SIZZLING SHOWCASE:
TEMPERATURE STUDY OF THE ADELL McMILLAN GALLERY AT THE UNIVERSITY OF OREGON ERB MEMORIAL UNION

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ABSTRACT

In examining the Adell McMillan Gallery in the EMU, our team sought to shed some light on what factors could be causing the room to feel so much warmer than adjacent spaces. Major factors that we investigated were the radiant floor heating system (controlled by set point outdoor temperature), the large gallery display lights, and solar gain through the windows of the room (facing west). After monitoring the gallery's air temperature during entire days with the lights off and with them on, cloudy and sunny, our results suggest that operation of the lights increases the average temperature of the room throughout the day, and that the amount of sunlight entering the room in the afternoon effects the peak temperature the room achieves each day, which occurs during the afternoon. We also investigated floor surface temperatures in the gallery and found them to be generally higher when the lights are on, but the temperature pattern over the floor seems largely the result of the radiant heating system being located only under the western half of the floor.

1. INTRODUCTION

Built in the 1950s and having undergone one major expansion since, the Erb Memorial Union (EMU) functions as the heart of our campus, providing vast amounts and varieties of space for academic interaction/exploration, campus events, eating, and relaxation. The particular space we studied, the Adell McMillan Gallery, displays work by anyone from students to international artists during month-long exhibitions. The gallery is located on the second floor, directly above the Taylor Lounge.

Fig. 1 The Adell McMillan Gallery, from the south, near the top of the main EMU stairs.

We stumbled upon this space while walking around the EMU, searching for "thermal differences" in the building to study. Despite being spatially connected to the main stair area and the foyer to the EMU ballroom, the gallery felt significantly warmer than adjacent spaces. The gallery is organized in such a way that there is a distinct division created between the western and eastern sides of the room by a row of structural columns. At ceiling height between the columns is an array of gallery lights, intense enough for one to directly feel their heat when standing below them. On our second pass through the space, we realized that one half of the room (western side) was noticeably warmer than the eastern half, despite having the same lighting conditions. We spoke with an employee who

Fig. 2 A view down the warmer west side of the gallery, beneath which the room's radiant heating system is located.

was setting up the gallery and mentioned the warmth of the floor. This inspired further examination on our part, and we learned that the gallery is heated by a radiant under-floor system, located only under the western half of the room, whose heat output is determined based upon the outdoor air temperature (set point). Our attention was also drawn to the effect that solar gain during from the row of windows along the gallery's western wall could have during afternoons.

We investigated various factors that could bear upon the excessive feeling of warmth in the gallery as well as upon the temperature differences within the space: the nature of the radiant floor heating system, the intensity of the gallery lights, and solar gain through the windows. The various thermal influences to study and test, and the impact that the warmth of the space had on those within it were draws that inspired us to learn more. It has lead to a full-fledged testing of the gallery on our part; our process and findings to be revealed below.

2. HYPOTHESIS

The Adell McMillan Gallery is 5˚ F warmer than the adjacent vestibule at the top of the main EMU stairs.

3. METHODOLOGY

In order to examine the extent to which the gallery is warmer than adjacent rooms and to investigate possible reasons for this temperature discrepancy, we made two data collection efforts. First, we monitored the ambient temperature in different parts of the gallery, and then we examined the surface temperature of the gallery floor.

Air Temperature

- We arranged to collect data during four twenty four-hour periods (midnight – midnight) under different conditions—1) Tuesday 4 March: display lights *on*, generally sunny weather; 2) Wednesday 5 March: display lights *off*, generally sunny weather; 3) Thursday 6 March: display lights *off*, generally cloudy weather; and 4) Friday 7 March: display lights *on*, generally cloudy weather.
- By collecting ambient temperature data *for an entire twenty four-hour period* for the different sets of conditions, our intention was to control for the various variables stemming from time of day that could have compromised our data, such as occupancy. Additionally, each data collection period was on a weekday, meaning occupancy patterns were likely not too different each day, and *all* the data collection periods saw an event held in the EMU ballroom (which tends to increase traffic in the gallery). We considered the radiant heating system as having a constant effect, since its heat output is based solely on outdoor temperature and heat output fluctuation based on this

Fig. 3 The gallery display lights.

