The Vital Signs Class IV

A CERES Student Scholars Program

Figure 1: South side exterior elevation. Within the highlighted square is the location of the two offices in the study.

Ball State University Alumni Center Lighting Study

Visual Discomfort in South Side Offices

1998

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Abstract

This report is the product of a four-month field study of the southern office spaces found within the Ball State University Alumni Center in Muncie, Indiana. We hypothesized that the visual discomfort experienced in these offices was a result of the combined effects of high levels of illumination, material reflectance, and resulting brightness contrasts in the occupant's field of view. Office 255, most representative of the offices within the wing, and office 256, most unique in its layout, orientation and size, were the subject sites of the study.

We focused on two major times within the normal workday, mid-morning and mid-afternoon. Measurements were taken at times of sunny and overcast conditions. Luminance-spot readings were taken to identify the reflectance of surfaces and contrast ratios within the workspace. Illumination was recorded at the work-plane level throughout the room. From these readings we created isolux contour maps, showing the distribution of light in the room. Long-term illumination readings were taken to gain a better range of best to worst case scenarios for each office. We also photographed the offices from different perspectives, showing the differing levels of luminance. Additionally, we recorded each occupant's comments about the lighting environment as it affects their daily activities.

We found that the visual discomfort experienced in the south-side offices was not rooted in the high reflectance levels of the surfaces as we initially thought. Rather the discomfort was a result of more than one factor. High contrast ratios proved to be a problem in the standard office. Veiling reflections were present in both offices under sunny conditions, but played more of a factor in the unique office space. Also, the factor of office width was a main concern for the occupant of office 256. This was because the sun was able to creep deep into this office space. Finally, affecting each of these factors, the high amount of illumination entering the offices was an element that must not be overlooked. The shades currently hanging in the windows have not solved the problems for the office employees, nor will any higher grade of opacity of a similar shade. Unless the shade was 100 percent opaque, contrast ratios would still present a problem. What would help alleviate the occupants' discomfort, without changing the outside appearance of the building, is a two-part solution. The current shades at 80 percent opacity should remain, but additionally, venetian blinds would need to be installed just inside the shades as to direct external light coming into the office up onto the ceiling rather than directly on the workspace.

Introduction

This lighting study of the Ball State University Alumni Center was conducted through a course entitled Vital Signs IV, offered through the Center for Energy Research/ Education/Service (CERES). CERES is an interdisciplinary academic support unit focused on issues related to energy and resource use, alternatives and conservation. The Vital Signs Program was developed through the University of California, Berkeley, Center for Environmental Design, and is funded by the Energy Foundation, Pacific Gas and Electric, and the National Science Foundation. Students currently enrolled in this program at Ball State University, are either studying in the College of Architecture and Planning or in the Honors College.

Ball State University's new Alumni Center opened in November of 1997. It is located on the Northwest side of campus adjacent to the Scheidler Football Stadium. It is a conference, reception and event center available for use by the university administration, faculty, staff, and students. The 50,000-square-foot facility houses the departments of Alumni Association, University Development, University Relations and University Foundations. Along with the departmental offices which mainly occupy the second floor, the building includes a major assembly hall, break-out conference and meeting room space, a board room, the Alumni Library, a conservatory, and reception and lobby spaces.

The internationally renowned architectural firm Pei Cobb Freed and Partners, designers of such buildings as the addition to the Louvre Museum in Paris and the Holocaust Museum in Washington, D.C., designed the building. Jim Freed was the principal designer. In the initial stages of the design, there were two overriding concerns. The first involved the site. The designer faced the problem of constructing a two-story building next to a stadium without having the stadium overwhelm the site. The second concern dealt with the evolution of the shape of the building. The designer needed to create a building that could be approached and experienced from all sides. By drawing a line from the southwest corner of the football stadium to the southwest corner of the site, the rectangular plot of land was divided into two triangles. Thus the triangular shape took form. Internally the triangular shape also allowed the second floor of the building to be divided in such a way that the three branches of University Advancement could share a common space yet still hold their individual identities as seen in *figure 2*.

The layout of the two office spaces selected for this study is seen in *figure 3.* Office 255, most representative of the offices found on the south side of the building, appears to be rectangular in shape with approximate measurements of 10 feet by 15 feet. Florescent bulbs fixed in the ceiling supply the artificial lighting in this office. Approximately 50 square feet of glass create the two large windows running the entire width of the office on the south wall. Shades covering the windows are a cream color and 80 percent opaque. The other three walls are white and textured. Desks, tables, and bookshelves are the color of natural wood with a glossy varnish. Carpeting and upholstery are deep red in tone. The occupant's desk and computer are placed against the east wall, only a few feet from the window. A table sits in the northeast corner and the door is on the north wall in the western corner. Office 256, unique in its layout and shape, is similar in its color scheme and the materials used. However, office 256 is approximately 15 feet by 15 feet. It

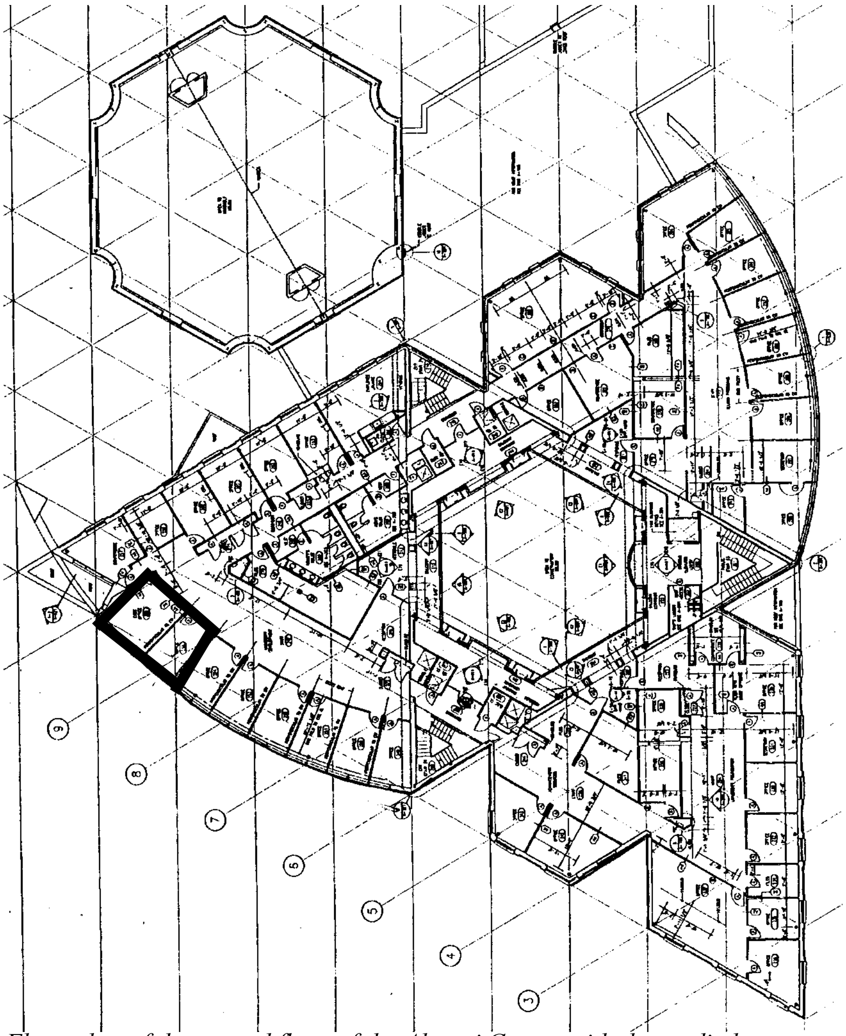

Figure 2: Floor plan of the second floor of the Alumni Center with the studied rooms highlighted with black box.

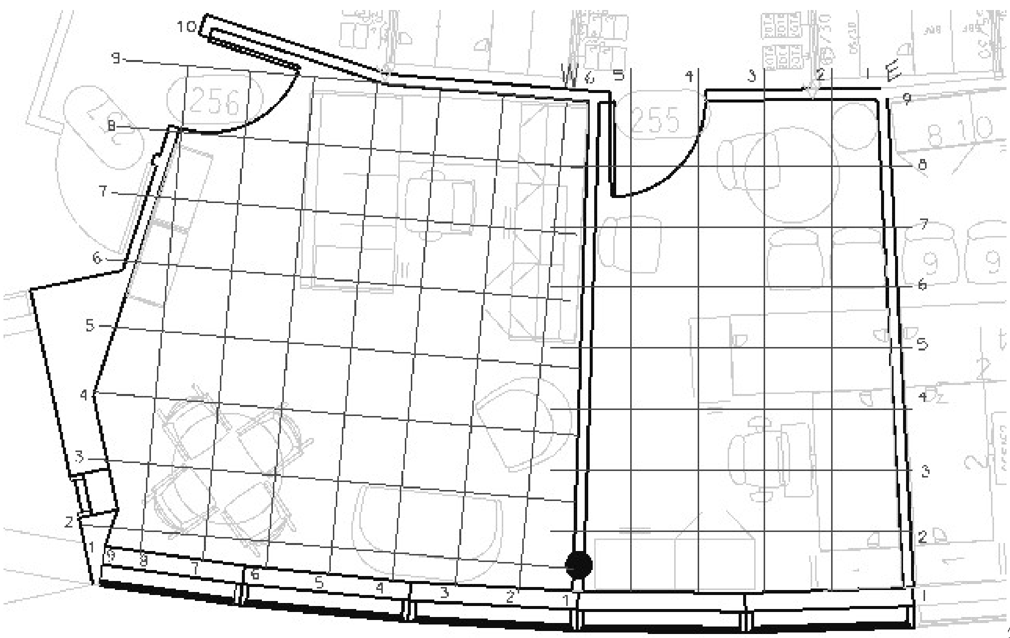

Figure 3: Layout of the two offices studied with a ceiling grid overlaid.

