Vital Signs IV

A study of lighting efficiency in the second level circulation spaces of the Alumni Center

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Table Of Contents

Abstract

This report describes a semester long instrumented field study conducted during the fall of 1998 that questions the necessity of use of electric lights during daylight hours on the second floor balcony corridor spaces at the Ball State University Alumni Center, located in Muncie, Indiana. It investigates whether the balcony corridor's intended use is for circulation or exhibit space and compares the actual lighting levels to those recommended by the Illuminating Engineering Society (I.E.S.). This report also offers alternative lighting solutions that may result in more efficient and cost saving use of electric lighting.

The Alumni Center was designed by the renowned architectural firm of Pei, Cobb, Freed & Partners. The building houses University Development offices, a conference center, various meeting spaces and a central, two-story day lighted conservatory at the center. *(See Fig. 1)*

During early visits to the building, each team member made observations of various spaces and their lighting conditions, (*see appendix A for individual observation notes*). As a team, it was decided to focus the study on the balcony corridors on the second floor that surround the main conservatory. During the daylight hours this space appeared to have acceptable lighting levels without the use of electrical lights.

Initially, two light intensity data loggers were placed along the southern balcony to record lighting levels on a sunny day and an overcast day. This location received the least amount of direct sunlight of all the possible locations and our group felt that it would give us appropriate preliminary data. The data collected during the initial test period established the best time of the day to take instantaneous measurements to rationalize how the illumination was distributed over various points. For the second trial, two illumination data loggers were placed in each of the six balcony corridors. Light intensity data loggers were placed in each of the corridors to capture different levels of daylight due to the dynamics of the sun patterns. *(See Fig. 2)*

In addition to collection of lighting levels, a fixture and bulb inventory was conducted in order to measure energy use and costs. Finally, instantaneous measurements were taken from various wall surface points, with electric lights off to determine if the illumination level was acceptable using only the daylight from the conservatory.

Fig. 1
Exterior photograph of the Alumni Center taken from the Southwest corner

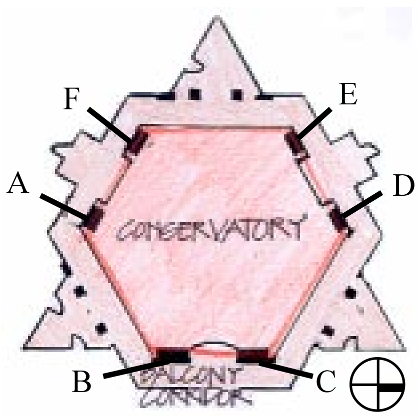


Fig. 2
Enlarged plan diagram of second level balcony corridor spaces and placement of light intensity data loggers A-F.

Interior photograph of the balcony vestibule space (south wall).

Introduction

This lighting study of the Alumni Center was conducted as part of an elective course entitled Vital Signs IV, offered by the Department of Architecture and staffed and administered by the Center for Energy Research/Education/Service (CERES) at Ball State University in Muncie, Indiana.

The Alumni Center is located in Muncie, Indiana, on the Ball State University campus. The primary spaces of the Alumni Center are arranged as follows: on the East side of the first floor is a row of small meeting rooms; located along the West side are large meeting rooms with removable walls. In the Northwest corner is a large two-story hexagon-shaped auditorium that can be divided in half for smaller groups. Along the North side is the staff and event kitchen, building support and maintenance offices *(See Fig. 4)*. The second floor is divided among the administrative offices for the Alumni Association, University Development, University Foundation, and Advancement Services *(See Fig. 5)*. The central core of the building is a hexagonal-shaped two story conservatory, which is primarily illuminated by a faceted skylight comprised of transparent and translucent glass.

The building's electrical lighting is a mixture of fluorescent and incandescent lamps. Conference, meeting rooms and office spaces use a variety of lamps controlled by wall switches. The meeting rooms have additional halogen spotlights. The boardroom and auditorium have the most diverse lighting systems. The lighting in these rooms, controlled by wall mounted dimmer switches, can range from very soft, low levels to intense, bright levels. On the second floor, all the adjacent offices and support staff work areas are illuminated by fluorescent lighting with some natural light from the windows of offices located on the exterior walls. Different wattages of incandescent lights are used for circulation areas, restrooms, lobbies, and other support areas.