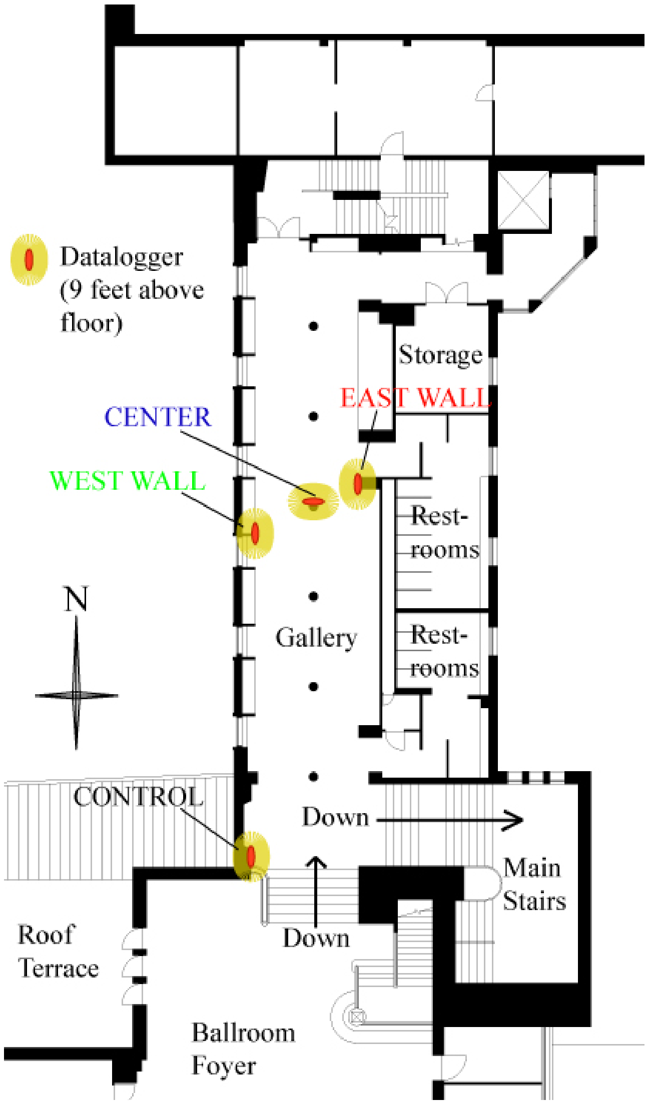

Fig. 4 Plan of the Adell McMillan Gallery and datalogger locations for our tests.

would only counteract fluctuations in heat loss to the exterior.

- For each data collection period, we positioned 4 Onset dataloggers at a height of approximately 9 feet (to prevent tampering with the equipment during data collection)—one on the west wall of the gallery, one on a middle column in line with the first Datalogger's position, another on the east wall in line with these first two, and a final one in the vestibule at the top of the stairs to the south of the gallery, to provide data for control conditions (see figure 4).
- We programmed the dataloggers to begin measuring temperature and light intensity at midnight on Tuesday 4 March. The light intensity measurement would help give us an idea of the amount of solar gain during the different testing periods and help us see more specifically what relationship this has with the gallery's temperature.

Floor Surface Temperature

- During the afternoon on Thursday 6 March (lights off, generally cloudy weather) and Friday 7 March (lights on, generally cloudy weather), we used a Raytek temperature gun to measure the surface temperatures on the whole gallery floor.
- To do this, we established a grid whose north-south coordinates were based on the columns and the edges of windows and whose east-west coordinates were 3 feet, 6 feet, 10 feet, and 12 feet from the western edge of the room as well as this and the eastern edge (see figures 13 and 14 for locations of the coordinates on this grid).
- We then used the Raytek tool to measure the surface temperature of the floor at each of the 114 different coordinate points on this grid. We did not actually mark the grid on the floor, but rather used a tape measure to determine the distance from the west wall and referenced the columns and windows for the north-south coordinates.
- By collecting this information around the same time (early afternoon) on both instances, we controlled for the time of day and its related variables.

