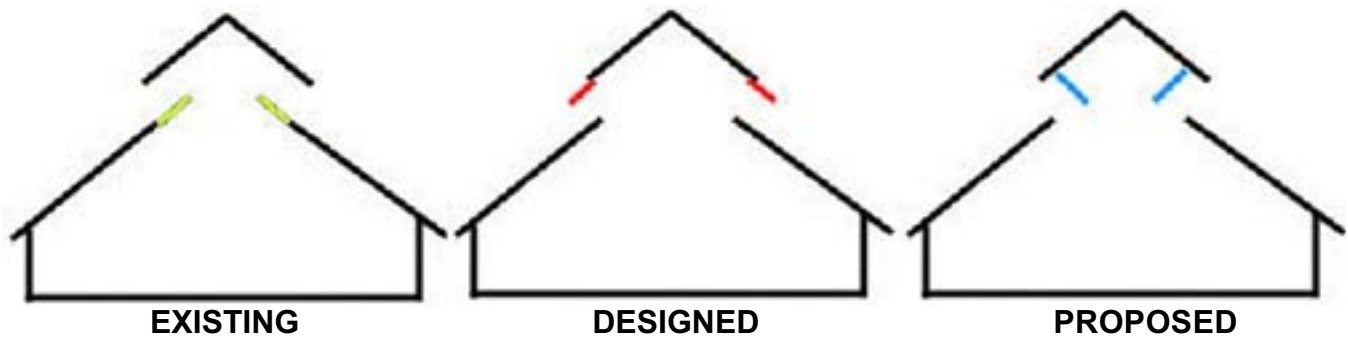
The fine bubble test enabled us to test all three configurations and qualitatively compare them, looking specifically at three criteria: the air exiting the building envelope through the windows, the air trapped at the peak of the roof, and the air being displaced back into the building. This last issue is of particular interest because of its theoretical effect on comfort.

Within eight seconds of beginning electrolysis, patterns of ventilation emerged. In the designed configuration (Figure 4), bubbles are already collecting at the peak of the belvedere. In the existing condition, the peak is relatively free, though bubbles appear trapped by the windows projecting into the space. Some expulsion out the windows is also evident. The proposed system has a similar bubble build-up at the peak as the existing condition. The bubbles trapped under its open windows, however, still have a chance to escape.

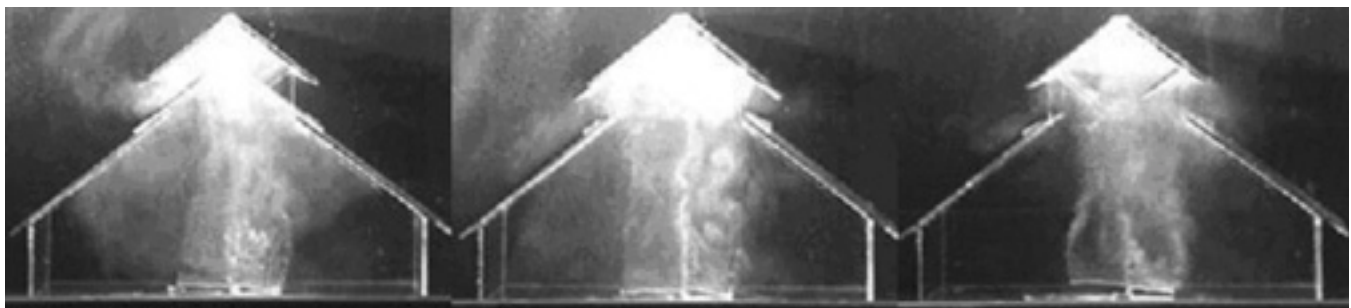
The results of the different window configurations are more dramatic after 80 seconds (Figure 4). In the designed configuration, the bubbles are not escaping fast enough to prevent back flow into the occupancy zone. The bubbles have gathered at a great density, seemingly blocking the

window openings, preventing the bubbles from flowing out. However, as seen in the top left-hand corner of the image, the bubble density outside the model is quite high. In the existing condition, the bubbles also flow back into the occupancy zone, though to a lesser degree; they have not yet reached the floor. This design configuration appears successful in expelling air. The bubbles achieve a greater velocity (as manifest in the swoop on the left side of the photograph at 80 seconds) as they exit these windows.