Window treatment is consistent throughout the building. The window shades are made of a light colored mesh material that is 80% opaque diffusing the daylight and reducing the amount of glare.

The skylight in the conservatory is comprised of three types of glass: frosted, tinted, and clear transparent glass. Most of the skylight facets are covered with a frosted translucent glass that in addition to diffusing the daylight, screens the view of the building's mechanical towers. The remaining facets are covered with tinted and transparent glass allowing substantial amounts of daylight to enter the building. A previous study, conducted by the members of the Vital Signs III class, found the filtering to be effective and the conservatory space to be visually comfortable, despite the potential for excessive levels of illumination.

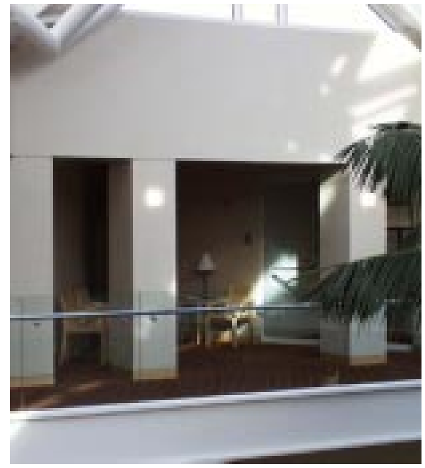


Fig. 3
View of vestibule balcony space at Alumni Association Wing

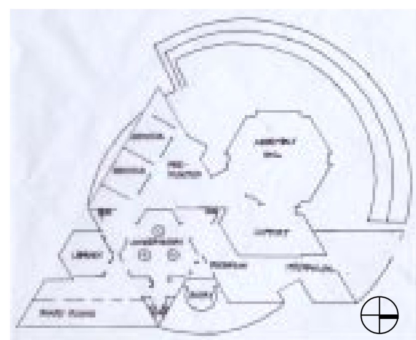


Fig. 4
Plan Diagram of functional spaces on the first level.

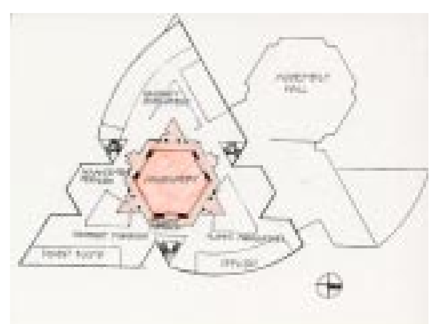


Fig. 5
Plan Diagram of functional spaces on the second level.

Fig. 6
Interior photograph of the balcony vestibule space covered by a corner of conservatory skylight (west wall).

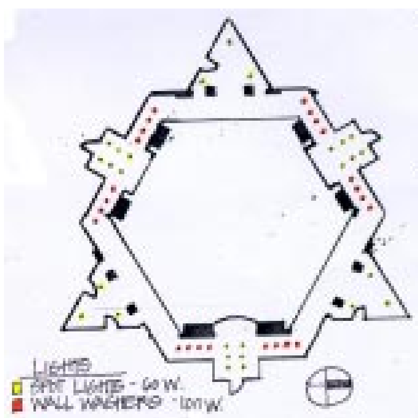


Fig. 7
Diagram of the circulation and vestibule lighting on the second level perimeter balcony spaces. Both spot lights and wall washers are incandescent lights.

The second level surrounding the conservatory is comprised of a series of vestibules, balconies and balcony corridors. Two of the three seating area vestibules serve the entrances to the administrative office wings, the third, located on the southern wall, is covered by a corner of the conservatory skylight *(See Fig. 6)*. The three balconies are directly in front of the seating areas and are open to the conservatory. The balcony corridors are separated from the conservatory by walls that also serve part of the air movement systems, portraits of distinguished alumni are displayed along the interior walls of the balcony corridors.