4. DATA AND ANALYSIS

Tables 1 through 4 summarize our air temperature and light intensity results. From these results, the air in the gallery is clearly warmer than the air in adjacent spaces, as our hypothesis predicted. Indeed, the daily average temperatures recorded by the dataloggers within the gallery were from 3˚ F to 4˚ F warmer than those recorded by the control datalogger for all four days, regardless of sun and mechanical lighting conditions. Furthermore, irrespective of these factors, our results indicate that there is, an air temperature gradient from the east to the west side of the gallery, with the west being the warmest. The graphs in figures 5, 7, 9, and 11 also reveal this trend, since the lines for the four different dataloggers tend to be fairly well stratified, with the west wall temperature the highest line and the control temperature by far the lowest line.

We also found that days during which the lights were left on were, on average, approximately 1˚ F warmer than days during which the lights were turned off. This held true regardless of average light intensity (or whether the day was sunny or cloudy). However, the higher temperature of the gallery cannot be solely attributed to the mechanical lighting, since, tables 1 through 4 and the temperature and light intensity graphs in figures 5 through 12 illustrate that the peak (afternoon) temperature for both days that had the lighting system on *and* days that had the lighting system off

TABLE 1: SUMMARY DATA—TUESDAY 4 MARCH (LIGHTS ON, MOSTLY SUNNY)

Sensor Location	Average Temperature Over 24-hour Period (˚F)	Average Temperature During Afternoon, 12:00-18:00 (˚F)	Average Light Intensity During Afternoon, 12:00-18:00 (lum/ft²)
West Wall	76.8	77.6	23.2
Center	76.4	76.8	26.1
East Wall	75.7	76.2	46.4
Average Within Gallery	76.3	76.9	31.9
Control	72.4	72.2	1.9

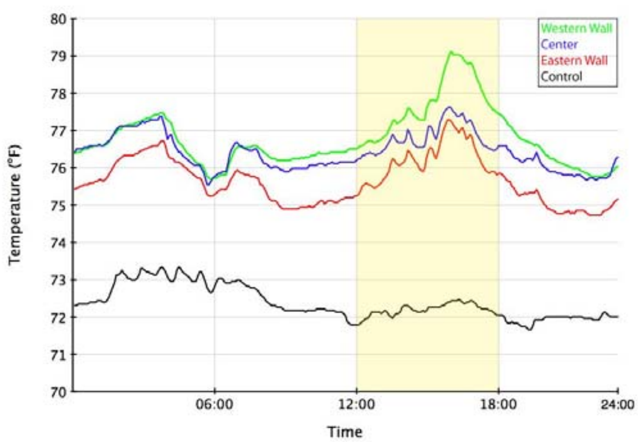

Fig. 5 Temperature measurements—Tuesday 4 March (Lights on, mostly sunny) (afternoon peak period shaded)

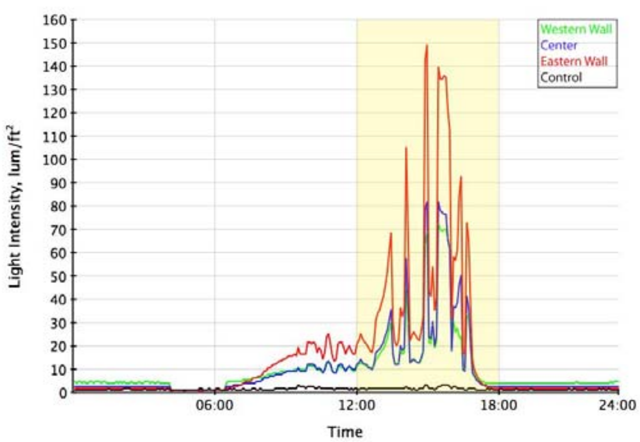

Fig. 6 Light intensity measurements— Tuesday 4 March (Lights on, mostly sunny) (afternoon peak period shaded)

