A tale of three zones

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ABSTRACT: With the most recent renovation of Eric W. Allen Hall on the University of Oregon campus, completed in March of 2013, the designers, users, and campus planners are interested in comparisons of predicted and actual thermal comfort levels. This case study serves to analyze thermal comfort in three different zones of the building. Both occupant surveys and physical measurements are utilized to collect data. Further, data will be compared to standards set by American Society of Heating Refrigerating and Air Conditioning Engineers (ASHRAE), in order to check the appropriate performance of the mechanical systems used throughout the building. Allen Hall features three distinct thermal zones, each with their own unique systems and strategies. Based on initial observation, it is hypothesized that the southeast zone, containing the most recent addition, achieves the highest level of thermal comfort. Through quantitative and qualitative analysis, this hypothesis was proven to be partially correct.

KEYWORDS: Thermal comfort, Allen Hall, Post-Occupancy Evaluation (P.O.E.)

INTRODUCTION

Completed in 1922, Eric W. Allen Hall has been an integral part of the campus, housing the School of Journalism and providing a space for student collaboration. In 1954, a new addition was constructed for the expanding program. This building remained relatively untouched until the most recent renovation in 2011 – 2013 (Figure 1), connecting the two buildings and creating a cohesive whole (Woofter, Matthews, 2014).

Figure 1: Rendering of the 2011-2013 renovation of Allen Hall. (© Yost Grube Hall Architecture Inc. and TBG Architects and Planners)

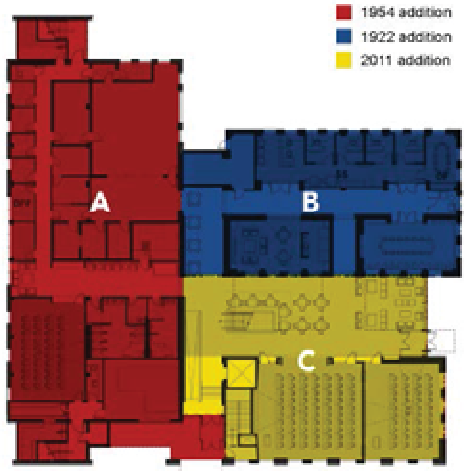

Figure 1: Plan of Allen Hall with thermal zones outlined. (© Yost Grube Hall Architecture Inc. and TBG Architects and Planners)

Figure 3: Allen Hall east atrium.

The three thermal zones (Figure 2) are designated Zone A, B, and C for the purposes of this study. The original building in 1922 utilized operable windows for cooling and radiators (steam) for heating. Today, that portion of that building (Zone B) uses baseboard heating, operable windows, and paddle fans. The 1954 portion (Zone A) is currently heated and cooled by a Variable Air Volume (VAV) system, a type of heating, ventilating, and air-conditioning system that supports one duct, which distributes variable amounts of air in order to achieve designated temperatures. The newest addition (Zone C) uses passive and active chilled beams, baseboard radiant heating, and operable windows. These systems were designed to maintain are the integrity of the different areas of the building, to maintain excellent comfort conditions for the students and faculty, and to support campus energy efficiency policies. Strategies for outstanding comfort and efficient building operations were important to becoming a campus model in sustainability and green practices.

When commissioned for the renovation of Allen Hall, the design team had many goals in mind. Among attempts to establish a clear entry and create a collaborative environment, a majority of the other goals were directly connected to the building's upgraded systems and their performance:

1. "Net Zero" in terms of added energy consumption
2. 40% better than Oregon Electrical Specialty Code OESC 2007 Energy Code
3. 25% better than Oregon Electrical Specialty Code OESC 2010 Energy Code
4. 2030 Challenge EUI 60% better than Commercial Buildings Energy Consumption Survey (CBECS)

The design team hoped to "use wisely what [they] had" by considering benefits of the site, water conservation, energy consumption, and life cycle costs. Energy measures such as new windows, insulation and external shading, lighting and controls, temperature drift, central plant cooling, variable chilled water loops, steam to hot water, natural ventilation, passive and active chilled beams, a Dedicated Outdoor Air system, a heat recovery chiller, point of use water heat, and an enhanced Building Automation System were incorporated. However, since the opening of the new renovation in March 2013, no post-occupancy evaluation has been conducted on the performance of these systems.