The research presented in this report focuses on the above mentioned balcony zones. The balcony corridors serve as a circulation link to each of the departmental wings, and during daylight hours these corridors are illuminated by four 100-watt wall washer fixtures in addition to the daylight from the conservatory skylight *(See Fig. 7)*. The corridor walls display distinguished Alumni portraits. During the early visits to the Alumni Center the team observed that the overhead lights cast a veiling reflection on the portraits. This report questions the necessity of the use of electric lights in these spaces during the daylight hours; investigates the architect's intent for the corridors use (to be circulation or exhibit space) and compares the actual lighting levels against the recommended lighting level as defined by the I.E.S. Finally, after compilation of all the data the report offers alternative lighting solutions that may result in more efficient use of electrical lighting in this area.

Hypothesis

Our team chose the hypothesis after agreeing on the selected space to study. We narrowed the hypothesis down to a testable statement that would use data collected in field visits, observations, and survey information to reach a true or false conclusion. Early ideas included comparing two spaces to study the effect of one on the other (such as the conservatory on the perimeter alcove spaces). However, because of the difficulty of collecting measureable data, the decision was made to limit the study to the balcony corridors.

Based on the architects intended programmatic function of circulation for the second floor balcony corridors surrounding the conservatory and the Illuminating Engineering Society (I.E.S.) recommended lighting levels for that function, we believe that the existing downlights lights are not necessary during daylight hours and that the energy saved can be translated into cost savings for Ball State University.

Fig. 8
View of Balcony corridor looking west. Note the shadow at the center of the space that shows that the space contains reflected light.

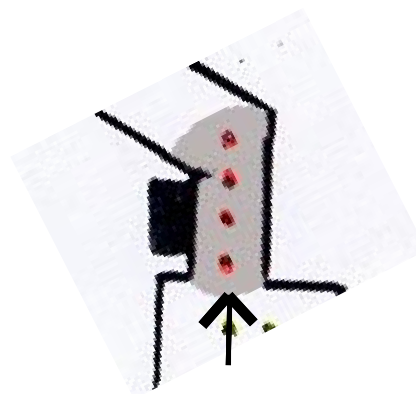


Fig. 9
Plan view of balcony space shown in Fig. 8. The four wall washer lights shown here are the primary source of light for the space identified above.

Fig. 10
View of east balcony corridor

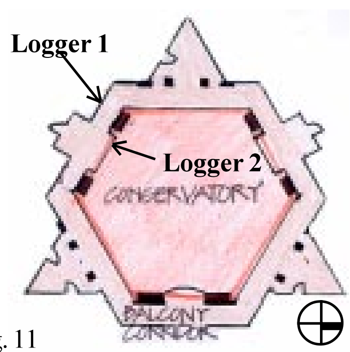


Fig. 11
Placement of data loggers for first 2-Day Measurements.

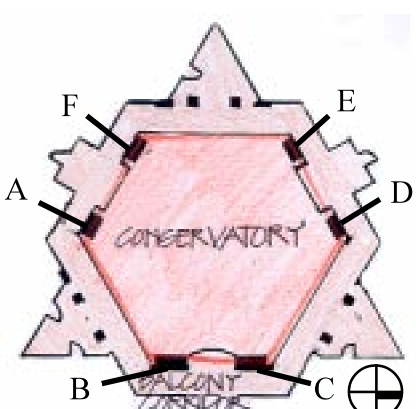


Fig. 12
Second level balcony space with placement of light intensity meters A-F.

The following methodology was used to test the hypothesis. The sequencing was determined while developing the report and talking to the visiting scholars.

1- <u>*Architect Interview*</u>
The class conducted a phone interview with the architect directly involved in the design of the Alumni Center. Each team asked a predetermined question and one follow-up question in direct relation to the individual team studies. Our team asked what the programmatic intent was for the second level balcony corridors surrounding the conservatory. We asked this question because there are different lighting levels for different types of spaces, and to continue with our study, we had to figure the intent of the space.

