HOT LUNCH

A Post Occupancy Study of the Food For Lane County Building

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ABSTRACT

Recognized by the AIA for sustainable design excellence, the Food For Lane County building was an appealing subject for an Environmental Control Systems post-occupancy study. The building employs numerous passive strategies for heating, cooling and daylighting. Early investigations revealed that thermal stratification was making the offices on the mezzanine level uncomfortably hot. We hypothesized that overheating on the mezzanine correlated to the amount of direct insolation through the building's south-facing glazing. This hypothesis was a means of exploring a solution to the uncomfortably hot temperatures. Two weeks of temperature, humidity and light intensity data revealed that there was a strong correlation between light intensity and overheating. We found that the mechanically operated windows are not functioning, which prevents night flush-cooling and ventilation of the space, contrary to the architect's design intent. Additionally, carpet isolates the thermal massive floors from the space, thus preventing thermal temperance. Because the building employs so many innovative strategies, it offers a number of opportunities for further exploration.

1. INTRODUCTION

The Food For Lane County building encompasses 38,000 square feet of office, warehouse and commercial kitchen space in West Eugene and facilitates the distribution of 6 million pounds of food to 80,000 Lane County residents per year. Constructed in 1999, the building was designed by Galen Ohmart and Mike Hatten in consultation with G.Z. Brown of the University of Oregon Energy Studies and Building Laboratory. The structure incorporates a multitude of passive and active solar strategies such as south-facing glazing, abundant daylighting, solar shading devices, light-sensitive dimming fluorescent lights, automated night flush-cooling, stack ventilation and mechanically operable windows. In 2001, the building won the AIA National Architecture + Energy Sustainable Design Award.

Fig. 1: South façade of the Food For Lane County building.

The building's numerous energy-saving systems made it an attractive prospect for a case study. We simply had to determine exactly which system to examine. The answer came immediately after our arrival at the building, during a discussion with the building's operations manager, Ron Detwiler. Ron informed us that the office space on the mezzanine level was uncomfortably hot on sunny days regardless of the time of year. In fact, during the summer employees on the mezzanine routinely finish their workday at 2 o'clock, just before the heat grows to an unbearable level. After investigating other aspects of the building, such as the passive cooling in the warehouse, daylighting use, shading device performance and thermal mass, we concluded that studying the overheated mezzanine would offer the most design lessons. The persistent excess heat on the mezzanine level was a particularly intriguing phenomenon, considering that the building was painstakingly designed to avoid such thermal variations.

Fig. 2: Mezzanine office space with clerestory above.

Since Ron and other building occupants most commonly correlated clear, sunny days with the space being too hot, we chose to find if there is in fact a correlation between the two. Even a day generally considered clear and sunny often has short shady events. To deem a day sunny, we decided that the building must receive direct insolation more than 50% of the solar day. ASHRAE Standard 55 dictates a range of acceptable operative temperatures for any given humidity. The uppermost temperature for 1.0 Clo at very low relative humidity is 79^0 F.

2. HYPOTHESIS

On days when the Food For Lane County offices receives direct insolation more than 50% of the time, the space on the mezzanine level is warmer than acceptable by ASHRAE Thermal Comfort Standard 55.

3. METHODOLOGY

Our interest was to investigate the conditions and factors that contributed to uncomfortably high temperatures on the mezzanine level of offices at the Food For Lane County Building. Our approach was to collect a broad spectrum of both qualitative and quantitative information about the space so that we could begin to infer possible solutions to the overheating problem as well as create a base for further studies of the building. To test the hypothesis, we interviewed building occupants and measured light intensity, radiant surface temperatures, dry bulb air temperature and relative humidity.

Method:

(1) We observed the site for traces and modifications made to make the environment more comfortable. Additionally, we conducted informal interviews with approximately 25% of the building occupants.

(2) We talked with the building manager to better understand factors that may influence our results. Whereas we could not control the use of ceiling fans or open windows on the first floor, he did assure us that the windows in the clerestory would not be opened during the time we were testing. Additionally, he confirmed that the building is unconditioned on weekends, windows remain shut and the fans are never on.

(3) We measured dry bulb temperature, radiant surface temperature and light intensity in a variety of places to determine the best locations for long term data collection. These locations were selected because the conditions in these locations were constant and representative of horizontal layers that we identified to be key thermal zones in the building. All of the locations were centrally located in the building and equidistant from heating registers, windows and fans.

