THE FAN CLUB

Brooke Standifer, David Rathmann, Jason Riffle
University of Oregon
Department of Architecture
Eugene, OR 97403

bstandif@uoregon.edu
jriffle@uoregon.edu
drathman@uoregon.edu

ABSTRACT

The following is a case study prepared for the Environmental Control Systems course offered at the University of Oregon. Based on assessments of an apartment in East Eugene, Oregon, we determined that the thermal separation from floor to ceiling was unusually high, resulting the resident's lack of thermal comfort. We attributed this thermal separation and lack of comfort to an inadequacy of overall circulation and began testing.

1. INTRODUCTION

A lack of thermal comfort is a common complaint voiced by building occupants. Due to the subjective nature of personal "comfort," the issue of thermal comfort is one of the hardest qualities to objectively test and analyze. This paper summarizes our investigation of thermal properties of a home located in Eugene, Oregon. Prompted by reports from the apartment's sole resident of a large temperature difference between sleeping quarters and the main floor, we decided to evaluate the heating conditions within the space. The resident's regular heating habits consisted of setting her thermostat such that it would keep the space just warm enough to promote comfort in the loft space, above the living space in the apartment (Fig. 2). Heating the apartment to maintain thermal comfort on the main floor meant hot and sleepless nights while keeping the loft space thermally comfortable made for extremely cold temperatures on the main floor in the late evening, through the night, and in the morning.

The 400 sq ft apartment sits atop an old garage, to which it was added in 1964. The addition was designed and partially built by a former University of Oregon graduate student and current Portland architect. Construction of the apartment was finished at a later date by the current owner, who lives in the main house adjacent to the apartment.

The overall space is composed of one primary living room/kitchen/entry, to which a small office, bathroom, and bedroom are attached (Fig.3). The sleeping loft is accessible by ladder and centrally located above the main space. The loft space is closed on two sides and lies 5 feet below the ridgeline of the vaulted ceiling. There is no seal between the entry and loft space, nor is there a seal between the rear bedroom and the loft space. In effect, this space acts as a thermal bridge between the two largest spaces in the apartment.

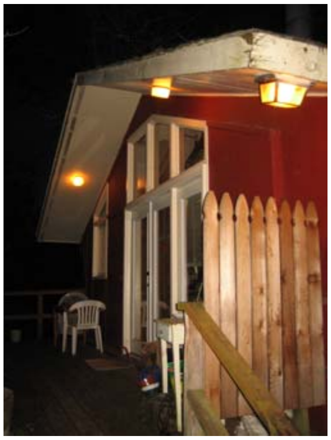

Fig. 1: General exterior

Fig. 2: Living room and loft space

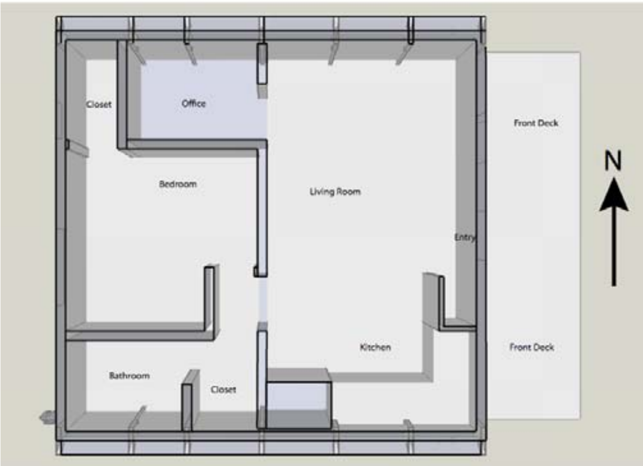

Fig. 3 – Plan view of the apartment

As reported by the resident, it is a challenge to keep the apartment warm during winter months. The tall ceiling (twelve feet at the ridge) provides a mostly uninterrupted space in which large masses of mechanically heated air tend to accumulate. The resident pointed out that the main living space, and especially the floor, often remain uncomfortably cold when the loft space approaches unbearably hot temperatures.

For such a small space, the apartment is more than adequately furnished with mechanical heating of two varieties: an electrical baseboard heater (radiant heat, no fan), and an in-wall unit (with a circulator fan). While an apartment of the same size laid out on a single floor with a lower ceiling height might have little trouble distributing heat, the apartment in question has notable difficulty both distributing and retaining heat.

The electrical heaters lack the means to distribute the heat produced into the space continuously and supply hot air close to the floor level. This air, in turn, moves upward and away from the primary living space, sequestering itself at the high ceiling ridge.

At the outset, we speculated that evaluating these thermal differences could be accomplished with dry bulb temperature readings at regular intervals, using data loggers. We also expected that tracking the change in thermal differences would have to be evaluated with a measure of air speed and direction. Our expectation was that these variables could be tracked with data loggers, anemometers, and through the “soap bubble method.”

2. HYPOTHESIS

Increasing circulation in the apartment with an 8” household fan will decrease the difference in dry bulb temperatures between floor and ceiling air by a minimum of 50 percent.