2 - <u>*Initial Overview Measurements*</u>
Our team took both digital and analog measurements of the illumination of the wall surfaces and portraits for day time conditions *(See Fig. 14 for image of GE analog meter)*. The measurements were taken in the balcony corridors 36 inches above the floor directly beneath each light. This initial data gave estimated light levels the corridor space receives in relation to the Illuminating Engineering Society (I.E.S.) recommended levels of 10-20 footcandles for a corridor space.

3- <u>*First 48 Hour Measurements*</u>
Two light intensity data loggers were launched on the second level balcony area to take light measurements for 48 hours. *(See Fig. 15 for image of light intensity data logger)*. Both of the loggers were set to record at 1 minute, thirty-six second intervals. A Hobo logger was placed directly on the front of the balcony glass to record the daylight received in the conservatory area. A Stowaway logger was placed on the wall between two portraits, which was exposed to artificial lighting and some filtered light from the conservatory *(See Fig. 11 for placement of loggers)*. This location was selected, based on the spot measurements taken in method two, because it received the lowest amount of natural daylight. This method was intended to tell us what time of day the largest amounts of daylight are received in the corridor space.

4 - <u>*Second 48 Hour Measurements*</u>
The second 48 hour measurements were taken by setting up two light intensity data loggers in each of the six corridor spaces. All loggers were set to take light intensity readings at 1 minute, thirty-six second intervals. A Stowaway logger was placed on each of the six column walls opposite the portrait walls. The

loggers were placed in these locations because we felt it would give us the worst possible conditions for this space. This determined the different light levels in each corridor area. *(See Fig. 12 for placement of data loggers).*

5 - <u>*Nighttime Measurements*</u>
Measurements were taken at night corresponding with the daytime measurements taken in method four. We then subtracted the nighttime light levels from the combined daylight and electric light levels to determine the amount of daylight entering the corridor. This data was collected to support the hypothesis that the need for electric lighting during daytime hours is minimal.

6 - <u>*Section Analysis of Light Levels*</u>
Two sections were drawn showing the physical (built) conditions of the space and graphing the illumination in footcandles at 1 foot intervals. The analysis included sunny, cloudy, and nighttime sky conditions. These sections were used to determine the range of light in footcandles throughout the space. Sections include:
- Facing the column in the balcony corridor space
- Facing the portrait wall in the balcony corridor space

7 - <u>*Portrait Wall Spot Measurements*</u>
An image was taken of the portrait wall surface and converted to gray scale. By adjusting the brightness and contrast levels we could see the different illumination levels. We used spot measurements and plotted them on the image to show the different levels of light falling on the wall. This was done to show the inconsistency in the range of light on the wall.

8 - <u>*Conservatory Cross-Section Analysis*</u>
To show the effect of the conservatory illumination levels on the balcony corridor spaces, a cross-section of the conservatory space that cuts through the balcony corridor on the second level and through the main stair was drawn. Instantaneous illumination measurements were taken at 4 foot intervals from the start of the stair to approximately 64 feet into the conservatory. The high illumination levels (up to 570 foot-candles in the center of the atrium) still remain just beyond the balcony on the second level of the alumni center. This data was used to prove that there is an uneven distribution of light in this space due to the adjacency of the corridor to the atrium.

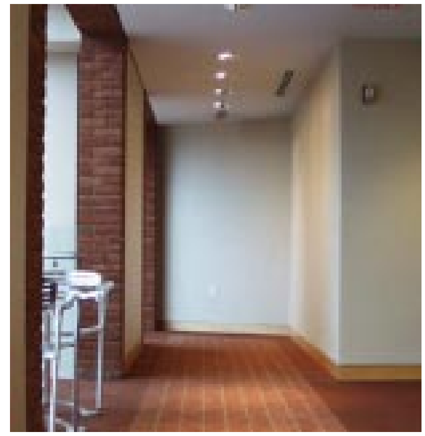


Fig. 13
View of East balcony corridor off from main stair

Fig. 14
GE handheld analog meter used to take instantaneous illuminance and luminance measurements.

Fig. 15
Light intensity data logger used to take illuminance measurements over a two day period.