Through initial observations by our team, we raised the following questions:

1. Are the systems performing to the levels predicted by computer analysis?
2. Why are only the windows on the southeast propped open?
3. How does occupant thermal comfort in each zone compare to each other?
4. In addition, how does occupant thermal comfort compare to that prior to renovations?
5. How do the standards set by ASHRAE Standard 55 compare to occupant's preferences?
6. Are the building systems being operated as intended?

The topic of occupant thermal comfort in Allen Hall is of great interest to the campus planners and architects. The topic became the goal of this study, to compare design intent with actual performance of a building.

1.0 HYPOTHESIS

We hypothesized: "The occupants in the 2011 addition (2nd floor of Zone C) of Allen Hall were the most thermally comfortable in the building according to the comfort zone parameters of ASHRAE Standard 55 Thermal Environmental Conditions for Human Occupancy."

2.0. METHODOLOGY

The results of this study were gathered through both qualitative and quantitative research methods. Occupant comfort "votes" were compared to the physical conditions measured in each zone. Data was collected on the second floor due to the presence of offices in all three zones. The second floor had numerous faculty and staff offices that were accessible for our study for the distribution of thermal comfort surveys. Only the faculty and staff participated in this study in order to narrow the scope of research and provide results for the occupants whom spend the most time in Allen Hall.

1. Gain necessary permissions: building manager, facility manager, dean's office for access to various spaces for setting up data logging equipment and survey distribution.
2. Develop and test occupant thermal comfort survey using online software (*Qualtrics*). Disseminate survey.
3. Launch 15 Onset HOBO dataloggers (Figure 4), 5 in each zone to collect temperature and relative humidity at 1 minute intervals for one week, including a weekend
4. Place HOBO data loggers in appropriate locations throughout Allen Hall for an accurate and comprehensive analysis. (Figure 5)
5. Compare results of quantitative data to ASHRAE Standard 55 through tables, graphs, and charts.
6. Compare qualitative data with quantitative data and note any trends through graphic analysis and written description.
7. Determine which zone achieves the greatest level of occupant comfort and offer solutions for other lower performing zones.

Figure 4: Onset HOBO datalogger

Figure 5: Datalogger locations on the second floor

3.0. DATA AND ANALYSIS

3.1. Quantitative Data

Quantitative data was collected from May 10, 2014 through May 16, 2014. During this period of time, the average outdoor temperature was 60 °F, with a range between 43 °F and 75 °F. Results from the Hobo data loggers indicated the following office temperatures shown in Figure 6.

Average Daily Temperature:

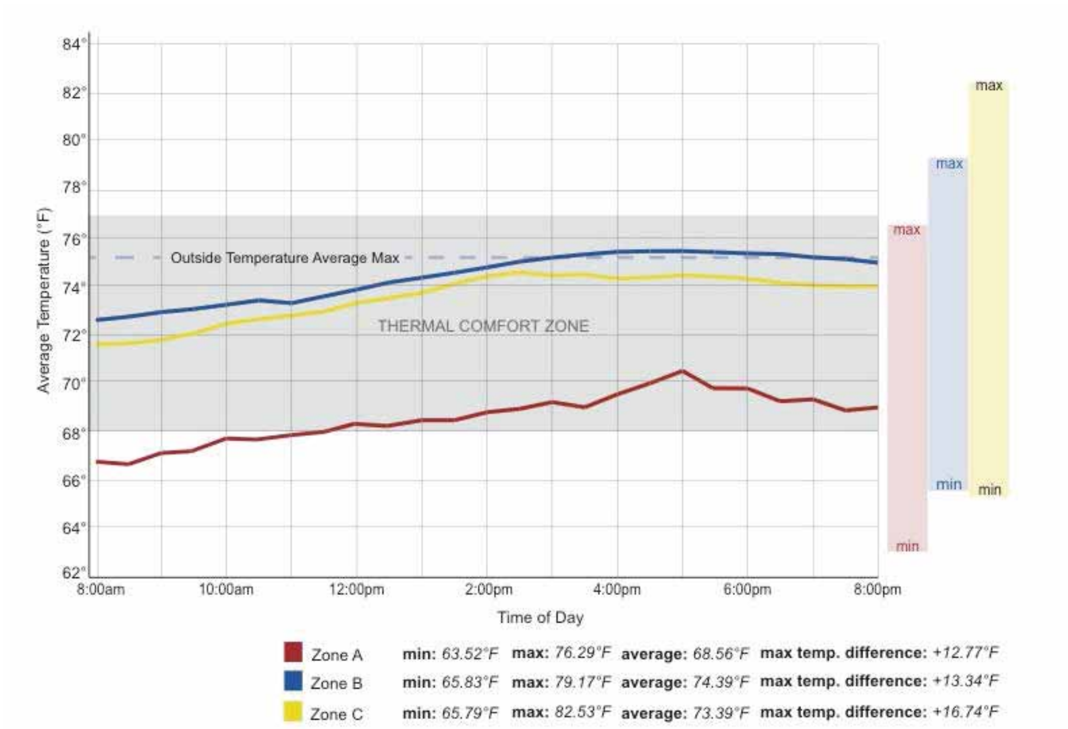

Figure 6: Average daily temperatures in each zone plotted against the temperature parameters of the ASHRAE thermal comfort zone.

According to the data collected and the graph above, all three zones tend to fall within the comfort zone conditions defined by ASHRAE Standard 55. However, Zone B and C tend to be on the warmer side of the comfort zone, while Zone A tends to be cooler. Average temperatures indicate that Zone B and C fall within the comfort zone, while Zone A is slightly too cool. Furthermore, occupant discomfort could be caused by large temperature swings. For example, on Thursday May 15th, temperatures in office 216 A (Zone B) ranged from 65.8 °F to 78.7 °F. This temperature change of more than 12 °F far exceeds the limit of 5.5 °F [Grondzik et.al., 2010].

In addition to temperature, relative humidity was also recorded during the same time frame. The combination of dry-bulb temperature and relative humidity, placed onto the ASHRAE thermal comfort zone allowed visualization of the thermal conditions of each office in each of the thermal zones of the building (Figure 7).

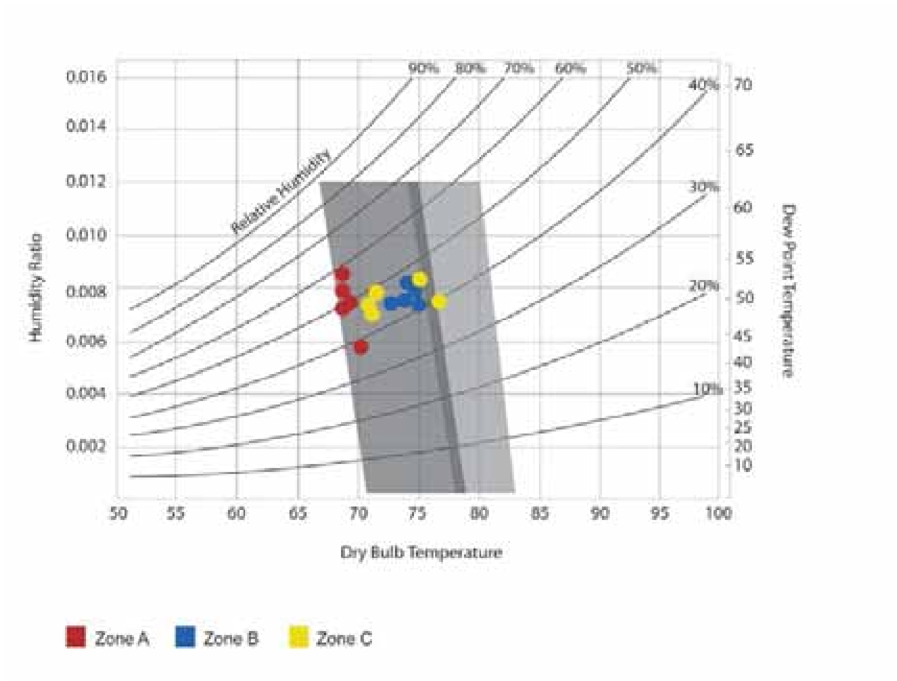

Figure 7: Thermal conditions for each office in each of the Allen Hall thermal zones superimposed on the ASHRAE comfort zone.