Introduction Continued

appears to be more square-shaped, but narrows in the northern portion in the office. Having five extra feet of width, there is an additional large window on the south wall. There is approximately 75 square feet of glass creating the windows. Fluorescent bulbs fixed in the ceiling as well as two incandescent table lamps and one incandescent task lamp provide the artificial lighting. The occupant's desk and computer are placed in the northeast corner, against the north wall. A worktable sits in the southwest corner of the room a few feet from the window. There is also a small couch and sitting area in the northeast corner of the room. The door is on the west wall in the northwest corner of the office.

Our study focuses on these office spaces, found within University Development, located on the south side of the building. We decided to study the south side offices, as opposed to the northwest or northeast offices, after consulting the building manager, Matt Stevenson. He informed us that most complaints concerning the rooms being "too bright" came from the employees of University Development. Stevenson's suggestions, these complaints, and our interest in helping solve a chronic problem for a group of professionals all contributed to the genesis of this project. Preliminary readings and interviews led us to focus our hypothesis on visual discomfort.

Figure 4: View out door of office 255 from the desk showing high brightness contrast between office and hallway.

Figure 5: View from office 255 occupant's desk to where a guest would sit.

Hypothesis

Visual discomfort experienced in the south side offices is a direct result of high contrast ratios in the work environment and high levels of illumination. The orientation of the light entering the office creates drastic shadows on various surfaces within the office space. The high levels of illumination entering the office, which also causes several different light levels throughout the office space, mainly cause the visual discomfort. This is primarily caused by highly reflective surfaces receiving high levels of illumination within one's field of vision while at his/her workspace.

Instrumentation

In the process of gathering our data, we used the following equipment. For illumination readings, we used the *Sylvania digital light meter*, model DS-2000; a hand held tool which measures light in foot candles. Another hand held meter we used to measure illumination was the *General Electric analog light meter*, model 217, which could read up to 10,000 foot candles. This was useful in taking outdoor illumination readings. Long term lighting and temperature measurements were taken with *HOBO* and *Stowaway* data loggers, manufactured by Onset Instruments. These meters take readings in Lumens per square foot or temperature, and are able to store data for later connection to a computer. This data could be downloaded onto a computer using BoxCar Pro version 3.51 and could then be transferred into an Excel spreadsheet. To obtain our luminance readings we used the *Minolta luminance spot meter*, model LS-100. This instrument takes readings with a one-degree acceptance angle within a nine-degree field of view across the space. Then it averages these readings, and displays this number as the luminance of that surface. Instruments we used to photograph the offices include a Pentax 35mm camera and a digital camera. Adobe Photoshop and Microstation software were then used for image manipulation. The final paper was produced in Microsoft Word 97 and Adobe PageMaker 6.5

Figure 6: View of north desk workspace in office 255.

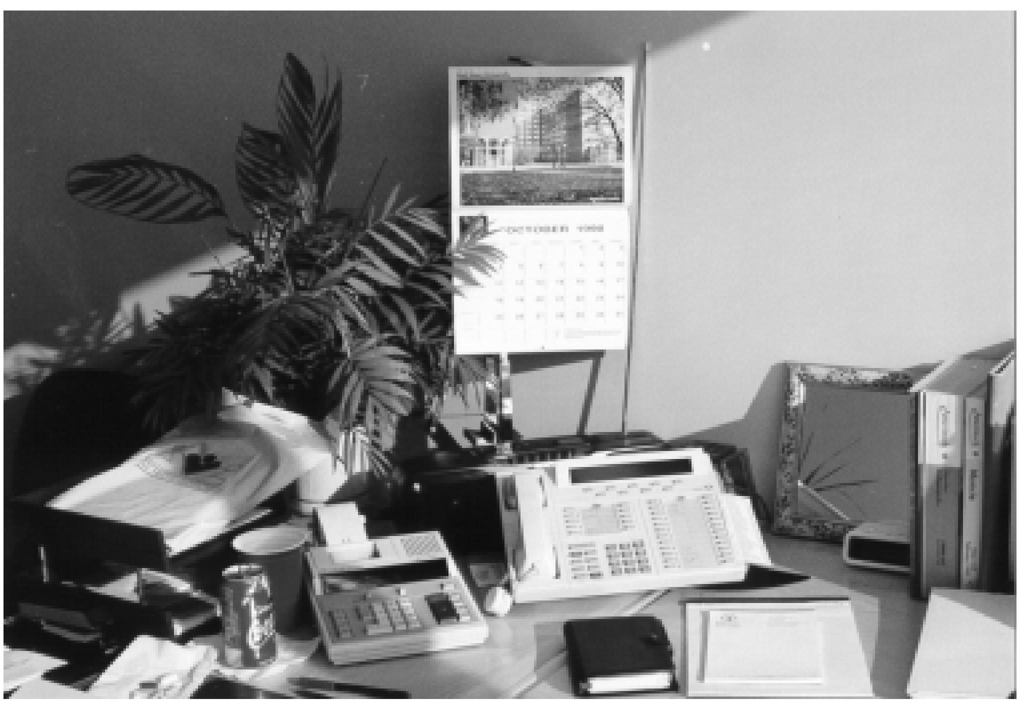

Figure 7: View of shadows that existed on east side of office 255 during a sunny afternoon.

Research Methodology

Through this study, we analyzed the contrast ratios in south side offices 255 and 256 by taking luminance readings of each environment. This was followed by illumination readings so that we could obtain reflectance values, amount of light each surface was receiving, and readings to show the difference between an area in the sun and one in shadow.

Exploration of Space: The first visit was one of exploration of the space to obtain an understanding of what we were dealing with. Some views of office 255 can be seen in *Figure 4 thru 8.* This visit consisted of the documentation of the size of office 255 by counting the number of tiles on the ceiling and transferring this grid to a sketch we had of the room. Based upon this grid we located the furniture in the room to give some relevance to the readings we took. We proceeded to take illumination and luminance measurements in the afternoon along both the east and west walls to obtain the reflectance value of the walls within the office spaces. Also, we obtained afternoon illumination and luminance readings of the main surfaces such as the desk, other work planes, and chairs throughout the room for the purpose of having their reflectance values. Before leaving the offices for the day, we placed the *HOBO* instruments in the room. We placed one at the window on the southeast side and one on the northeast side of the room on the table. This was to obtain light levels through time on work-planes at opposite ends of the office. The location of these instruments can be seen later in the Findings section of our paper. *See Figure 24.*

Defining the Room: With our second visit we brought a tape measure and measured the room to obtain a more exact drawing of the space. We also obtained the exact size of all the furniture located in office 255 and the placement of it in the room. We later obtained from Dan Stevenson of Ball State University a computerized furniture layout of our two rooms in the study so we could compare our measurements. This acted as a check against our measurements, to make sure we had taken our measurements accurately.

Sunny afternoon: On our second visit we retrieved our *Hobo's* that we placed on the first visit as to download the data and replaced them with the Stowaway instruments. We placed one Stowaway on the southwest window ledge and another in the northeast corner of the office on the floor with the Stowaway temperature device. This was a test to evaluate the effect on the air mass. It also provided a check to verify that discomfort in the offices was not due to the air system in the building not working properly. Realizing that this did not pertain to our hypothesis this information was excluded from the report but can be found in

Procedure at Normal Visit:

Isolux Contour: We used the GE light and Sylvania light meters to produce an isolux contour map at the work-plane level of the office. Our readings were obtained relative to the ceiling grid in the offices.

Luminance: We used the digital camera to take views within the offices and at the same time we shot readings of the views with the Minolta Luminance Meter so that we could construct contrast ratio images.

Box 1: Lists the procedure of activities that occurred on multiple office visits.

Figure 8: View of office 255 computer work environment on a sunny afternoon with the areas of veiling reflections noted.

Figure 9: Luminance contrast at the computer in office 255 on a sunny day.

Appendix B. The temperature Stowaway was also placed next to the Stowaway measuring light, as to make sure that this meter was not being hit directly by any beams of natural light. To finish the visit we created an isolux contour map. The procedure can be found in *Box 1* under *isolux contour.*

Artificial Lighting: We obtained the wattage of the fixtures in office 255. A plan of the office's light fixtures was then produced to help us understand the effect of fluorescent light in relationship to that of natural light. This was important to our study since both office occupants have their lights on at all times when they are in the office.

Sunny Morning: We made a return trip on a sunny morning to obtain another isolux contour map, procedure can be found in *box 1* under *isolux contour.* The morning hours needed to be studied since this was a period of time that the occupants found themselves feeling less or no discomfort in the work environment. This also allowed us the opportunity to gain visual observation in the morning as to avoid a study that is not solely based upon raw data. In discussing the issue of comfort, humans are the best judges of such qualitative observations. Also, including the morning readings in the report allowed us to show more than the worst-case scenario, the harsh afternoon winter sun. During this visit, we gathered all our long-term instruments that were still in place in office 255 for downloading and analysis. We also did the *luminance* study as described in *Box 1*.

Project Architect Discussion: During the process of our study we talked to the project architect of the Alumni Center. He was able to tell us some interesting facts about the overall project and the individual spaces. He explained how there was no design consideration when it came to the different facades of the building based upon the direction they were facing. He also confirmed that the shades that existed in the building were supposed to block out about 80 percent of the natural light.

Office 256: While taking our readings on this visit we were told by the occupant of room 256, that we should study his office. His reasoning was that that his office received so much light by 3pm on a sunny day that he had to move to the conference room to work because he no longer could see his computer screen. We measured illumination at several points in his room along the window and near his work surfaces.

Overcast afternoon: On our next visit we worked in both offices. In office 255, we did both a *contour* and *luminance* study as noted in *Box 1.* This information was needed so we could compare these readings with sunny days of the same time. We then placed both the Stowaways and Hobos in office 256 to obtain measurements throughout this space. We placed meters in the window, on the table he uses for meetings, his desk, and the bookcase near the door. These locations can be seen on a plan later in the Findings section. *See Figure 27.* A *contour* and *luminance* study were not done because after looking at the numbers we obtained from office 255 we noticed that not much would be gained at this time since the numbers were located at reasonable levels compared to the IES recommendations ranging from 50-100 foot candles. In addition, office 256 is being used as a worst case study, so we felt that average data was not crucial.

