LECTURE HALL COMFORT AT THE LILLIS BUSINESS SCHOOL: EUGENE, OREGON

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ABSTRACT

In order to qualify thermal activity in the new Lillis Business School second floor auditorium, temperature and humidity were measured and compared with the ASHRAE-55 2004 guidelines for thermal comfort. Although the room was always within the comfort zone throughout the room during the official test date, partially completed pilot studies made in previous weeks indicate that this might not always be the case throughout the season. Furthermore, a temperature gradient from the front to the back of the room, sometimes in excess of 12º F, indicates that moderating measures would be productive after further experimentation determines the specific cause(s) of the gradient.

1. INTRODUCTION

According to the University of Oregon press release, the Lillis Business Complex (located in Eugene, Oregon) is "the only environmentally friendly building at a top-ranked business school." The Complex, designed by SRG Architects and finished in 2004 is considered at the leading edge of sustainable design in architecture.

Lillis 282 [Figures 1 & 2] is a 243 seat lecture hall designed to incorporate a combination of passive and active environmental controls, both for lighting and for ventilation. Active ventilation occurs through two systems of air inlets, each with a separate VAV distributor. One set of vents serves the front of the lecture hall near the podium and one serves the back, near the entrances. The passive system is fueled by a stack at the north end of the room.

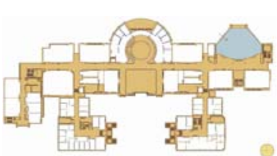

Fig. 1: Second Floor of the new Lillis Business Complex with Room 282 highlighted.

Fig. 2: Northwest facade of Room 282. Stack air inlets visible at right and operable windows at left.

I chose to investigate the thermal qualities of the room and present them in a quantitative manner in reference to the American Society of Refrigeration, Heating, and Air-Conditioning Engineers' 2004 standards. Specifically, I decided to compare the thermal performance of 282 Lillis to the ASHRAE 55-2004 thermal comfort guidelines. I hypothesize that 282 Lillis is...

> ...within ASHRAE 55-2004 comfort zone during February and March throughout the school day, defined as hours of the day during which classes are in session in the lecture hall.
>
> ...within ASHRAE 55-2004 comfort zone during February and March throughout the lecture hall, defined as the zone in which students sit throughout the lecture hall, as measured below an imaginary line five feet above the floor.

2. FINDINGS

2.1 Methodology

To test my hypotheses, I placed five HOBO microdataloggers in the positions shown in Figure 3 and one on the north side of the building adjacent to the lecture hall. These dataloggers recorded relative humidity and dry-bulb temperature in 5 second increments from 8:25am to 8:45pm during test days. I placed the sensors only on Wednesday in order to get comparable data between days with identical class schedules. Measurements were taken February 9, 16, 23, and March 2. The February results were not used to prove or disprove my hypotheses due to removal of some sensing devices by students during a few of the test classes.

Fig. 3: Sensing devices located under desktops attached to chairs (highlighted in red).

Sensors were placed on the underside of movable desktops as shown in Figure 4. The desk up and desk down position were tested on February 9 along with readings taken at chest level by researchers present in a morning lecture. Measurements between all sensor positions were nearly identical, indicating that the subsequent sensor positions give results that are both relevant and accurate.

Fig. 4: Typical sensing device attachment

2.2 General Analysis

Results of the March 2 tests are displayed in figures 5,7,8,9, and 10 with degrees Fahrenheit as the range and time of day from 8:25am to 8:45pm as the domain. In addition, a flat line is included for each sensor, indicating the average temperature read by the sensor throughout the testing period. Times of day when the room is occupied are shaded regions on the graphs. There are three morning classes (the third following immediately after the second), two afternoon classes, and one evening class. Indoor humidity remained between 30 and 40% during the test period and is not shown on the graph.

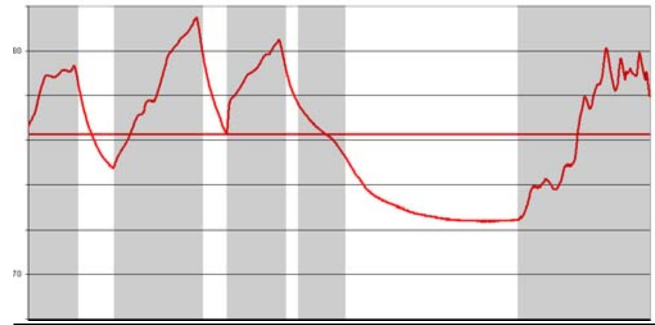

Fig. 5: Temperature of "red" position [see Fig. 6] as plotted against time as well as an averaged flat-line.

Figure 5 shows the temperature of the middle-back region labeled in Figure 6. These data indicate the room heats up when classes are in session and declines in temperature when class is not in session. The average temperature here is 76.3 F.