(4) Data loggers measuring dry bulb temperature, relative humidity, light intensity and logger battery voltage were placed at 1.5', 5' (head height), 8.5', 12' and 15.5' to monitor the first floor and 16' (3.5'), 19.5' (7'), 23' (10.5'), 26.5' (14') and on the clerestory sill (approximately 25'). (Heights in parentheses are the height above the mezzanine level.) Additionally, data loggers measuring dry bulb air temperature were placed outside in shady, protected places on the west and east sides of the building. Light intensity readings in front of the clerestory were used to determine presence of direct sunlight hitting the building.

(5) Data was collected at 10 minute intervals for 13 days to ensure that two weekends (time with no building occupants) and a broad mix of sunny and cloudy days were covered.

4. DATA AND ANALYSIS

Three of our data sets became corrupted for different reasons. The data loggers at 2’ near the ground floor and 19.5’ had inconsistent data due to bad batteries. Unfortunately the data logger at 19.5’ was the one collecting Mean Radiant Temperature data, so we have no MRT data. The data collector at 22’ collected consistent data, but at different intervals from the other loggers, so it is not easily comparable to other data collected, although it shows the same trend that other data showed.

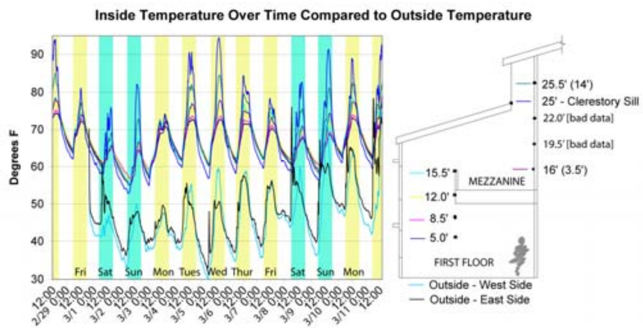

Fig. 3: Graph showing dry-bulb temperature at a series of vertical spaces inside the building compared with outside temperature on the west and east sides of the building. Color bars show approximate daylight times. Blue bars show weekend times when the building is unconditioned.

Fig. 3 shows the dry-bulb temperature at all of the other locations. Peak and low temperatures of the interior measurements line up exactly with those of the outside measurements, in other words, there is no thermal lag. Although the peak temperatures for the locations nearest the ground floor remain relatively consistent, the temperatures for the mezzanine level and clerestory vary dramatically. On March 4th, 5th and 9th a considerable amount of thermal stratification can be observed in Fig. 3. Additionally, first floor temperatures are much cooler than normal over the weekend when the building is not conditioned, while clerestory temperatures are still volatile. As expected, days with the highest temperatures tend, also, to have the lowest temperatures.

The period of Monday, March 3rd through Thursday, March 6th was selected for further analysis because it had two of the warmest and two of the coolest days in the data set and represents the general trends of all of the days observed. The range of relative humidity and dry-bulb temperature are plotted on the phychrometric chart in Fig. 4. Very little of the range actually fits in the human thermal comfort zone for one Clo as defined by ASHRAE Standard 55-2004. Interestingly, most of the time the building is cooler than deemed acceptable, however, this time is generally not during business hours. Of the four days plotted, only one high temperature fit nicely within the comfort zone, one day’s high is clearly above the zone, and the remaining two are on the border of too hot.