Figure 10: View at computer of office 255 on an overcast afternoon. The surrounding environment had more constant zones of lighting, but the monitor not being turned on appears darker than the rest of the area creating the higher contrast in the view.

Figure 11: Office 255 on a sunny morning showing veiling reflections on the two desks and the adjacent wall. Also, along the wall on the left it can be seen how the light reaches into the room when the shades are up causing veiling reflections on the monitor.

Checking ourselves: Next, we analyzed our information to verify that we were not overlooking an aspect that could effect our data. We compared our data to that of recommended illumination levels to see if the room is obtaining excessive levels of illumination. Also, we checked luminance measurements to see the role a high level of contrast played as a factor causing discomfort. This allowed us to see if these measurements were worth obtaining any longer.

Overcast morning: On this visit, we only obtained measurements in office 256. We created an isolux contour and obtained luminance readings while there and the procedure for these studies can be found in *Box 1*. These readings were needed to show that office 256 was not always as bad as we found on sunny afternoons. After taking a quick look at our data, we had just gathered we decided that we would not gain much from taking readings in office 255 unless some veiling reflection or glare were noticed and none were. Before leaving we took a quick look into office 255 and did not notice any circumstances in the room that caused any discomfort.

Sunny afternoon office 256: On the final visit that our team made to the Alumni Center offices, we collected our long-term instruments to download the data and analyze it for office 256. We also created another isolux contour map for this office following the protocol in *Box 1.* After creating the contour map, digital photos of the room were taken of the different views. Luminance studies were wanted but due to the time of the day being after 4 p.m. the sun was getting into some low level clouds which was making the readings fluctuate too much to get an accurate reading. The pictures would still be useful because they captured the visual glare and location of where the sun was falling in the workspace.

Final step: Analyze the data we gathered and produce a possible solution to the visual discomfort that occurs in the offices along the south side.

Findings

- In studying the energy density of office 255, we found that there were four fixtures, each at 13 watts, equaling 52 watts per square foot. Each fixture runs on 130 volts. This information was helpful in that the occupants usually use the artificial lighting systems. The occupants stated that they usually turned the lights on by force of habit, however, one occupant stated that, having the lights on, helped eliminate some of the shadows cast on the workspace.
- We found that veiling reflections occurred often on the computer screen, especially in the afternoon as seen in *Figure 8.*
- The contrast ratio of the computer environment on sunny afternoons is harsh due to the fact that the screen is so dark and the surrounding context is lighter in color. The monitor appears twice as dark as everything else in the surrounding context. This can be seen in *Figure 9.*
- *Figure 10* presents the overcast afternoon scenario where it can be seen that the contrast ratio is not as large as it was on the sunny afternoon. However, a problematic contrast ratio still exists due to the darkness of the monitor.
- The problem that occurs most often on a sunny morning is veiling reflection off the desk as seen in the visitor's view of the room. See *Figure 11.* The veiling reflection is only noticed when viewed at an angle from the surface of 15 to 20 degrees. The occupant does not notice the veiling condition because the work environment that is viewed is between 30 and 60 degrees. Also, veiling reflection appears on the computer screen in the morning from the visitor's viewpoint when the shades are up.

Figure 12: Scene from doorway of team member posing as occupant working at computer in heavily lit environment. Due to the brightness of the background, the details of the individual and other objects are lost from the view.

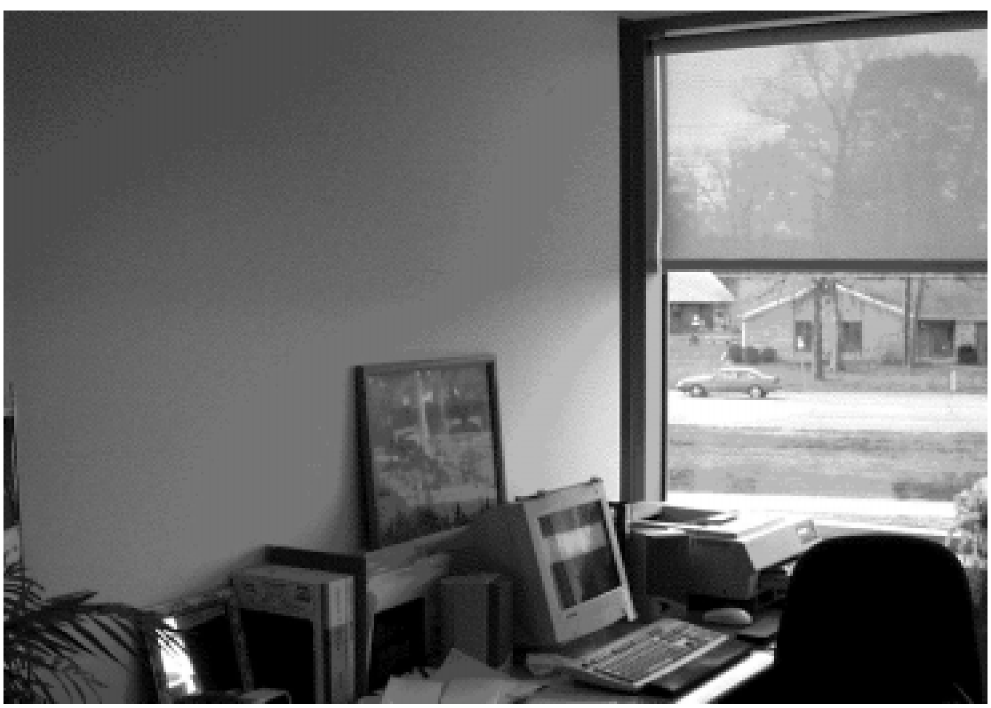

Figure 13: Office 255 on an overcast afternoon. This view shows many different zones of light levels existing within the work environment of the office.

Figure 14: View from doorway showing contrast between office and exterior background when shades are pulled down all the way on a sunny afternoon. The details in the room are totally eliminated and some objects start to look as if they are one. Veiling glare occurs on these surfaces.

Figure 15: View of office 255 from doorway on an overcast afternoon. In these overcast conditions, it can be seen that the lack of reflection disables one's ability to distinguish objects from one another.

Figure 16: Occupant of office 255 blocks out daylight on a sunny afternoon using posters. Some luminance readings are shown.

Figure 17: View of visitor in shadow of doorway of distant hallway from office 255, with

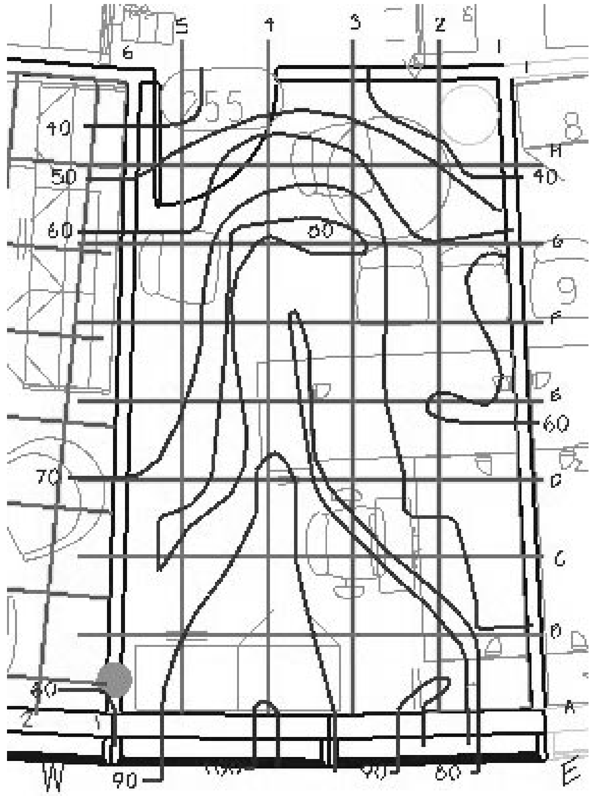

Figure 18: Layout and isolux contour map of office 255 on a cloudy afternoon with the shades pulled completely. The contours are spaced every 10 foot candles.

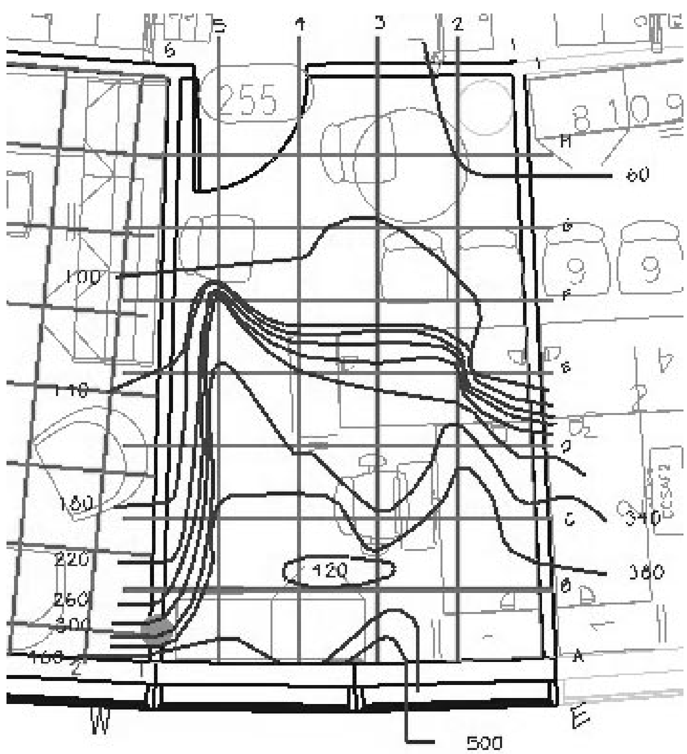

Figure 19: Layout and isolux contour map of office 255 on a sunny afternoon. Measurements were obtained with the shades pulled down completely. The contours are spaced every 40 foot candles.