9 - *Lighting Energy Assessment*

The wattage of the lights were assessed and calculated to find the lighting density in the balcony corridor. Our team estimated the hours of operation during a typical week and also found the average cost per kilowatt hour for the Alumni Center. This data was used to figure the amount of energy that the University could save by turning off the lights during bright, sunny days or during all daylight hours.

10 - *Daylight Test Without Electrical Lighting*

The original design of this method was to repeat the fourth procedure leaving the elcectrical lights turned off, collecting only daylight measurements. This would produce the most dynamic data due to the large fluctuations of light on sunny and overcast days. Since the corridor lighting is circuited with the stairways, the lighting in the balcony corridors could not be turned off for an extended period of time because of fire and safety codes. As an alternative method, we turned the lights off for approximately thirty minutes and took spot measurements with digital and analog meteres from the same location that the data loggers were placed in procedure four.

11 - *Occupants Response to Daylight Test*

While the electric lights were turned off, as described in method ten, our team surveyed several employees who passed through the corridor. The people were asked if they noticed a difference in the lighting of the corridor. Their qualitative feedback, in conjunction with general observations made by each team member about the light quality of the space, gave us a foundation on which to make recommendations for alternative lighting solutions.

FINDINGS

1- *Architect Interview*

On October 20, 1998, the Vital Signs IV class spoke with Tom Baker, project architect of the Alumni Center, via telephone conference. Our team's question focused on the programmatic intent for the balcony corridors. According to Mr. Baker, the function of the balcony corridors was twofold: to function as a ceremonial or events stage for viewers in the conservatory, and to allow circulation around the second level of the conservatory.

2- *Initial Overview Measurements*

Using a Sylvania ditigal light meter, instantaneous measurements were taken on Tuesday, October 20, 1998, at approximately 9:50 a.m., under clear sky conditions. We found measurements ranging 50-100 footcandles on the portraits. These readings were compared the I.E.S. recommended levels of 10-20 footcandles for a corridor space. The data also helped us determine where to hang light intensity data loggers later in the study.

3- *First 48 Hour Measurements*

The graph in Figure 16 shows the data collected during the first 48 hour measurement that began on October 20, 1998, at approximately 10:10 a.m. The first portion of the graph displays data collected under sunny sky conditions. As shown on the graph, the light levels were more stable. The second portion of the graph displays data collected under partly cloudy sky conditions which prove to be more erratic, especially in the conservatory area. The third portion proves to be consistent with the first portion which was a sunny day. The flat lines between the hours of 9:00 p.m. and 6:30 a.m. represent the nighttime conditions. Lights are turned off in the balcony corridor while accent lighting at night in the conservatory. One correlation drawn from the graph is that when light in the conservatory increases, the amount of light in the corridor also increases. Both of these curves prove that lighting levels in both spaces are well above the I.E.S. recommended illumination levels for a corridor space of 10-20 foot candles . *(See Fig. 16)*