TABLE 2: SUMMARY DATA—WEDNESDAY 5 MARCH (LIGHTS OFF, MOSTLY SUNNY)

Sensor Location	Average Temperature Over 24-hour Period (˚F)	Average Temperature During Afternoon, 12:00-18:00 (˚F)	Average Light Intensity During Afternoon, 12:00-18:00 (lum/ft²)
West Wall	76.0	76.7	27.8
Center	75.6	75.7	35.6
East Wall	75.1	75.5	64.9
Average Within Gallery	75.57	75.97	42.77
Control	72.2	72.0	2.2

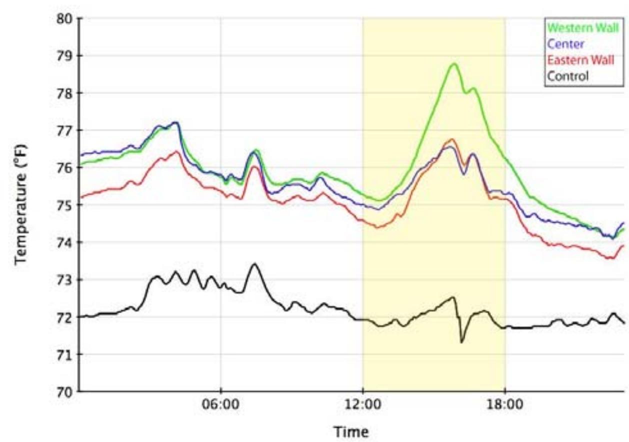

Fig. 7 Temperature measurements—Wednesday 5 March (Lights off, mostly sunny) (afternoon peak period shaded)

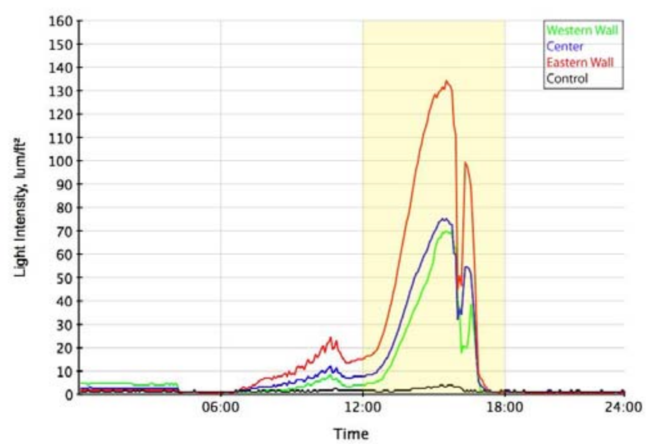

Fig. 8 Light intensity measurements—Wednesday 5 March (Lights off, mostly sunny) (afternoon peak period shaded)

TABLE 3: SUMMARY DATA—THURSDAY 6 MARCH (LIGHTS OFF, SOMEWHAT CLOUDY)

Sensor Location	Average Temperature Over 24-hour Period (˚F)	Average Temperature During Afternoon, 12:00-18:00 (˚F)	Average Light Intensity During Afternoon, 12:00-18:00 (lum/ft^2)
West Wall	75.5	76.2	18.3
Center	75.0	75.3	24.7
East Wall	74.8	75.4	43.4
Average Within Gallery	75.1	75.63	28.8
Control	72.1	72.1	1.9