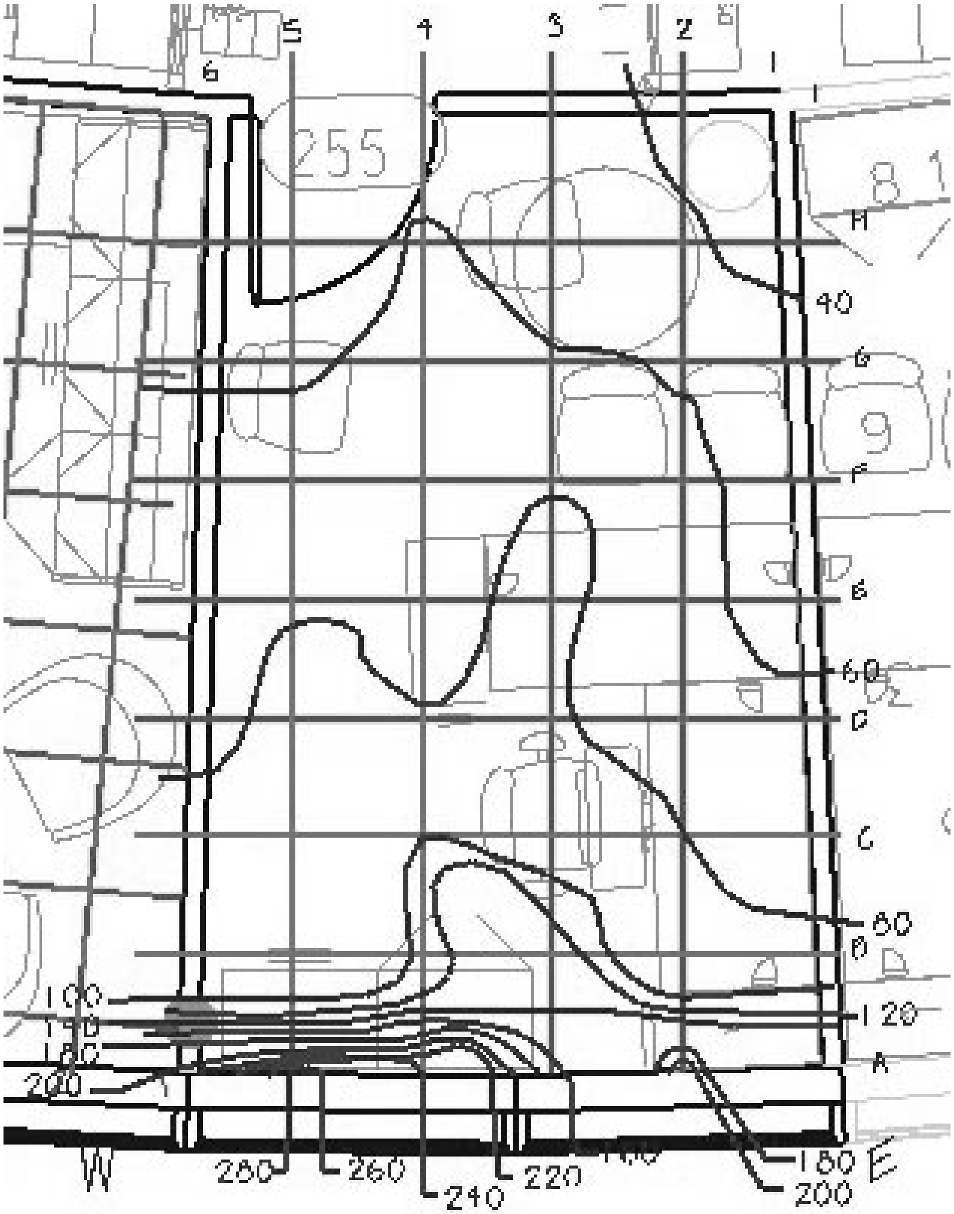

Figure 20: Isolux contour map of office 255 on a sunny morning with the shades pulled down completely. The contour lines are spaced every 20 foot candles.

- What occurs no matter the conditions outside is a loss of detail in the room for anyone who is looking towards the window as seen in *Figure 12*. Due to the bright contrast from outside to in, the view of only shapes and objects can be seen. *Figure 14* shows the high level of contrast that occurs on a sunny day and how even more detail is lost and masses start to combine together to form one shape, this is where veiling glare can be found.
- The following scenario occurs for the occupant as he/she views the door and hallway. The office occupant is looking from a bright environment into a background that is much darker as seen in *Figure 17.* Therefore anyone that approaches from the hallway is less visible in a shadow. *Figure 13* presents another situation in which light drastically changes as one proceeds through the room.

- On overcast afternoons visible detail of objects in the office becomes less than that of sunny afternoon conditions. This is due to less light being able to reflect off of the different surfaces to highlight them for our eye. There only appears two levels of light one of brightness and one of darkness, causing some veiling glare, but it actually is not as bad as a sunny afternoon. A view of the room in these conditions can be found in *Figure 15.*
- We found that the occupant of office 255 hung posters in the windows in an attempt to block out the light and eliminate veiling glare. The only thing this managed to do was display veiling glare on the sunny day. It made the workspace easier to work in but the view toward the window became worse. This was due to the creation of very bright and dark areas, all on the same viewing plane. Without the posters, at least the light gradually washed out as it reached deep into the room. This caused hot and cold zones of light.
- The isolux contours that were created for office 255 show that on overcast days the light levels fall between the IES recommended levels of 50 foot candles to 150 foot candles. However, a problem does exist in how the light level varies through the room. There is no constant level of light in any one location of the office, as seen in *Figure 18.*
- From *Figures 19 and 20,* it can be seen that there are many levels of light entering a room on a sunny day. Depending on the time of day, light falls differently in the room. On a sunny afternoon at the office's main workspace, the light levels were three times the IES recommended levels. We obtained values in the workspace that exceeded 300 foot candles. The morning conditions are different. A bright spot exists along the west wall, but through the work environment of the office there is adequate light based on IES standards. Also, the light is spread more gradually and evenly across the work surface, not creating light changes over the object being worked on.
- We found the walls to have a reflectance of around 76 percent. This was based on eighteen readings along the two walls in the room. All the readings were not used because of values appearing too low or high when compared to the other points of gathered data. A table of data measurements can be found in *Figure 21.*
- *Figure 22* shows a table containing the reflectance values of the objects that exist within office 255. Most of the reflectance values that were obtained exist at a reasonable level for the room. There are only four surfaces in the room that exist with a reflectance of over 50 percent. One of these surfaces is the door, which is appearing higher in our readings than it actually is. This is due to the fact that the illumination readings were obtained in the corner by the door. The other sources of high reflectance are the desks. This is not noticeable in the office since they are normally covered with items eliminating much of the desk's surface area from view.
- In *Figure 25,* long term readings that were obtained from October 21st through October 27th are presented. The light levels in the southeast corner of the window with the shades down were between the IES recommended levels. The data recorded in this situation was lower than it should have been since the location of the light meter caused it to be directly shaded by the adjacent window frame. Despite readings taken directly next to the window frame, on most afternoons, the illumination levels exceed 150 foot candles. The light levels obtained at the round table surface in the northeast corner of the room consistently ranged in the IES recommended levels of 50 foot candles to 150 foot candles. To see the placement of the instruments refer to *Figure 24.*

	West Wall Readings			East Wall Readings		
position measured at 5'-0"	illuminance	luminacne	reflectance	illuminance	luminance	reflectance
	in foot candles	in foot candles		in foot candles	in foot candles	
A	470	196	41.70%	393	227	57.76%
B	220	167	75.91%	338	301	89.05%
C	193	145	75.13%	292	178	60.96%
D	147	120	81.63%	138	114	82.61%
E	124	88	70.97%	115	87	75.65%
F	99	75	75.76%	90	73	81.11%
G	92	74	80.43%	83	68	81.93%
H	80	58	72.50%	64	55	85.94%
I	65	45	69.23%	68	51	75.00%
average along each wall			75.20%			77.60%
average combining both walls	76.32%					
spaces with gray were not used indeterming the reflectance				not used		

Figure 21: Measurements showing values of reflectance from the walls.

	West Wall Readings			East Wall Readings		
position measured at 5'-0"	illuminance	luminacne	reflectance	illuminance	luminance	reflectance
	in foot candles	in foot candles		in foot candles	in foot candles	
A	470	196	41.70%	393	227	57.76%
B	220	167	75.91%	338	301	89.05%
C	193	145	75.13%	292	178	60.96%
D	147	120	81.63%	138	114	82.61%
E	124	88	70.97%	115	87	75.65%
F	99	75	75.76%	90	73	81.11%
G	92	74	80.43%	83	68	81.93%
H	80	58	72.50%	64	55	85.94%
I	65	45	69.23%	68	51	75.00%
average along each wall			75.20%			77.60%
average combining both walls	76.32%					
spaces with gray were not used indeterming the reflectance				not used		

Figure 22: Reflectance of objects within the office 255.

along window	348
through glass at window	1895
outside indirect	3000
amount of light through shade	0.183641161

Figure 23: Illuminance values in office 255 which show the amount of light the shades block out.

- *Figure 26* presents a better picture of the light levels that normally enter an office. As this figure shows, illumination levels reached above 150 foot candles frequently over the course of a week. In one day we had foot candle readings at the window exceeding 600 foot candles.
- To help prove that office 256 was a worse case scenario, we averaged the measurements taken by the long-term instruments and found that, with the shades down, there were over 500 foot candles arriving at the work space and conference desk in this office. The instrument on the round conference desk was obtaining readings that were averaging about 3000 foot candles.