In the proposed system, the back flow has not reached the occupancy zone, implying the window configuration is allowing more of the bubbles out of the house. Also the bubbles have not reached the density of the two other conditions and the windows are relatively clear of accumulated bubbles. The bubbles that have accumulated at the peak of the roof could easily be extinguished with a roof venting system. Air trapped at the top would not directly affect occupants' comfort and was, in fact, a clear sign that the stack effect was working.



8 seconds



80 seconds

Fig. 4. Simultaneous digital images of the “stack effect” midway (8 seconds) and at the end (1 minute, 20 seconds) of the flow demonstration. Superimposed lines sketched onto the image indicate the extent of the “air” trapped in the living space below the belvedere. The design of the proposed configuration performs well.



Fig. 5. Placing the copper wire leads through the base of the model while submerging it into the tank of water required several sets of hands.

We conclude that the stack effect is greatest in the proposed condition because the bubbles have exited the model at a consistent rate. The least stack effect is in the designed configuration, in which the propulsion of air only occurs in spurts when the model can no longer hold the sheer density of bubbles.

According to the results of this experiment, the designed configuration is, in fact, much less successful than the existing condition. The proposed system is the most successful, a physical manifestation of the elusive “magic-arrow” diagram.

5. CONCLUSIONS

The issues related to passive cooling by air movement through the Logan house are complex and have led us to utilize several different methods: a) an equipment- and people-intensive technique and b) fine bubbles through a scale model, yet none of these methods gave perfect results. We were able to observe general patterns of air movement along one dimension through the space, but the number of hot-wire anemometers and people available limited the extent to which we could record patterns. The dynamic nature of wind evident in the fluctuating and turbulent measurements also made it difficult to capture a moment in time for such a varying element. The fine bubble technique was exciting to observe through the three-dimensional scale model, informative, and economical, although visualization was not completely clear. For future studies, we assembled a list of things to do to improve the methodology and to obtain clear patterns of movement.

What is a designer to do when there are no definitive design tools for natural ventilation? Future work at the Logan house includes year-long monitoring of temperature and humidity. We plan to develop new ways of testing and characterizing airflow and to validate the results from the fine bubble technique using wind tunnel experiments and computational fluid dynamics. The Logan House is not yet signed off.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

- (1) Brown, G.Z. and M. DeKay, Sun, Wind & Light: Architectural Design Strategies (2nd ed.), John Wiley and Sons, New York, 2001.
- (2) Vital Signs Curriculum Materials Project: <http://arch.ced.berkeley.edu/vitalsigns/>
- (3) Kwok, A. and W.T. Grondzik, “The Logan House: Measuring Air Movement,” Proc. 1999 Conference of the Amer. Solar Energy Society (Portland, ME), Amer. Solar Energy Soc., Boulder, CO, 1999, pp. 635-640.
- (4) Kwok, A. and W.T. Grondzik, “The Logan House: Stack Effect Effectiveness,” Proc. 2000 Conference of the Amer. Solar Energy Society (Madison, WI), Amer. Solar Energy Soc., Boulder, CO, 2000, pp. 461–466.
- (5) Kwok, A. and W.T. Grondzik, “The Logan House Revisited,” Proceedings from The 17th International Conference on Passive and Low Energy Architecture, Cambridge, UK, July 2–5, 2000, pp. 268–269.
- (6) Chen, Z.D., Y. Li, and J. Mahoney. “Experimental modeling of buoyancy-driven flows in buildings using a fine-bubble technique,” Building and Environment, 36, 2001, pp. 447-455.
- (7) Kwok, A. and W.T. Grondzik, “Understanding Building Performance by Taking a Building’s Vital Signs”, Proc. Performance of Exterior Envelopes of Whole Buildings VIII (Clearwater Beach, FL), Amer. Soc. Heating, Refrigerating and Air-Conditioning Engineers, Atlanta, 2001, in press

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