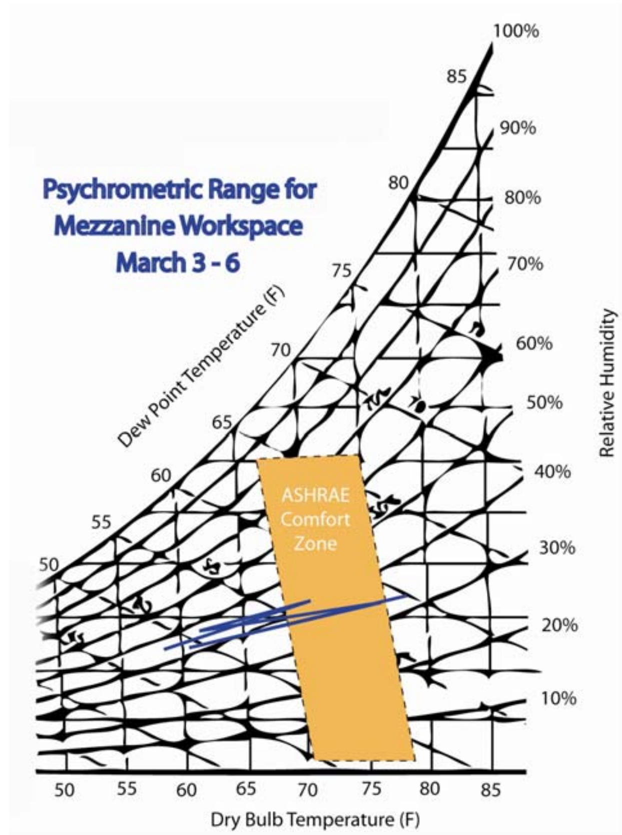

Fig. 4: Psychrometric chart showing relative humidity and temperature range at mezzanine level for March 3-6 referenced to ASHRAE thermal comfort zone.

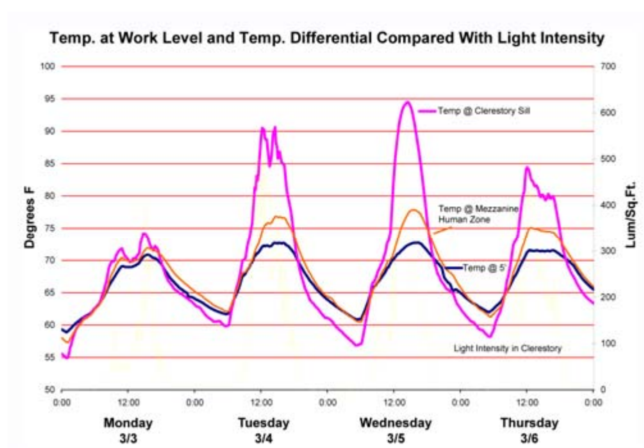

Fig. 5: Graph showing temperature at mezzanine level, ground floor and clerestory sill compared to light intensity in the clerestory.

Fig. 5 shows the temperature data of our lowest location, highest location and the mezzanine work level compared to the light intensity measured in the clerestory. The light intensity measurement was our primary means of determining if the building was receiving direct insolation. The amount of sunlight appears to correlate with the amount of thermal stratification in the space. Tuesday and Wednesday, the days with the most amount of direct light, had a large temperature difference from the clerestory to the first floor. Monday, when the building received very little direct sunlight, maintained temperatures in all locations that were nearly equal to one another. The temperature of the mezzanine work level also appears to correlate with the amount of direct sunlight. Tuesday and Wednesday are the hottest days of the set, while Monday is the coolest.

5. CONCLUSION

On days when direct sunlight reached the Food For Lane County building more than 50% of the time, the space on the mezzanine level was warmer than acceptable by ASHRAE Thermal Comfort Standard 55.

Dry bulb temperature in the mezzanine significantly correlated to the amount of sunlight striking the Food For Lane County building. More sunlight equaled higher temperatures. In fact, there was little or no time lag between the outside temperature and the inside temperature as the outside air grew warmer. This is likely due to several unrealized thermal moderators in the passive solar systems, such as inadequate insulation on the roof, and the presence of insulation (carpet) on the First Floor slab. Additionally, the mechanically operated windows malfunctioned not long after installation. This prohibited the automated night flush cooling, and seriously reduced the user-interface window operation.

6. DESIGN LESSONS

It is clear that the building is not currently operating in accordance with the architect's design intent. Most obvious is the lack of operability of the windows in the upper south façade and clerestory. The building was designed to utilize stack ventilation for night flush-cooling of the air mass and slab floors (see Fig. 6). Since the windows do not operate properly, they are only opened during the hottest season and not in sync with the heating and cooling requirements of the building. If a cost effective mechanized solution cannot be found, we recommend that a more easily accessible manually operated system is installed. This will allow the windows to be closed in the morning as outside temperatures rise and opened in the evening to permit night flush-cooling.

We observed that the open service door between the mezzanine offices and the warehouse cooled the office space rather quickly one hot afternoon. A solution worth exploring is to make the windows between the warehouse and office operable. Although this would assist the stack cooling of the offices, the effect on the natural ventilation of the warehouse should be considered carefully.