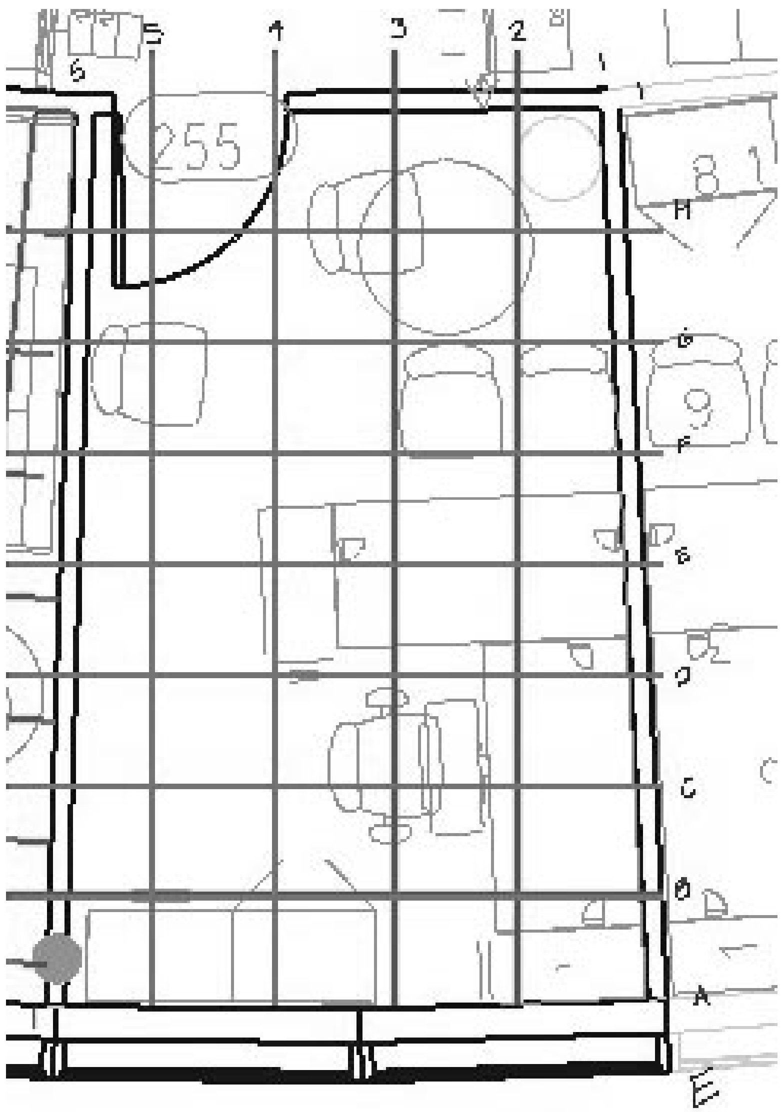

Figure 24: Placement of the instruments for Figures 25 and 26 in context of office 255.

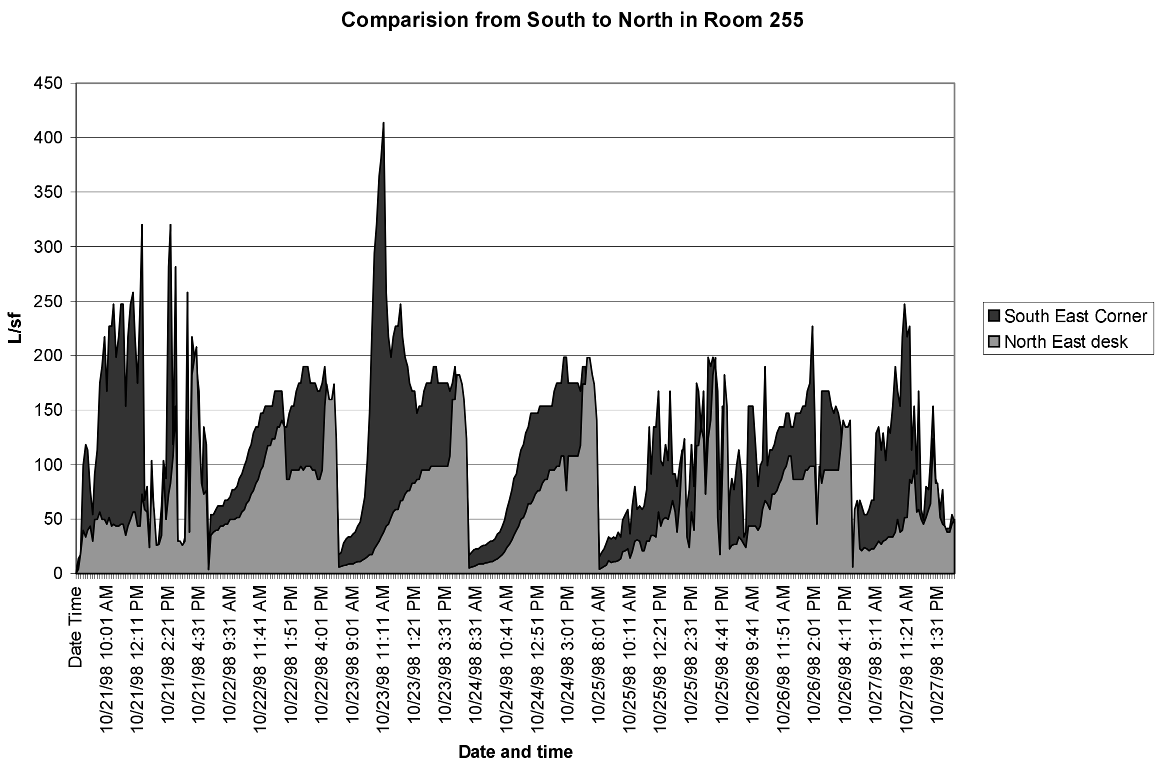

Figure 25: Illumination readings from southeast corner and northeast corner of office 255 on October 21, 1998 through October 27 with only 8 a.m. to 5 p.m. readings shown.

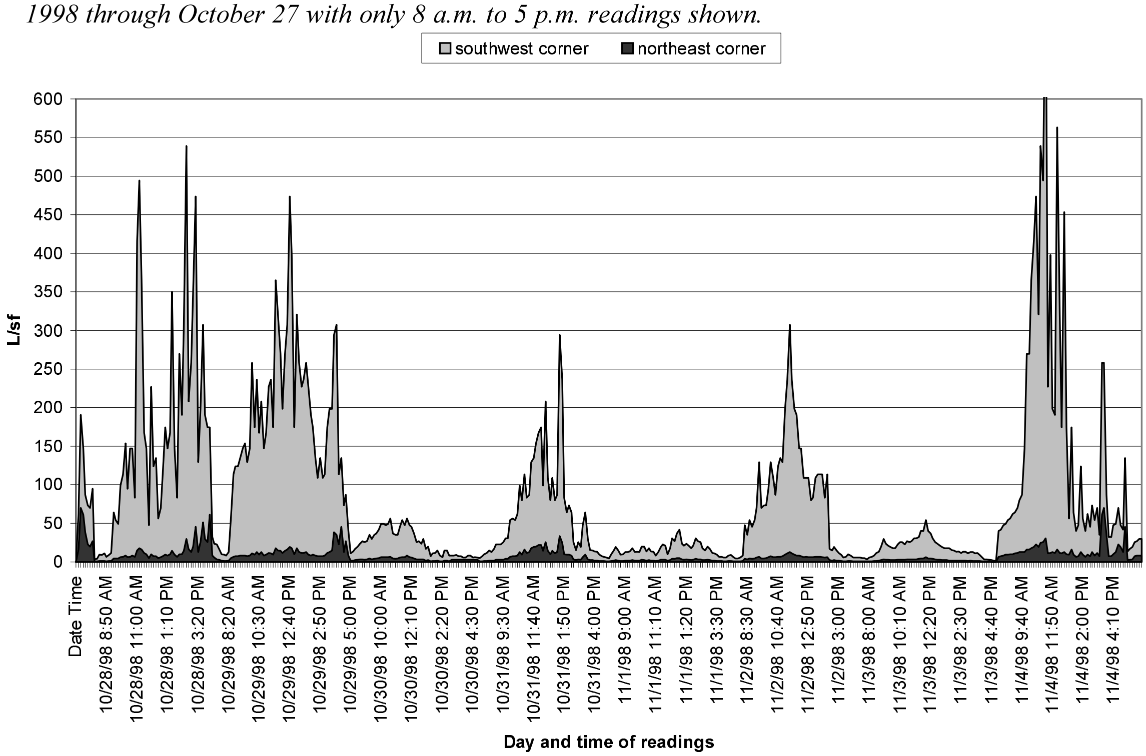

Figure 26: Illumination readings from the southeast corner and northeast corner of office 255 on October 30, 1998. The illumination readings of the southwest corner were obtained from the window sill and the northeast corner from the shaded corner of the room on the floor.

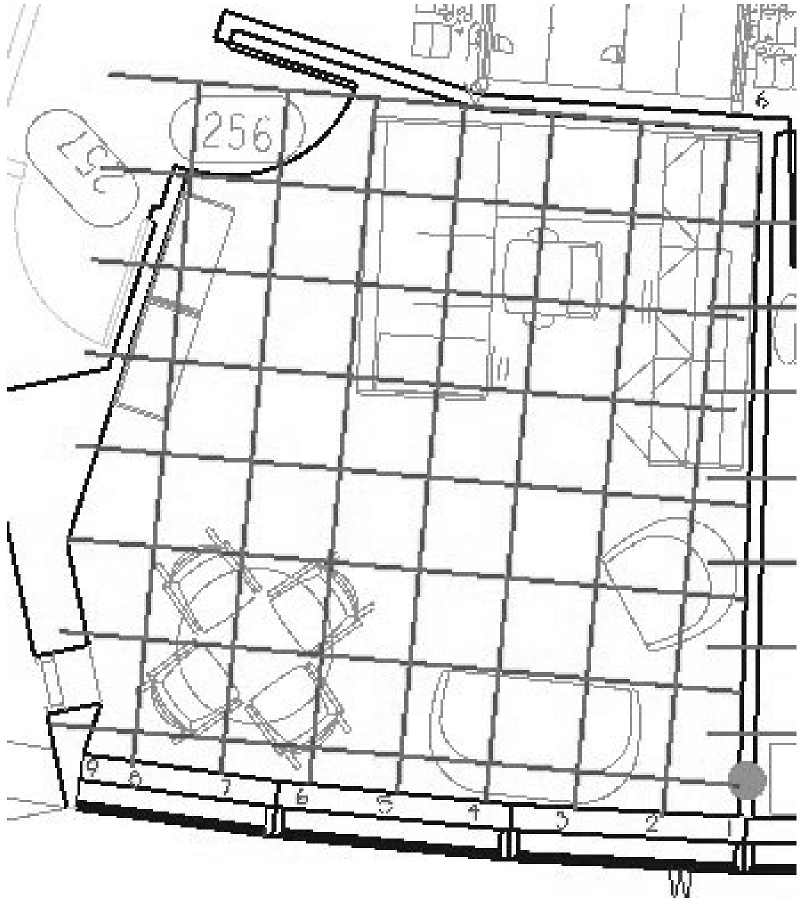

Figure 27: This plan shows the location of the instruments that were used to produce the graph in Figure 28.