3. METHODOLOGY

3.1 Control

Our investigation began with an attempt to analyze the temperature stratification from floor to ceiling under “normal” heating conditions. All temperature data collection was performed over twelve-hour periods. Two control experiments were run under the following “normal” conditions: the resident agreed to set her thermostats to a comfortable setting (reported as 57°F) which would remain set from nine o’clock p.m. until nine o’clock a.m.; windows were to remain shut for the duration of the collection periods; the resident kept her normal sleeping pattern intact. We selected this period for collection to assure that activity levels and other internal load fluctuations were minimized.

To accurately measure temperature stratification, we collected dry bulb temperatures for each twelve-hour period using seven data loggers. The data loggers were strung from the ceiling, hanging at three foot intervals: <6”, 3’, 6’, 9’, and 12’. Additionally, data loggers were placed outside on the porch and in the unheated garage below the apartment (Fig. 5).

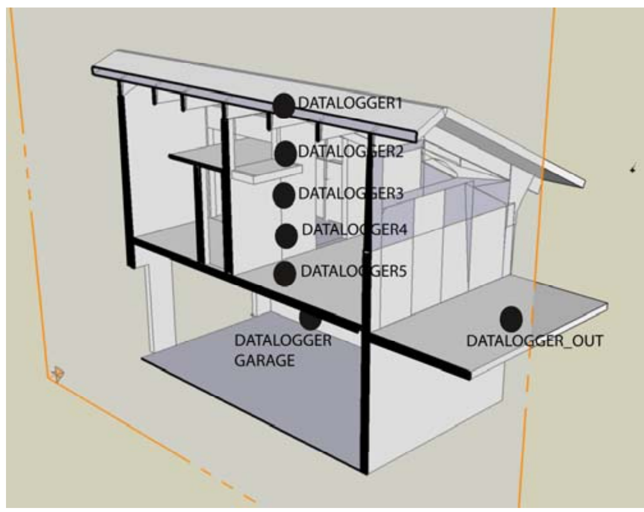

Fig. 5 – Data logger placement in and outside apartment

3.2 Fan

After collecting data under normal heating conditions, we began to introduce measurable amounts of circulation within the apartment. We placed an 8” Honeywell (HT 800-19) fan (Fig. 6) and ran it on a "low" setting for the twelve hour period. After collecting temperature data, we analyzed it to determine the effect of the added condition. Adding too much circulation too early risked destroying the temperature gradient before we had a chance to determine the amount necessary to achieve a 50% reduction. In other words, the desired effect of adequate heat distribution would be made more meaningful if we knew just how much additional air circulation was required.

A second round of data was collected using the 8" fan (Fig. 6). Data loggers were arranged in the same manner as in the control experiment, and the fan was set to run for the same twelve hour period.

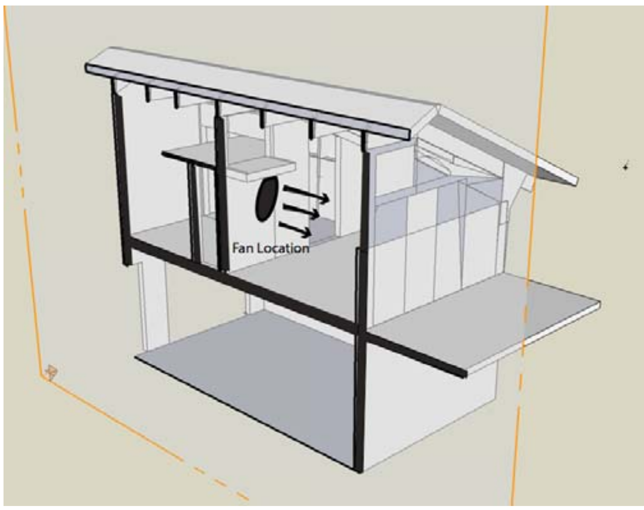

Fig. 6 – Fan location

3.3 Circulation

After reviewing data, we mapped circulation pathways in the apartment (with fan running). Anemometer readings were taken at various points. We made these readings first under normal conditions and second under fan conditions with the rear bedroom thermostat set to 57°F. After recording these anemometer readings, we mapped air circulation, with the fan running, using the bubble test (Fig. 7).

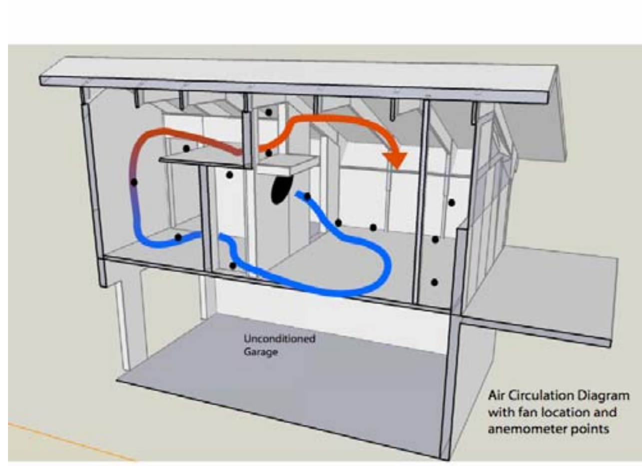

Fig. 7 – Air circulation, fan location, and anemometer points

4. DATA & ANALYSIS

4.1 Temperature Stratification

When heating a home, it is ideal to heat the entire space to a constant temperature. In the apartment we tested, the temperature at the floor stratum was significantly lower than that at the ceiling stratum. We collected a set of control-data to determine the temperature stratification under normal conditions and a set of fan-data to determine what effect air circulation would have on the temperature stratification.