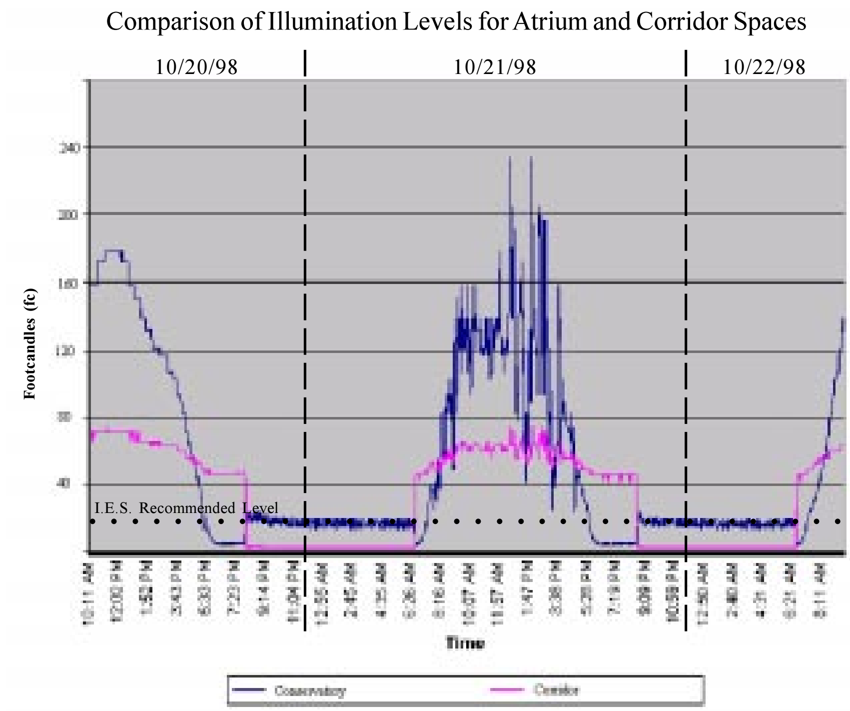


Fig. 16

Fig. 16
Initial raw data collected. After the color correction factor was figured into the data, the graph shows us that when a large amount of light is present in the conservatory it increases the amount of light in the corridor. This graph also proves that the amount of light in the corridor is significantly higher than the I.E.S recommended illumination level of 10-20 footcandles. From the graph, we know that the lights in the corridor space are turned off around 9:00 pm and then turned back on at 6:30 am.

4 - <u>*Second 48 Hour Time Measurements*</u>

Six light intensity data loggers were launched on November 3, 1998, at approximately 3:00 in the afternoon. The sky conditions for the first day were overcast and gray. Sky conditions for the second and third days were partly cloudy. Because the data collectors were not color corrected, we took spot measurements with the digital meter at the same location the loggers were placed. We then divided the reading from the meter by the logger reading to find the correction factor. The graphs show the color corrected data on a typical overcast day, the illumination levels are consistent with the I.E.S. recommended illumination levels 10-20 footcandles for corridor spaces. On a sunny day from 10:30 am to 4:00 pm, the average light levels exceed the recommended levels significantly which shows that there is a need to reduce lighting during these times. *(See Fig. 17 for placement of loggers and Figs. 18-23 for graphs of data.)*

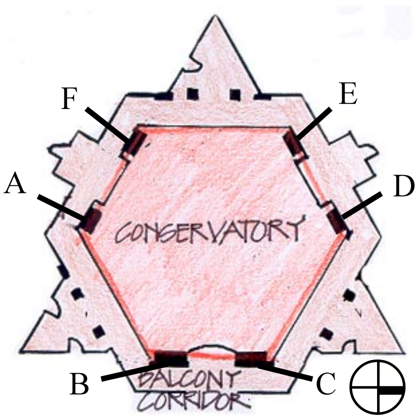


Fig. 17
Locations of illumination meters A-F

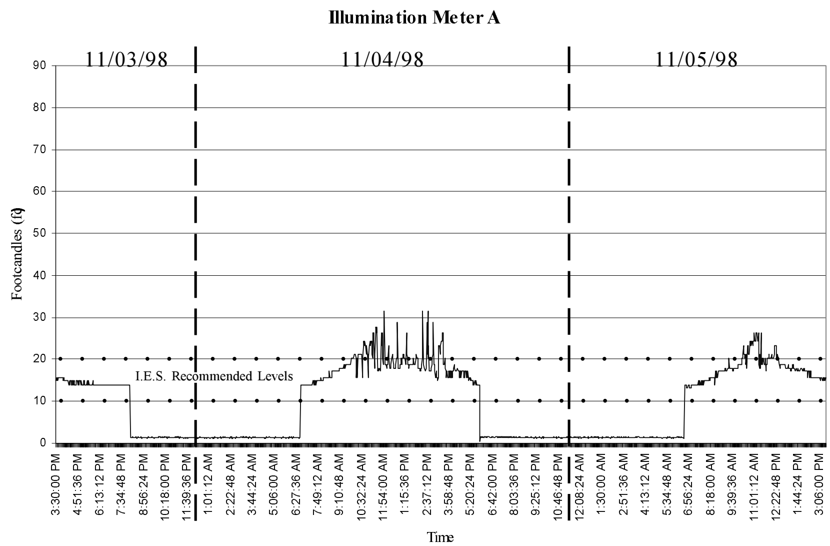


Fig. 18

Fig. 18
Data from test 2 -Meter A
(I.E.S. recommended illumination level for corridor space is 10-20 fc)