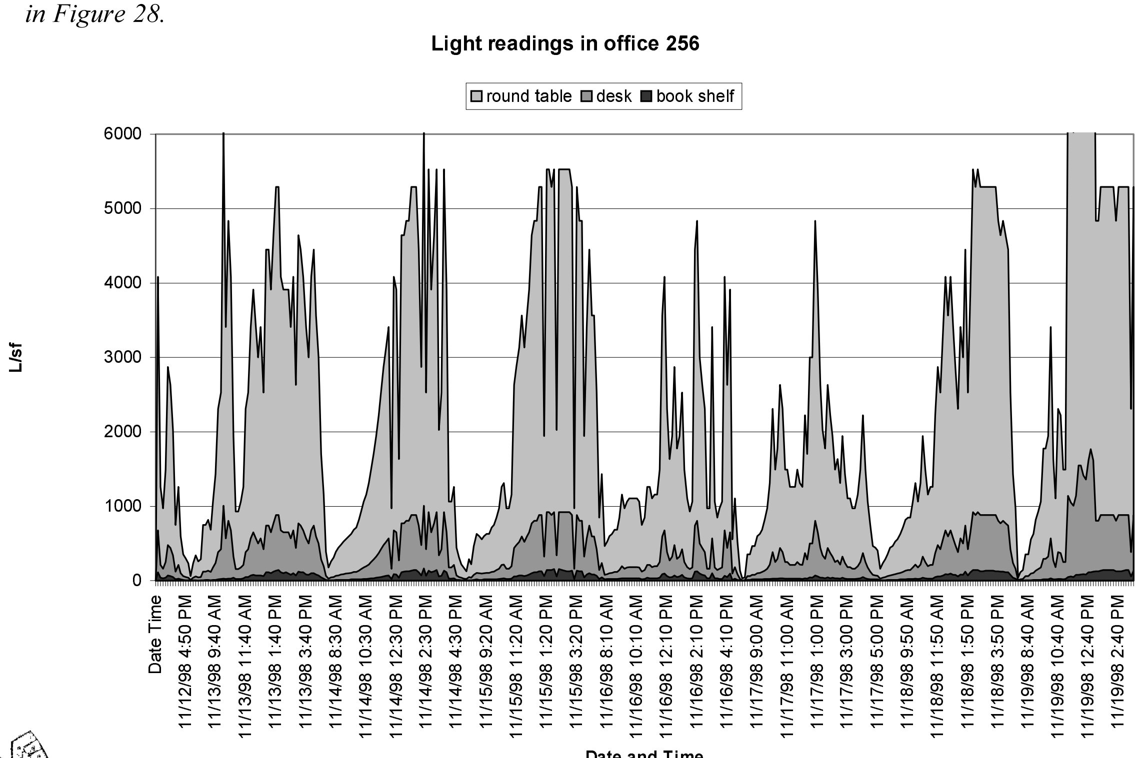

Figure 28: Light levels in office 256 during a week at these different locations in the office. Reference Figure 27 for instrument location.

Figure 29: Office 256 west desk, the main workspace. The lamp on the desk is used to eliminate the lighting level changes that take place around the main work surface.

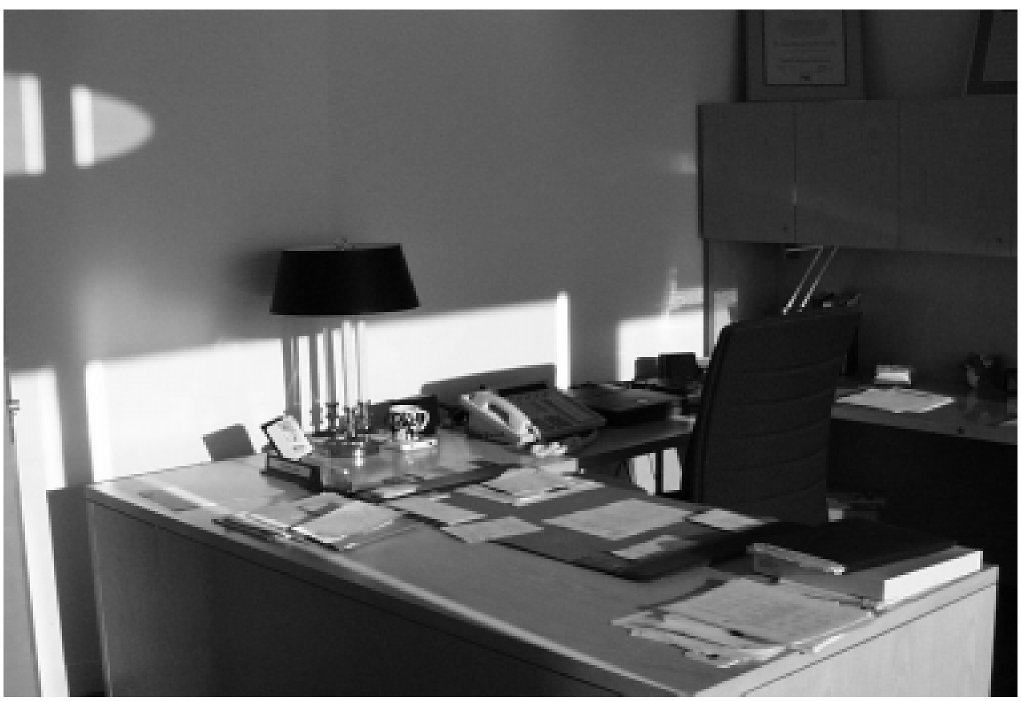

Figure 30: Office 256 on a sunny afternoon, showing the sun washing the shole work area with high levels of natural light with the shades closed.

- In office 256 the occupant is required to use a desk light to help eliminate the lighting level changes that occur across the work surface. See *Figure 29 and 32.*
- In office 256, on sunny days, it can be seen that the late afternoon sun reaches to the north wall of the office creating an exceedingly bright work environment for the occupant. When the environment appears as it does in *Figures 30, 33, 34, and 35,* the occupant has to go to another office or conference room to work because using the computer becomes practically impossible.
- In *Figure 31*, the isolux contour shows that with the shades open on a sunny day the room would have readings that exceed 100 foot candles. Even with the shades all the way down these measurements would still appear high because the value of the contour lines could be reduced by 80 percent. It also emphasizes the wide variety of light changes that occur across all workspaces on a sunny day.
- The windows in office 256 provide a source of veiling glare as one enters the office. To try to eliminate the problem the natural light caused, the occupant of office 256 placed posters in the window to reduce the sun reaching the workspace. The posters accomplished this, however, they created a veiling glare that was even stronger if one looked toward the window, because the areas became smaller and more intense. Refer to *Figures 34 and 35.*
- The round conference table in office 256 received an excess amount of natural light, making it hard to use, and making visual aids harder to read. In *Figures 36, 37, and 38,* veiling reflections are shown, along with reflections from images within close proximity of the table.

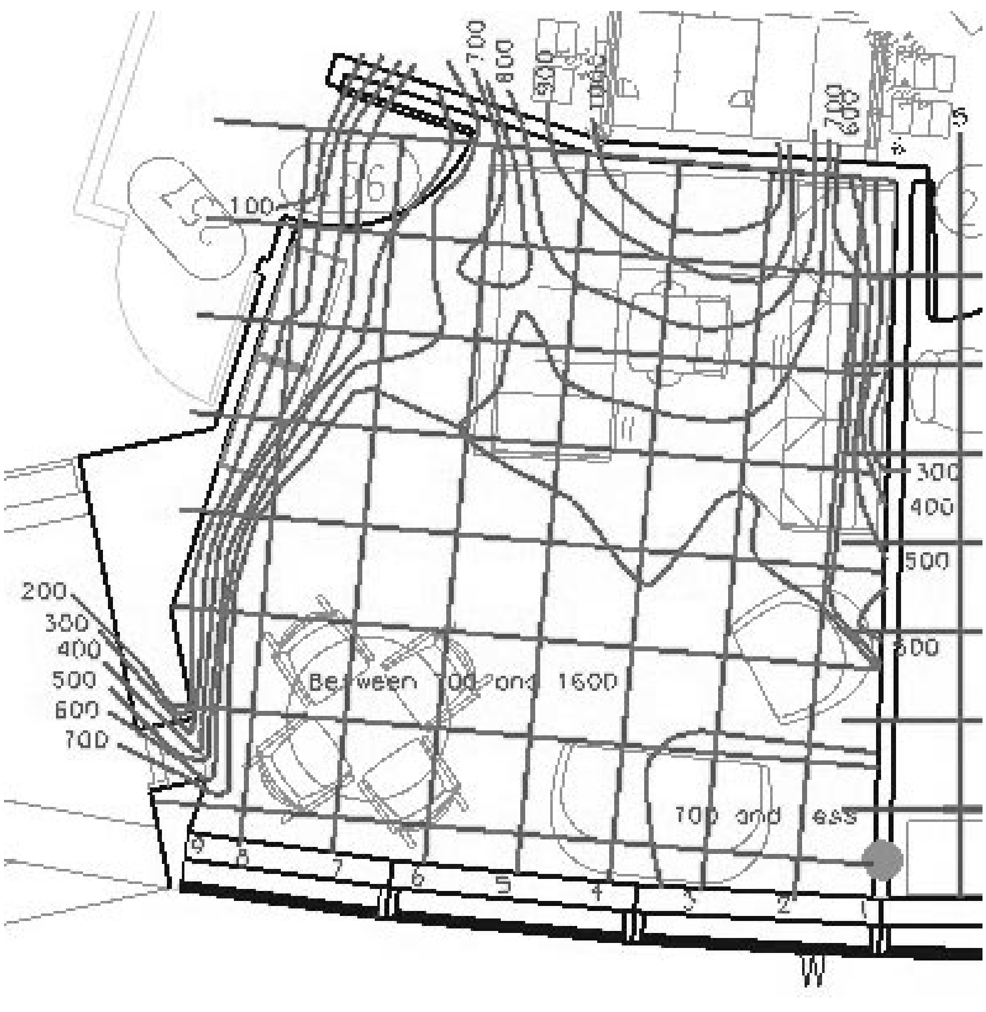

Figure 31: Isolux contour map of office 256 on sunny afternoon with the shades up completely. The contour lines are drawn every 100 foot candles.