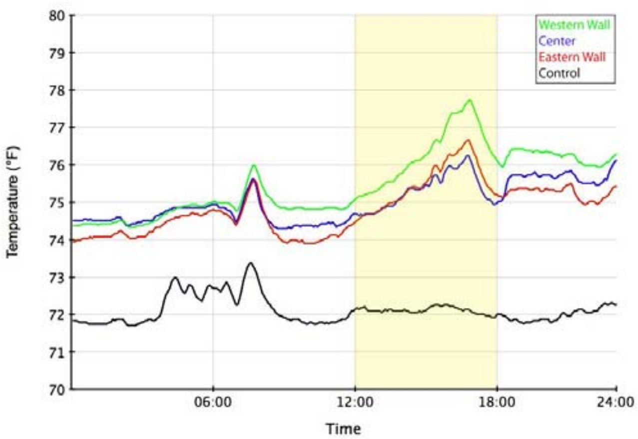

Fig. 9 Temperature measurements—Thursday 6 March (Lights off, somewhat cloudy) (afternoon peak period shaded)

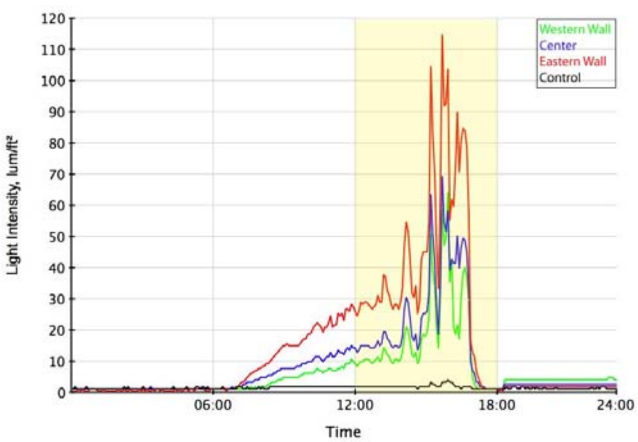

Fig. 10 Light intensity measurements—Thursday 6 March (Lights off, somewhat cloudy) (afternoon peak period shaded)

TABLE 4: SUMMARY DATA—FRIDAY 7 MARCH (LIGHTS ON, MOSTLY CLOUDY)

Sensor Location	Average Temperature Over 24-hour Period (˚F)	Average Temperature During Afternoon, 12:00-18:00 (˚F)	Average Light Intensity During Afternoon, 12:00-18:00 (lum/ft^2)
West Wall	76.6	77.3	8.8
Center	76.2	76.7	8.2
East Wall	75.6	76.3	12.9
Average Within Gallery	76.13	76.77	9.97
Control	72.1	72.1	1.4

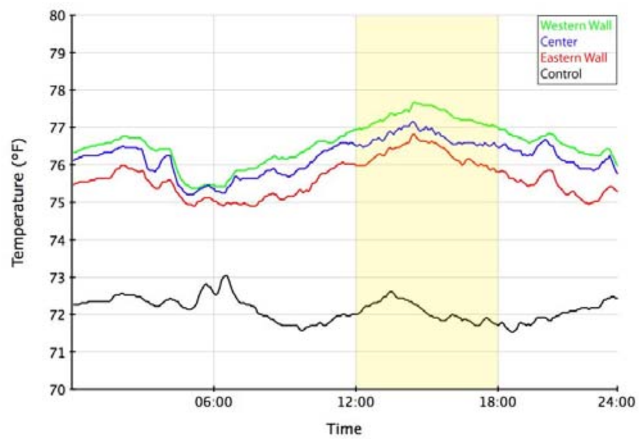

Fig. 11 Temperature measurements—Friday 7 March (Lights on, mostly cloudy) (afternoon peak period shaded)

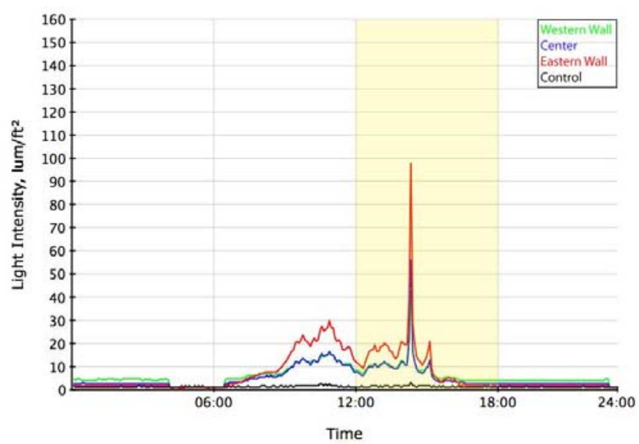

Fig. 12 Light intensity measurements—Friday 7 March (Lights on, mostly cloudy) (afternoon peak period shaded)