Allen Hall's zones tend to cluster within the thermal comfort zone, demonstrating that each heating and cooling system was successfully performing for the time period measured. Zone A tends to operate in a cooler side of the comfort zone, while Zone B and C were right in the middle of the comfort zone. It should be noted that May is a "transitional" season and outdoor conditions were still fairly cool. The darker shaded area of the comfort zone corresponds to "cooler" seasonal conditions when occupants might wear warmer clothing versus the lighter shaded area where conditions are warmer and occupants wear lighter clothing.

3.2. Qualitative Data

An online Qualtrics survey was distributed to the faculty and staff of Allen Hall. A response rate of 26% (36 of 139 surveys) was achieved. We found that occupants in Zone A tend to feel "cool" on the comfort scale; occupants in Zone B tended to feel "slightly warm", and occupants in Zone C felt the most "thermally neutral" or comfortable (Figure 8). These results support the hypothesis, stating that Zone C is the most thermally comfortable zone.

The most common reason stated on the survey for occupant discomfort in both Zones A and B was the inaccessibility of and lack of control over the thermostat. In Zone C, the most common reason for discomfort was the incoming daylight, which would make sense because Zone C is the most southern facing zone (Figure 9). As a result of these reported discomforts, occupants claim to use a variety of thermal adaptations, including opening and closing windows as necessary and wearing extra clothing (Figure 10). Unfortunately, some occupants, especially those in Zone C, do not understand how the systems operate and stated that this confusion inhibits the occupants from making appropriate decisions regarding the control of thermal conditions. Further, confusion is reinforced by unclear and uninformative signage throughout the building, discouraging the use of operable windows at all times. The following quote is taken directly from the Qualtrics survey:

> *"We don't have individually controlled thermostats, and, as I said before, the building is designed to react to open windows. So, for the most part, I don't open the window because of its potential effect on other offices. That's problematic because we don't know which office controls other offices." – Anonymous*

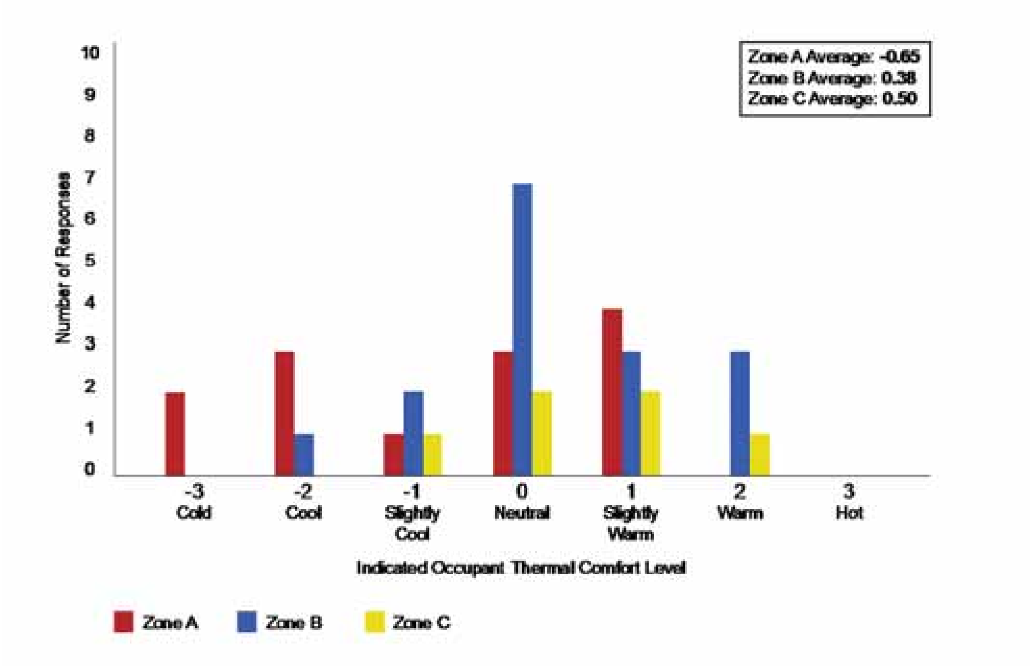

Figure 8: Reported occupant votes of thermal sensation (the range of -1 to +1 is considered to be comfortable).