Figure 32: Working environment on an overcast day of office 256 with both task lights at occupant's desk in use.

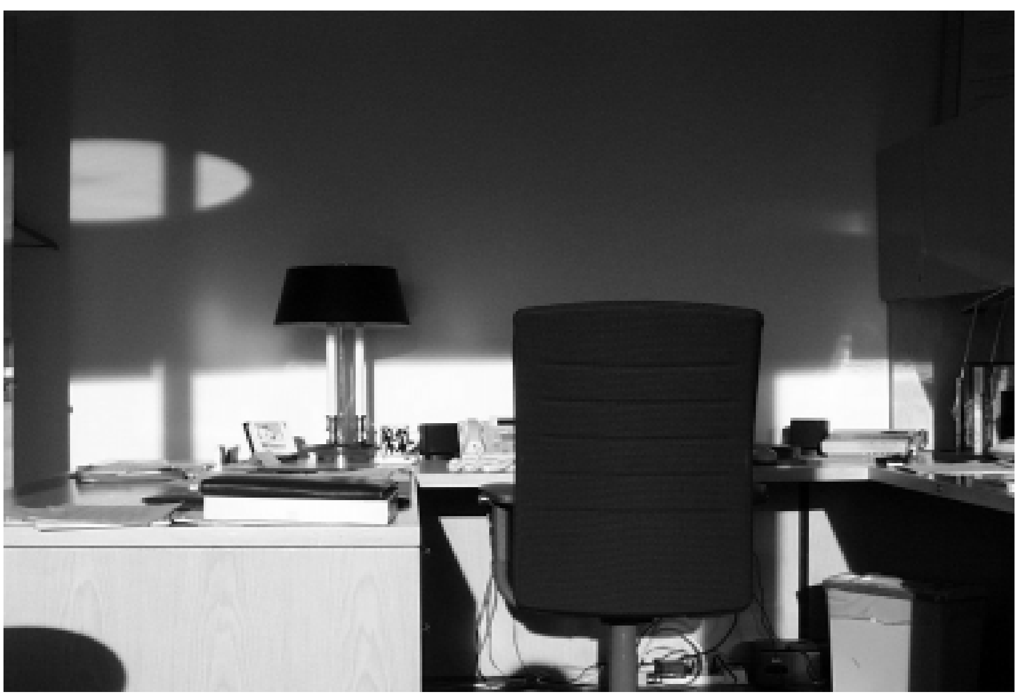

Figure 33: View looking north in office 256 showing the full effect of the daylight in the office.

Figure 34: View of windows in office 256 as one enters the room on a sunny afternoon. Due to the room's arrangement as one enter they encounter veiling glare.

Figure 35: The occupant of office 256 blocks daylight with posters attempting to lower light levels in the workspace.

Figure 36: Conference table in office 256 with veiling reflections occurring.

Figure 37: Veiling reflection occurring in office 256 showing that shades are usually closed completely to eliminate background reflections.

Figure 38: View of veiling reflections along with reflections in windows leading to unclear views.

Conclusion

In analyzing the data, we discovered that there was more than one factor causing the visual discomfort in the office spaces on the south side of the Alumni Center. The studies of office 255 exhibited the following problems. There were high contrasts in the levels of light as perceived from a number of vantagepoints within the standard office. When entering the office or sitting in the visitor's chair, specifically on sunny afternoons, the view toward the occupant was filled with discomfort glare. Since the shade allowed 20 percent of light into the office, the shade itself appeared as an illumination source. Compared to the other light levels within the office, the bright shade presented a high contrast. Therefore it was difficult to comfortably focus on the occupant or an object sitting in front of the illuminated background. A similar problem occurred from the view of the occupant. It was difficult to focus on someone entering the office. The cause of this disturbance, however, was that the occupant was in a highly illuminated room looking out into a much darker hallway. When someone stood in the doorway, he or she subsequently blended into a shadow. As the occupant of the office turned to see the visitor, his or her pupil attempted to adjust to the two different light levels. The visitor would not be able to draw focus since he or she was standing in a shadow surrounded by much brighter walls. In both of these situations, objects were unable to be easily focused upon due to the difference in the light levels within the office. In essence, the contrast ratios were so extensive that they caused a visual disturbance.

Veiling reflection at the workspace in the standard office also proved to be a problem. This obstacle was rooted in the amount of light striking the surfaces at or around the occupant's desk. When the light coming from outside would fall on the computer screen or the page of a book, text being viewed would seem to disappear. Veiling reflection became such a problem that temporary fixes were implemented by the occupant so that everyday tasks could be accomplished.

The occupant of office 256 experienced discomfort as the result of similar factors presented for the case of the occupant in the standard office. However, this particular case proved to be a worse case scenario. This office had an extra 25 square-feet of glass allowing sunlight into the room. Despite, placing the occupant's desk and main workspace in the northern-most portion of the room, opposite the windows, the direct sunlight was able to cause a problem for the occupant. Not only was the north wall receiving intense light from outside, but highly reflective surfaces were projecting spots of light onto walls and other work surfaces. In this case, direct beams were a problem more so than contrast ratios. Due to these intense beams of light working their way into the office space, veiling reflection became a complementary problem. The computer screen and surface of the small worktable were most susceptible to this problem.

We originally predicted that reflectivity would prove to be the major factor causing visual discomfort. Reflectivity did play a part in the lighting problems of the south-side offices. However, we found that the magnitude of illumination coming in from outside and the contrast ratios of the offices' light levels were overwhelmingly more troublesome.

Our recommended solutions for these problems are to install operable/horizontal blinds. Having a higher opacity, such blinds will allow more light to be blocked out. They will also allow the occupants to deflect the natural light up to the ceiling creating a better-balanced level of light in the room, while eliminating the direct beams of light on work surfaces. If the outside appearance of the building is threatened by using this type of blind, then we suggest leaving the current shade and installing the blinds behind them. Leaving the original blinds will not result in the loss of money and will keep the character of the building. What will not work is the installation of the existing style of shade even if it has a heavier opacity. It might cut down the amount of light entering the room, but the problems will still exist. Veiling reflection will occur because the sunlight, though not as intense, will continue to fall directly onto work surfaces. Veiling glare will present problems because the shade will still be illuminated resulting in a lighted surface of high contrast.

References

The following sources were used in the development of this experiment:

- Ball State University Alumni Website:
  http://www.bsu.edu/alumni
- Ball State University CERES Website:
  http://www.ice.bsu.edu/ceres
- Ball State University:
  Alumni Center Building Manager, Matt Stevenson
- Visiting Scholars:
  See Appendix A
- Project Architect:
  Tom Baker; Pei, Cobb, Freed, & Partners
- Vital Signs Notebook
- Vital Signs Instructors:
  Robert Koester and Jeff Culp

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Appendix A

Contributions of Visiting Scholars:

- Jeff Sailer, zoologist at the University of Florida and alumnus of Ball State University, spoke to the class the first week of the semester. He showed the students how to take the skills learned from the Vital Signs Class and apply them to other disciplines. He also explained that any project, including our project, should have a distinct goal with a numeric value, collect numeric data relevant to the goal, and interpret and extrapolate findings.
- Alison Grace Kwok, who received her Ph.D. from the University of California, Berkeley, greatly aided our team in starting this study. She helped us form our hypothesis as well as gave us practical advice. Especially helpful, was her advice to observe the space we had picked out in order to formulate questions about that space. This got our group really thinking about why we wanted to study the offices, and how to come up with a hypothesis about the office spaces. She informed us that a good hypothesis is exact, and that once finalized, it would be the anchor for our project, which we discovered is definitely true. Some “practical” advice we took from Alison was to keep a running story board type draft, so that by the time we finished our research, the main bulk of the report was pretty much finished. It was also good to hear a realistic view of the interpersonal side of this study. She brought to our attention the fact that our team would have to cooperate to make decisions about our project. She discussed how to assign jobs; as well as actually deciding who was going to do what; how to deal with people’s conflicting personalities, viewpoints, and emotions; and how to handle the delicate relationship between our team and the office occupants. Overall, she helped get our team off to a great start, with a fairly realistic view of the person-to-person aspect of our study.
- Bruce Hagland gave us good information concerning the details of our actual report. He used examples of past student reports to show us that using pictures with small amounts of data is less intimidating and more interesting than using exhaustive charts and graphs that are irrelevant. Bruce also showed us that a good way to give data about illumination and/or luminance in our report is to write the numeric value of a measurement right on a photograph of the room in the proper location. Bruce additionally directed us to thinking about the potential causes of glare in the office space. This, in turn, led us to conclude that the work-plane would be an important part of our study, one of our main focuses.
- Joel Loveland, who received his Masters of Arts in Architecture and Urban Planning from the University of California at Los Angeles, Los Angeles, California, helped us remember our initial perspective going into this study. Our study focuses on visual comfort, which is a study of one’s perception of light in a room. He reminded us that we needed to clearly indicate the relationship between our physical measurements and a person’s perception of the lighting in the office space, not forgetting that our most useful resource in determining that relationship is the office occupant, who experiences the lighting effects over time.