had a direct correlation to the amount of sunlight penetrating the gallery through its western windows. In general, both the temperature and the light intensity graphs have sharp peaks from about noon until 18:00, suggesting that it is the amount of solar gain that causes the afternoon temperature peaks. On the cloudier days, with lower average afternoon light intensity, the temperature peaks are slightly lower (with maximums around 77.7˚ F, see figures 9 and 11) than on sunnier days (with maximums around 79˚ F, see figures 5 and 7). Thus, our data indicates that differences in peak afternoon temperatures, and the fact that there *are* these prominent temperature peaks during the afternoon, may be due to differences in the amount of sunlight the gallery receives through its western windows. Also, since for both cloudy and sunny days there is an average of 1˚ F difference between when the mechanical lighting system is on and when it is off, we are able to attribute that 1˚ F difference in the *average temperature throughout the day* to the lighting system fairly confidently. It should be noted that the control datalogger did not see the extreme variability in temperature throughout each day that those in the gallery itself did, since the control datalogger was located in a space that does not receive any direct sunlight.

With regard to solar gain, the interior shading devices that once prevented solar radiation from over-heating the space have been removed as a result of vandalism, allowing for the sun's rays to have a larger than planned impact on thermal comfort within the gallery. Still, our investigation suggests that solar gain and the display lighting system are not the only causes behind the gallery to be warmer than surrounding rooms.

The maps in figures 13 and 14 below show the gradient of surface temperatures on the floor of the gallery. While our air temperature data show that the air tends to be slightly warmer on the west side of the room, the data in these temperature maps show clearly that the *floor* of the west side of the room is much warmer than that of the east side. The surface temperature of the floor on the two sides of the room differed by as much as 18˚ F. This temperature discrepancy is almost surely due to the fact that the radiant heating system runs only under the western half of the floor, its eastern boundary being the row of columns. The floor temperatures were generally slightly higher for Friday 7 March, when the display lights were *on*, suggesting the lights have a small impact on the floor temperature. Still, the overwhelming pattern of floor temperatures appears to be due to the location of the under-floor radiant heating lines.

Learning that the output of the radiant floor heating system is determined by *outside temperatures alone* also shed some light as to why this space felt warmer than the adjacent spaces. With shading devices removed, and the lighting system on twenty-four hours each day, the room will over-heat because the radiant floor heating does not factor in the

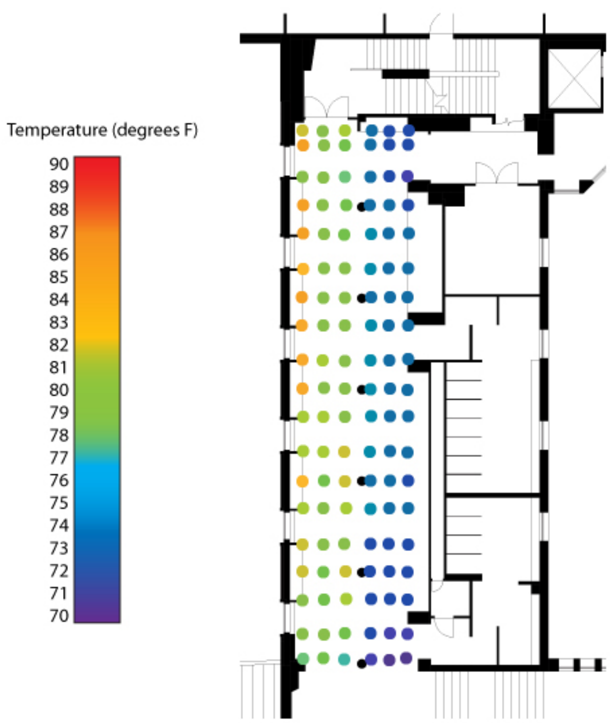

Fig. 13 Floor surface temperature map—Thursday afternoon 6 March (Lights off, somewhat cloudy)