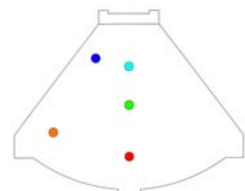

Fig. 6: Sensor position key for Figures 5, 7, 8, 9, and 10.

Figure 7 shows the temperature of the middle region labeled in Figure 6. These data indicate that the average temperature is slightly lower than the back position, but the temperature still generally oscillates depending on occupancy patterns within the room.

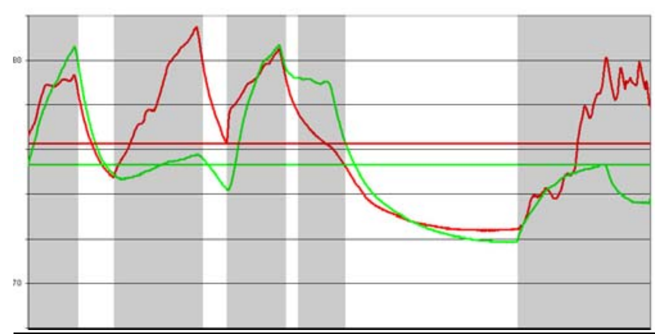

Fig. 7: Middle and back-of-room measurements.

Figure 8 shows the temperature of the middle-front region labeled in Figure 6. These data indicate that the average temperature is 4.5 degrees colder than the average temperature at the back of the room and that the temperature here is always colder than the back region. According to researcher observations during the test period, there are fewer students seated in the front than in the back throughout the day; the greatest disparity between front and back seating is during the evening class where the temperature differential between the two regions reaches 12 F.

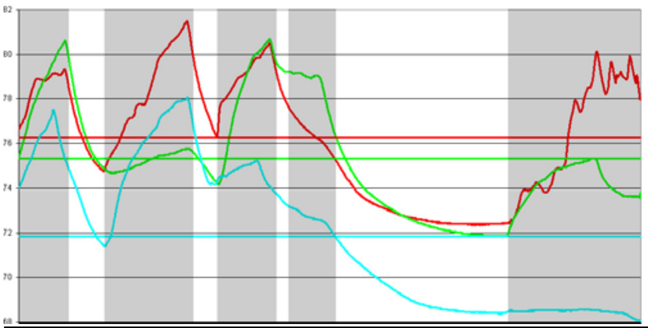

Fig. 8: Back, middle, and front-of-room measurements.

Temperature measurements taken at the east side of the room are shown in Figure 9. Although the average temperature is lower in the front than in the back, the disparity is not as great. The researcher observed that the disparity between the quantity of students sitting in the side-back versus the side-front is not as great as the population-dispersal disparity between the middle-back and middle front positions as shown in Figure 8. This indicates a possible relation between location of occupants within the room and heat level differences between the front and the back of the room.

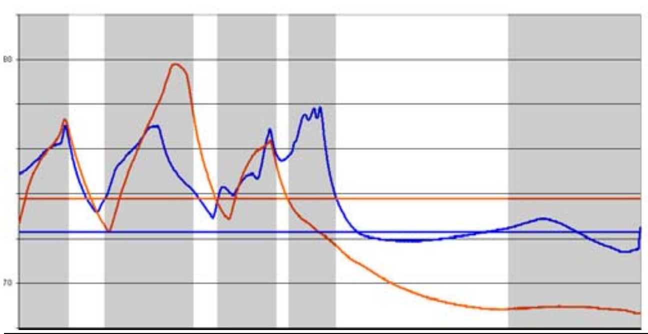

Fig. 9: Side-of-room measurements

Readings from all sensors are shown in Figure 10. Taken together with an outside reading, the heat in the classroom appears to be effected by the dip in outside temperature, indicating that the room is probably on the "passive ventilation mode" which is fueled by outside air. Even though there were roughly 120 students in the last class and the third class (the two hottest testing times), the overall temperature of the room is much lower in the last class than the first class. This effect could be due to either the lights being off in the last class, the outside temperature being lower, or a combination of the two phenomena.

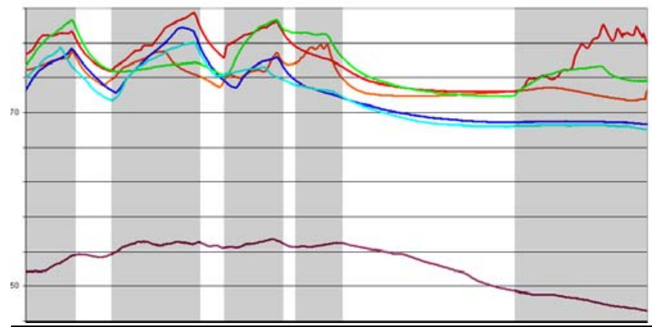

Fig. 10: Measurements from all microdataloggers.