Appendix A Continued

- Marc Schiler, our final visiting scholar, helped us see how to “wrap-up” our project. He helped our team think of possible solutions to the glare problems in the south side offices. Marc also directed the vision of our project so that we saw our project (data, finding, conclusion) as a whole, connected entity. We appreciate Marc’s honesty, knowledge, and willingness to give us feedback.

Appendix B

Temperature Data:

		Temperature in Fahrenheit		
		8am	noon	5pm
Tuesday	27-Oct	55	66	61
Wednesday	28-Oct	59	62	60
Thursday	29-Oct	47	53	61
Friday	30-Oct	57	63	54
Monday	2-Nov	46	46	42
Tuesday	3-Nov	38	42	43

Figure 39: Temperature readings from the outside environment.

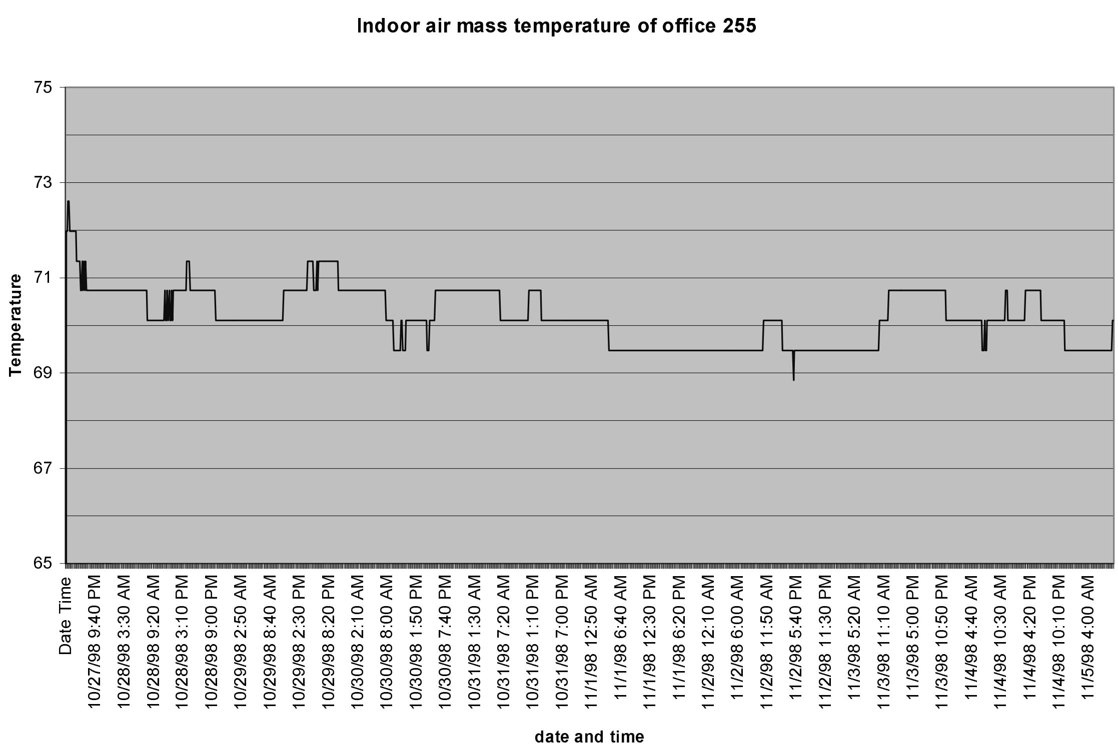

Figure 40: Graph of temperature readings throughout the time the data was collected.

Appendix C

Office 255 Isolux Data:

		Sunny Morning Visit			
	1	2	3	4	5	6
A	152	214	160	240	289	448
B	92	82	126	101	213	137
C	61	80	95	100	396	183
D	67	74	81	85	370	171
E	53	71	82	61	353	142
F	53	66	78	70	316	106
G	51	58	64	72	82	84
H	35	48	55	62	70	64
I	31	36	48	45	63	18

Figure 41: Light measurements at 9:00 a.m. on a sunny morning.

	Sunny Afternoon					
	1	2	3	4	5	6
A	315	283	524	422	483	448
B	390	403	430	436	213	137
C	360	365	343	403	396	183
D	290	373	164	334	370	171
E	94	287	273	299	353	142
F	56	105	135	107	316	106
G	76	91	101	94	82	84
H	58	62	99	88	70	64
I	48	64	82	80	63	18

Figure 42: Light measurements at 3:00 p.m. on October 27, 1998.

	Overcast A	cloudy day				
	1	2	3	4	5	6
A	75	91	88	100	95	57
B	70	83	84	94	90	62
C	68	77	82	99	84	68
D	68	68	77	95	76	69
E	60	60	77	86	70	64
F	57	64	78	84	65	60
G	61	60	80	81	61	61
H	36	50	69	67	54	48
I	27	30	47	48	38	34

Figure 43: Light measurementsat 2:00 p.m. on November 12, 1998.

Appendix D

Office 256 Isolux Data:

				Lights on in office 256 shades closed					
		Position from East to West							
		1	2	3	4	5	6	7	8	9
Position in	A	52	43	42	52	52	52	51	53	
room south	B	75	108	60	66	64	62	58	58	
to north	C	55	55	70	76	73	69	60	49	38
	D	58	55	73	79	77	72	58	46	34
	E	51	53	71	80	77	72	56	31	31
	F	16	16	73	80	74	71	53	34	29
	G	28	30	66	72	69	66	52	28	27
	H	26	31	52	58	115	57	48	35	
	I	7	9	41	54	168	41	34	25	
	J						36	28	23	

				Lights off in office 256 shades closed						
		Position from East to West								
		1	2	3	4	5	6	7	8	9
Position in	A	19	36	34	48	47	43	47	51	
room south	B	26	36	41	44	46	43	52	46	
to north	C	24	25	31	35	37	35	34	32	33
	D	20	22	24	29	28	29	25	25	23
	E	18	19	21	22	21	22	19	12	22
	F		11	16	18	18	18	15	9	15
	G		10	14	15	15	16	14	11	12
	H		9	12	13	13	14	14	11	
	I		8	12	13	10	13	9	11	
	J						12	10	11	

Figure 44: Office 256 measurements with lights off and on.

			Sunny afternoon with shades open							
		Position from East to West								
		1	2	3	4	5	6	7	8	9
Position in	A	230	310	242	1400	1552	1510	1662	1460	
room sout	B	325	280	340	890	806	1150	1147	920	
to north	C	1170	870	860	917	1063	1102	1078	900	133
	D	537	1024	920	860	875	900	912	886	137
	E	596	612	718	651	815	843	876	776	115
	F	280	615	694	600	675	700	747	306	121
	G	476	620	775	780	762	640	520	236	138
	H	425	605	925	900	846	712	500	160	
	I	318	506	1076	1074	998	758	420	443	
	J						505	205	52	

Figure 45: Office 256 Measurements on a sunny afternoon with the shades up in the room. If light levels are deisered with shades down then reduce each number by 80 percent.

Appendix E

General Observations of Team Members:

- “Walking through the Alumni Center for the first time, I honestly paid no attention to the lighting design itself. I was in awe of the spectacular spaces, such as the conservatory and the main conference room. However, giving some thought to what it was I was seeing, I realized that lighting was a key factor in what it was I was seeing. The conservatory was relaxed and cool. The natural light that filled the room gave me a sense of the outdoor environment. The room was alive. The library was completely different. There was less light filling the space, and this light was artificial. The light was much dimmer, but the room had a bit of class to it. The memorabilia was a major focus and established a sense of history. The room was warm, not speaking of temperature, making me feel comfortable. The clerical office space, in general, was well lit. The only natural daylight was spilling in from bordering offices. The offices were bright. I walked though at a time that the sun was not in direct line with the windows, but had it been, I am sure that the offices would be uncomfortable to work in. This concerns me, since these are the spaces most used on a daily basis.”

-Michael Cianciolo [Elementary Education, senior]

- “Upon starting this project, I knew of some of the lighting problems that existed in the Alumni Center and I have always been intrigued at solving problems and thought that this class would be a great opportunity. With our first visit and tour through the building I examined the possibilities and wanted any research and solutions that I cam up with to serve a purpose that would be noticed. This led to a colleague and me to talk with the building supervisor and hearing a little more about the problems that existed in the south side offices. When we saw the offices on this visit they were extremely bright and uncomfortable to the eyes, and this was with the shades pulled down. When noticing this, I realized that if we worked with the office spaces, we could be part of the solution to the lighting problems they are currently having.”

-Scott Marchisin [Architecture, senior]

- “When I first walked into the Alumni Center, I was amazed. The facility seemed to be well equipped and flawless. However, after observing the building for a while, I can see that the building does have some minor problems. There are several lighting problems that could have been easily avoided if things were carefully planned. A lot of money would have been saved by simply landscaping the building and concentrating more on the purpose of the fixtures rather than their appearances. Also, if more attention had been paid to the occupants and their specific roles in the office spaces, one would have noticed that there are indeed several distractions taking place.”

-Karen Michael [Biology/Pre-Med, sophmore]

- “When I for the first time walked through the new Alumni Center, I was impressed by many things. First, I liked the big open space and brightness in the Conservatory. I did not like, however, the fact that going from the conservatory to the other rooms the fact that it took some time for your eyes to readjust to new, darker light levels. I also liked the lighting in the lower-level meeting rooms, because it seemed adequate for working and/or presenting, and also gave a very professional atmosphere. I noticed that very many different types of lighting schemes were possible because of the various lamps the rooms had.”

-Marie Smith [Speech Pathology and Audiology, sophmore]