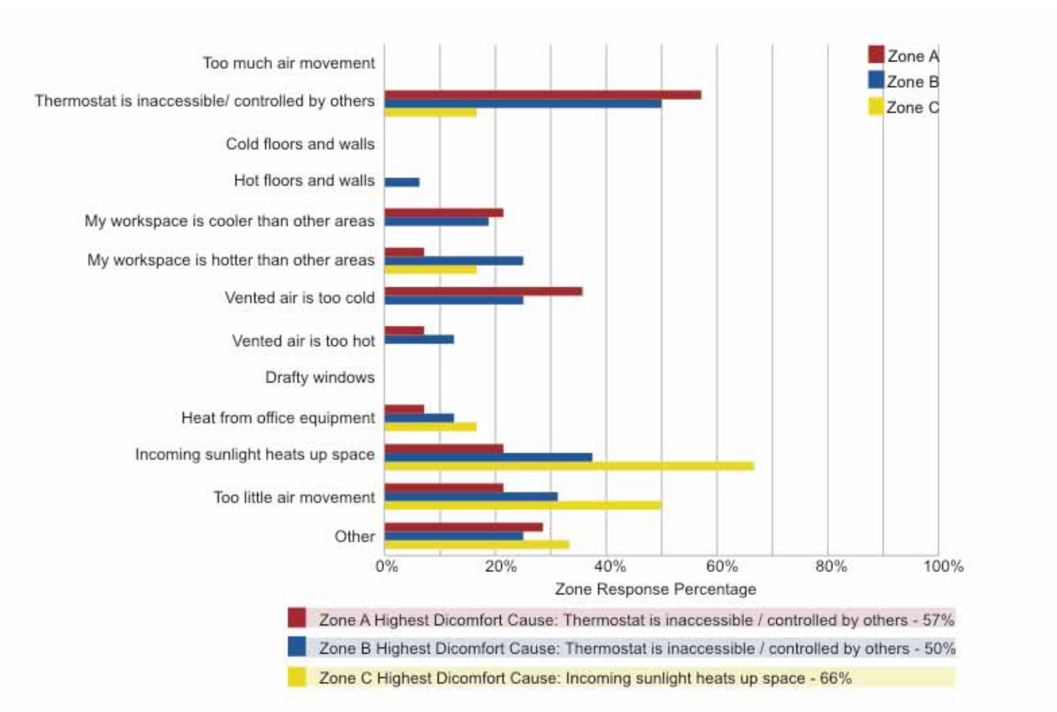

Figure 9: Reported reasons for thermal discomfort.