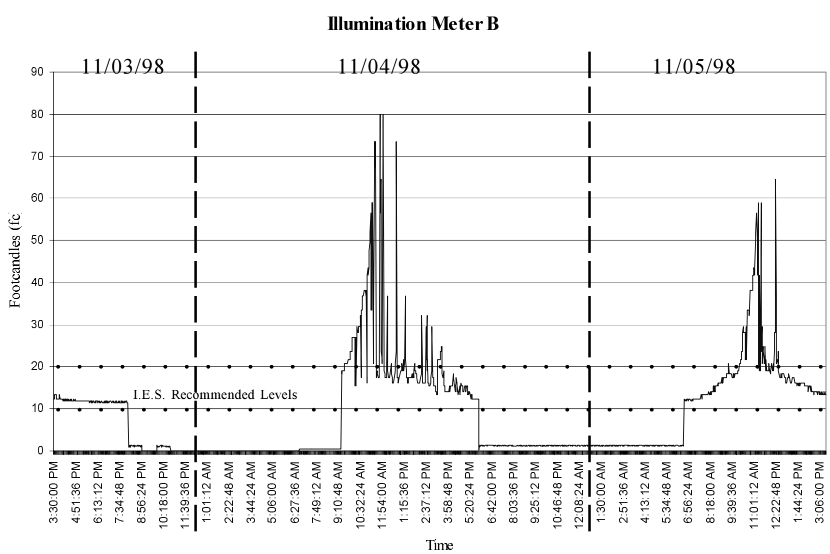


Fig. 19

Fig. 19
Data from test 2 -Meter B
(I.E.S. recommended illumination level for corridor space is 10-20 fc)

Fig. 20
Data from test 2 -Meter C
(I.E.S. recommended illumination level for corridor space is 10-20 fc)

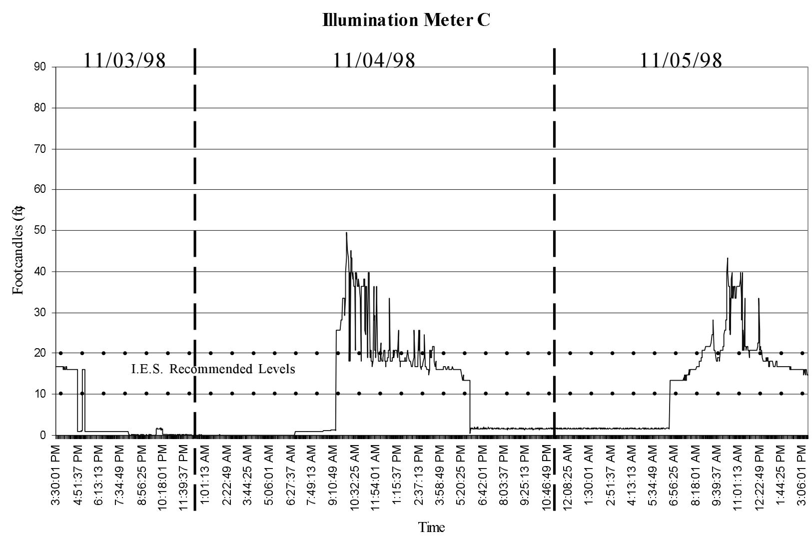
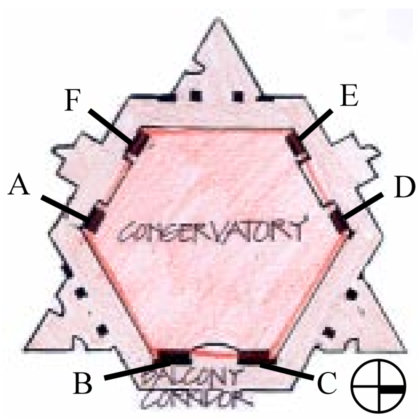