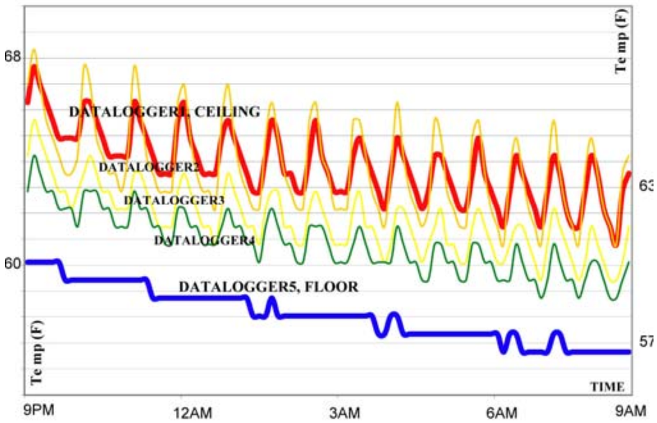

Fig. 8: Stratification (control).

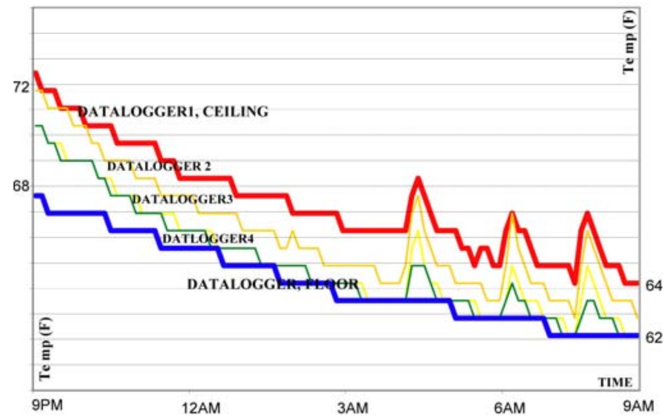

Fig. 9: Stratification (fan).

TABLE 1: AVERAGE TEMPERATURE (CONTROL)

Location	Temp (°F)
DATALOGGER1	63.88
DATALOGGER2	63.78
DATALOGGER3	61.72
DATALOGGER4	60.84
DATALOGGER5	58.09
DATALOGGER_OUT	35.79
DATALOGGER_GARAGE	41.50

TABLE 2: AVERAGE TEMPERATURE (FAN)

Location	Temp (°F)
DATALOGGER1	67.40
DATALOGGER2	66.22
DATALOGGER3	65.15
DATALOGGER4	64.99
DATALOGGER5	64.29
DATALOGGER_OUT	47.21
DATALOGGER_GARAGE	44.98

The difference in temperature (from floor stratum to ceiling stratum) was approximately 6 °F.

4.2 Temperature Stratification with Fan

In order to increase air circulation within the space, we placed an 8” household fan below the loft space as shown in Fig. 6. It was a few degrees hotter on the night we ran the fan test which is why the temperature appears higher on the graph. What’s really important to see in both Fig. 8 and Fig. 9 is not the temperature itself, but the difference between the high temperature and the low temperature because what we are really testing is the stratification (temperature difference from floor to ceiling).

The difference in temperature (from floor stratum to ceiling stratum) was approximately 3 °F.

4.3 Analysis

With an 8” household fan in position as shown in Fig. 6, we were able to decrease the temperature stratification by approximately 50%. The spikes in Fig. 8 and Fig. 9 correspond to the heater turning on and off as it attempted to maintain a constant temperature within the space. Comparing the spikes in Fig. 8 and Fig. 9 shows that the heater turned on fewer times on the night the fan was running.

We hypothesized a 50% decrease in stratification and were correct. On the night we ran the fan, the temperature difference from floor to ceiling was approx 3 °F compared to 6 °F on the night without the fan. Further tests may show an even greater decrease in stratification with an increase in fan-power or an increase in the number of air-circulation devices used. Further analysis may also prove that running an 8” household fan saves power over time.

4.3 Lessons Learned

Although it seems like a simple concept, increasing air circulation within a space can make a rather large difference in human comfort.

5. ACKNOWLEDGEMENTS

Thank you to Erin O'Meara for permitting access to her apartment, and all that it has to offer in terms of fantastic, yet perplexing, ECS phenomena. Thank you to Allison Kwok for letting us use the last plastic bubble dispenser. Last but not least, thank you to Michael Walsh for his patient and exhaustive oversight of our project, from beginning to end.