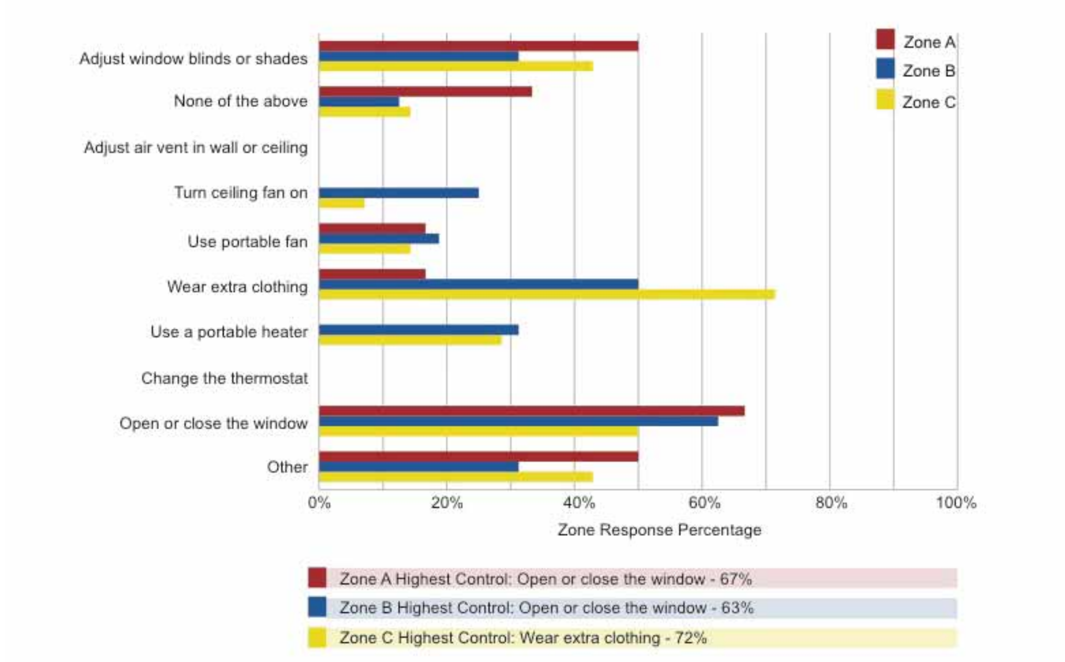

Figure 10: Reported occupant adaptive behaviors to control the thermal environment.

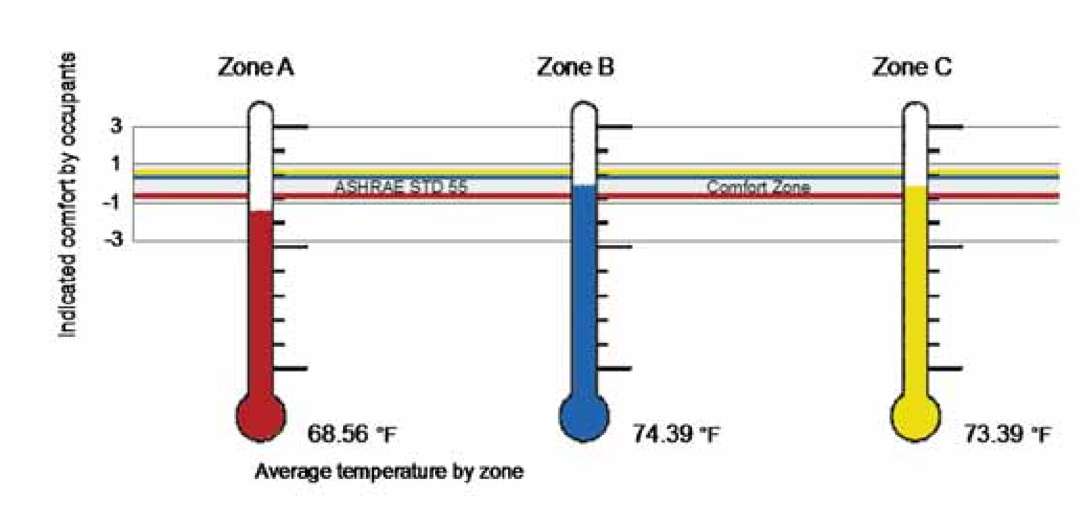

Figure 11: Reported occupant comfort by zone, average temperature, and comfort vote

4.0. DESIGN LESSONS LEARNED

While the heating and cooling systems of Allen Hall provided conditions that met ASHRAE Standard 55 comfort zone criteria, the performance of the systems could be improved by providing better information and education for the occupants about the function and purpose of the systems. In many cases, building occupants were not fully informed of exactly how the heating and cooling systems operate, leading to unnecessary thermal discomfort and wasted energy. For example, occupants who wanted to open their office windows (for fresh air) saw warning signs and were in fear of disrupting the functioning of the mechanical systems and the thermal conditions of neighbouring offices. Those occupants reported using portable fans, which in turn consume additional energy. Thus, more instructive signage and explanations should be provided; training, office manuals, or even an indicator light, installed near the window, indicating appropriate times to open the window might be successful.

CONCLUSIONS

Through both quantitative and qualitative data collection, the hypothesis was proven to be partially correct. We hypothesized that occupants in Zone C would be the most comfortable. The occupant surveys for Zone C showed an average vote of “+0.5” on the thermal comfort scale for both the cool and warm seasons; falling between “-1.0” and “1.0” considered by ASHRAE to be comfortable. Zone A (-0.65) and Zone B (+0.38), both within the comfort range.

The physical conditions of all three zones also fell within the comfort zone criteria specified by ASHRAE 55. Zone C achieved a comfortable thermal comfort rating according to the occupants, while maintaining a temperature and humidity level deemed acceptable by ASHRAE Standard 55. On the other hand, Zone B also achieved thermal comfort according to both qualitative and quantitative data (Figure 11).

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