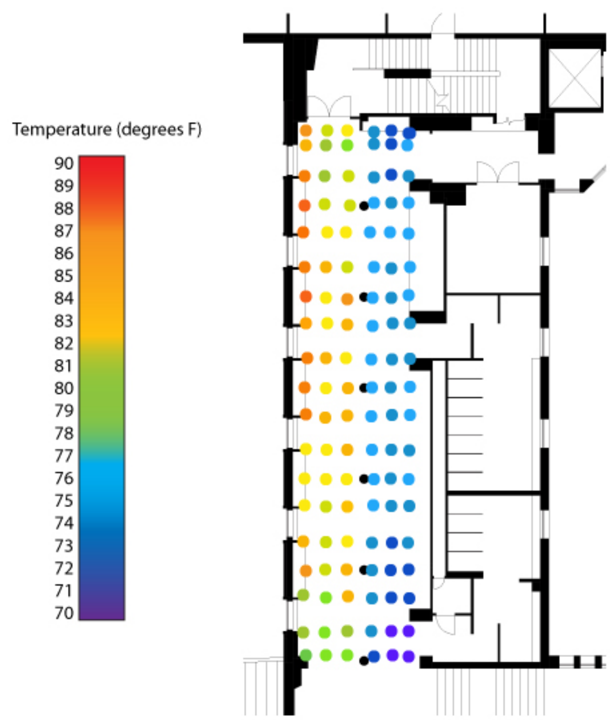

Fig. 14 Floor surface temperature map—Friday afternoon 7 March (Lights on, mostly cloudy)

heat output from solar and mechanical lighting radiation. As sunlight and the display lights heat the space, the radiant floor heating remains on just as if these gains were not occurring, as a result of its activity being determined solely by outside air temperatures.

5. CONCLUSIONS

According to our investigation, the Adell McMillan Gallery was warmer than the adjacent vestibule at the top of the main stairs; however, the temperature difference was less than the 5˚ F predicted in our hypothesis. During our investigation as to why this space in particular felt so much warmer than the nearby rooms, we learned several facts significant to the thermal performance of the gallery: firstly, the room is heated by a radiant floor heating system that is controlled by a set point outside air temperature; second, the space has substantial glazing on its western wall which was previously shaded until vandalism of the shading devices forced their removal; and lastly, that a row of lights down the center of the gallery were on twenty-four hours a day, seven days a week. We determined that because the radiant floor heating is controlled by the outside air temperature, it was negligible in determining the cause of the over-heating taking place within the gallery (since changes in the system's heat output should theoretically make up for changes in heat loss to the exterior). Our team therefore chose to monitor the light intensity, air temperature, and floor surface temperature of the space during four twenty-four hour periods; two of which allowed the lights to remain on, and two of which required the lights to be turned off.

The data collected shows that regardless of how sunny each day was, the days during which the lights were off achieved lower daily average temperatures. By monitoring the light intensity we determined that each forty-eight hour period had one sunny day, and one cloudy day within it, giving us fairly equal conditions for monitoring the mechanical lights. There is a direct correlation between the peak light intensity of each day of data collection, and the peak temperature recorded; however, even the sunny day with the lights off had a cooler *average* temperature *for the entire day* than did the cloudy day with the lights on. This leads us to conclude that regardless of external weather conditions, the mechanical lighting system affects the overall thermal comfort of the space.

Further study along the same lines as our investigation could be useful in gaining more accurate and specific information. Four days of data collection is really a fairly small sample size, and testing over more days would increase the ability of the data to be representative of real, long term conditions. Moreover, study of the thermal performance of the gallery during different seasons would also be useful, and could show significant differences in the space's thermal performance.