2.3 Conclusion

The coldest position / time during the occupied March 2 test period is the end of the last class of the day in the middle of the front of the room and the warmest position /time during the occupied March 2 test period is the end of the third class in the middle-back of the room. In both cases, the humidity / temperature readings are within the ASHRAE 55-2004 comfort zone [see Figure 11]. This proves my hypotheses correct; 282 Lillis is within the thermal comfort zone throughout the day and throughout the room.

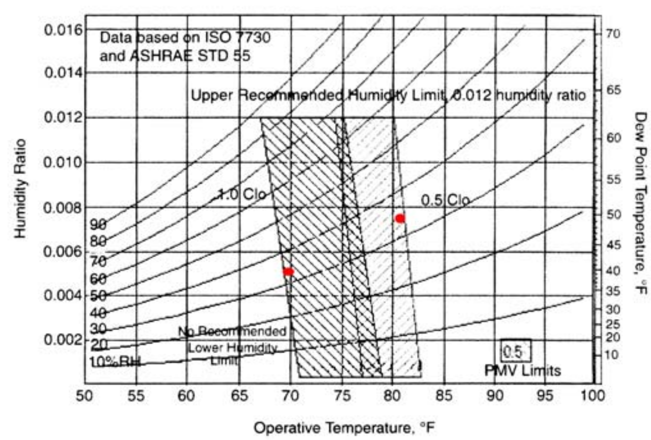

Fig. 11: Extreme hot and cold temperatures throughout testing period compared with ASHRAE thermal comfort zone (hatched region).

However, extreme hot and cold temperatures taken from pilot test data indicate that the temperature in 282 shown in Figure 12 could easily have been warmer and/or colder than is allowable within the ASHRAE thermal comfort zone. Although the pilot test data can not be used to prove or disprove the hypotheses, they indicate measurements should be taken during more test days within 282 to determine possible micro-seasonal effects on the temperature within the room.

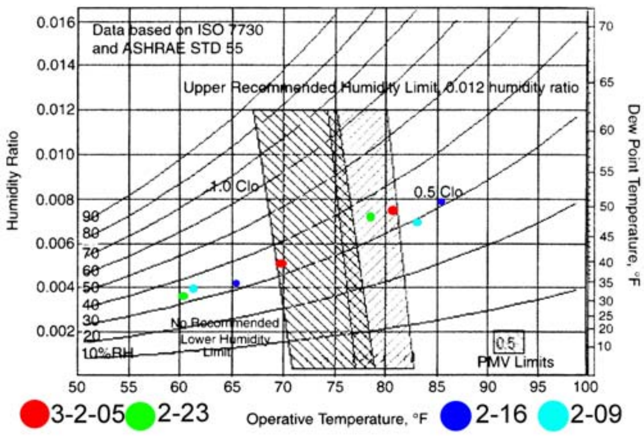

Fig. 12: Extreme temperatures from all testing days.

2.4 Additional Analysis

Although 282 is within the thermal comfort zone, there is enough variation in temperature within the room to merit extra attention. In Figure 13, data from HOBO dataloggers are supplemented by surface readings taken by a Raytec surface temperature sensor outside of the March 2 test period (March 7 from (2:00 to 3:00pm). These measurements, all taken along the north-south axis of the room at waist level, show that there is a steady rise in temperature from the front to the back of the hall. Although the surface temperature readings are not conclusive because they were taken on a separate day, there is much evidence from the HOBO measurements indicating a trend in temperature within the lecture hall that is at least partially dependent on location north to south within the room. The >6º F differential from the front of the room to the back could be due to a variety of causes, but as a trend it is unmistakable.

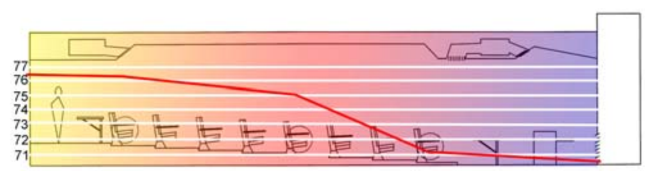

Fig. 13: Average temperatures plotted through the section of the room.

Possible causes of this differential include all or a combination of the following:

1. Overall dip in temperature of fresh air entering the room, caused by a change in outdoor air temperature.

2. Differences of internal loading caused by the number and distribution of students and changes in lighting.

3. Stack effect caused by room section geometry

4. Different rates of heat loss through skin caused by room plan geometry.

2.4 Directions for Future Study

In order to deem the conclusions of future studies even more usable, complete data sets should be obtained from different test days within the season or throughout the year. In addition to this, parallel subjective studies should be performed using questionnaires to obtain subjective comfort data. This would verify usability of ASHRAE 55 guidelines in determining subjective comfort in this particular setting. Future studies should include data taken from the Lillis room sensors on behavior of the rooms' ventilation systems. This would help isolate the effects of any difference in behavior between the passive and mechanical systems. Finally, the thermal behavior of the room should also be measured while the room is vacant to isolate effects of the geometry of the room and loss of thermal energy through the building's envelope.

3. ACKNOWLEDGMENTS

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