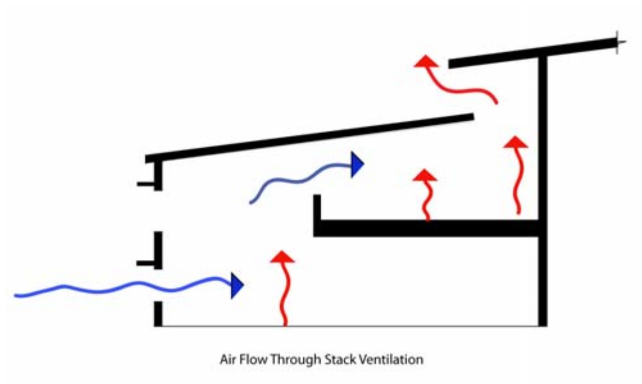

Fig. 6: Diagram of air movement through stack ventilation.

Flush-cooling is most effective when paired with thermal mass. We observed that there is no lag between the building's internal air temperature and the temperature of outside air. Additionally, the large thermal swing from one end of the ASHRAE specified thermal comfort zone to the other (particularly on the mezzanine level) indicates that the massive concrete floors are under utilized. The carpet covering the floor inhibits heat transfer to and from the concrete slabs. The slab would otherwise temper the thermal fluctuation in the space, delay peak temperatures on the hottest days until after business hours and help warm the offices on cool mornings.

Internal thermal loading is one of the primary considerations when designing office buildings. Since most office buildings, even in cool climates, require more cooling than heating, it is always desirable to minimize internal thermal loading. After an analysis of the office and personal electronics, electric lighting and human occupants, we determined that this office building has average to below average internal heat load density. The building, however, could be more efficient. We recommend the use of occupant sensor power controls for items like fans, lights and personal electronics to ensure that unnecessary heat is not being generated. Although photosensitive dimmers are in use in the warehouse space, we observed that the fluorescent lighting in the offices is continuously at full brightness regardless of the daylighting intensity. We even observed all of the lights on while driving by at midnight.

Direct insolation, is another critical factor in analyzing thermal loads of a building. We were concerned that there may be too much south-facing glazing on the building, so we calculated the glazing the floor area ratio. The Food For Lane County building's glazing to floor area ratio is 11.73%, just below the 12-24% recommended in MEEB, so we concluded that this is not a significant factor in the overheating of the space. If, however, this glazing is unshaded at critical times, it could be problematic.

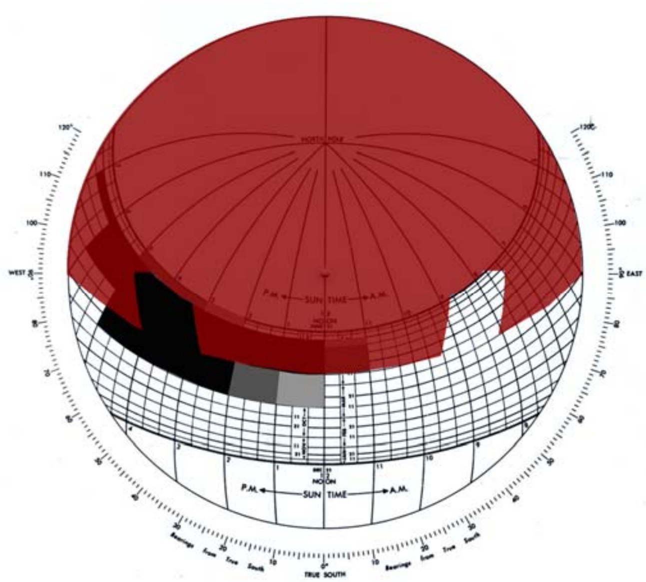

Fig. 7: Actual shading mask (red) of south facing shading devices overlaying ideal shading mask generated by SHADE2003.

Fig. 7 shows an ideal shading mask generated by the SHADE 2003 software using approximations of the space characteristics and occupancy use. A large number of variables go into the generation of the chart, so its accuracy is not particularly reliable. We set the cooling temperature to 72^{0}F since the space is not actively cooled. The red overlay is the actual shading mask of the shading devices on the building. It can be seen that a great deal of the shading parameters are not covered by the solar shades. It is unlikely that this is a large contributing factor to the overheating of the space, but the effectiveness of the shading devices is a topic worth further investigation. Although blocking insolation outside of the building envelope is the most efficient means of controlling solar heat in a building, we recommend that the building occupants experiment with the use of internal shading devices to better mitigate glare and overheating.

7. <u>REFERENCES</u>

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