6. DESIGN LESSONS LEARNED

This study sheds light on several design issues related to energy use and human comfort. First of all, it would seem that the McMillan gallery could simply be kept at a lower temperature in general. While the temperatures in the gallery tended to be within the U.S. comfort zone of 69˚ F to 80˚ F (Heschong 16), the effect of being in contact with a warm, radiantly heated floor may reduce the effective air temperature to which the room needs to be heated to achieve comfort, although our research did not extend to considerations of subjective comfort. Another thermal improvement that would be significantly beneficial to the gallery would be for the heat output of the radiant system to take into account not only external temperatures, but also *internal* sources of heat, such as the gallery lights and afternoon solar gain through the windows. Possibly, this could be as simple as installing an *indoor* thermostat, although we do not have the information necessary to asses how difficult it would be to install the necessary wiring and integrate the thermostat into the existing heating system. Such an improvement, however, would allow the system to use less energy and generate less heat when other sources are already providing some heat to the room.

In addition, our investigation made evident the value sunlight can have as a heat source. The afternoon solar gain had a significant impact on the temperature in the gallery. Thus, combined with a heating system that takes solar gain into account, even in spaces not specifically designed to be passively heated, solar gain can be used to advantage, reducing the energy use required by the heating system. In the McMillan gallery, the previously discussed changes in the heating system could allow the space to take advantage of solar gain for heating during the heating season. When this sunlight is not desired, exterior shading devices and adjustable interior shades (assuming the problem of vandalism can be overcome) could be used. Also, even with the heating system as it currently exists,

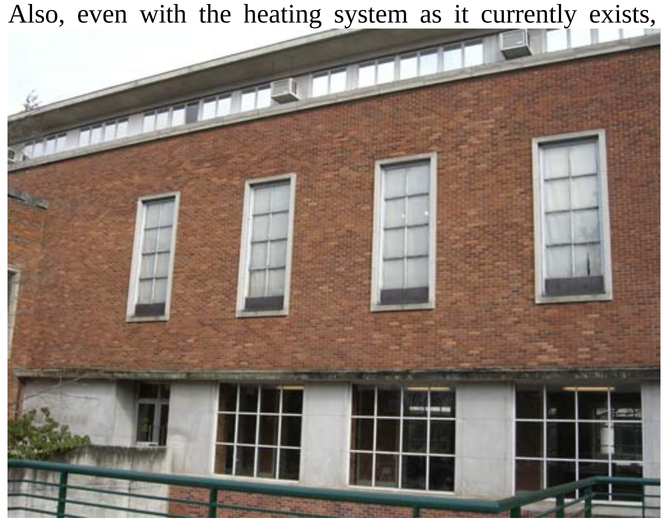

Fig. 15 Exterior shading devices may be able to improve the thermal performance of the McMillan gallery.

shades could still be quite useful in blocking solar gain during the afternoon, which right now merely increases the temperature of the room to possibly uncomfortable levels.

7. REFERENCES

Heschong, Lisa. Thermal Delight in Architecture. Cambridge, Mass: MIT Press, 1979.

8. ACKNOWLEDGEMENTS

We would like to thank the several people who helped us along our way and made possible this research. First of all, we would like to offer our gratitude to EMU Facilities Director Dana Winitzky for his permission to investigate the gallery and his information about the building. We extend our thanks to his assistant Erin Siegrist as well, for her help, information, and for directing us to all the other people involved. Our thanks also go out to Mandy Chong, EMU Cultural Forum Office Manager, for arranging to have the gallery lights turned off when we needed, her information about the gallery, and for tipping us off to the significant impact the sunlight conditions have on the thermal performance of the gallery. We are grateful to David Flock of EMU maintenance for sharing with us his knowledge of the building's mechanical systems and helping us to understand the workings of the heating system in the gallery and what effect that would have on our investigation. Additionally, we would like to thank the EMU custodial staff who operated the lights and turned them on and off to allow us to do our testing.