Fig. 20



Locations of illumination meters A-F

Fig. 21
Data from test 2 -Meter D
(I.E.S. recommended illumination level for corridor space is 10-20 fc)

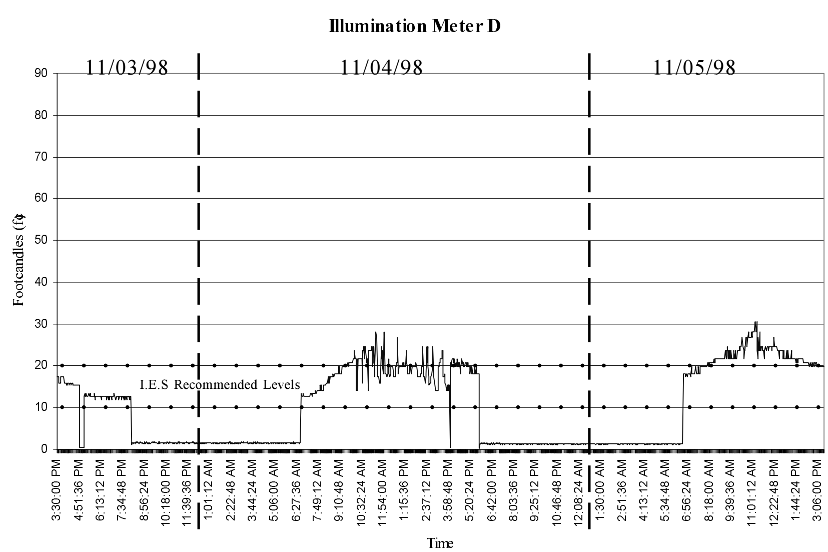


Fig. 21

Fig. 22
Data from test 2-Meter E
(I.E.S. recommended illumination level for corridor space is 8-10 fc)

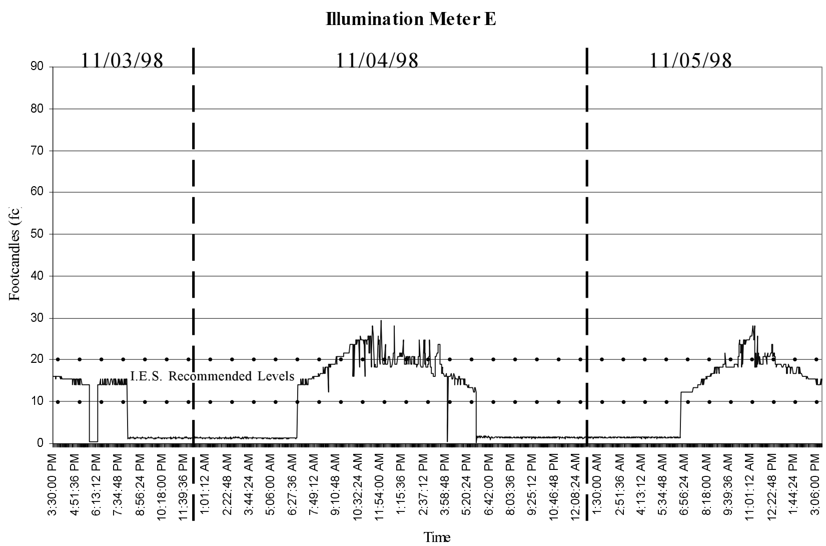
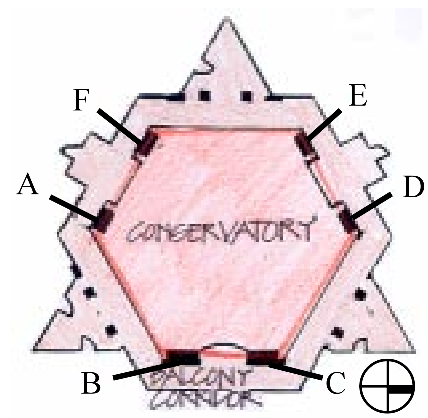


Fig. 22



Locations of illumination meters A-F

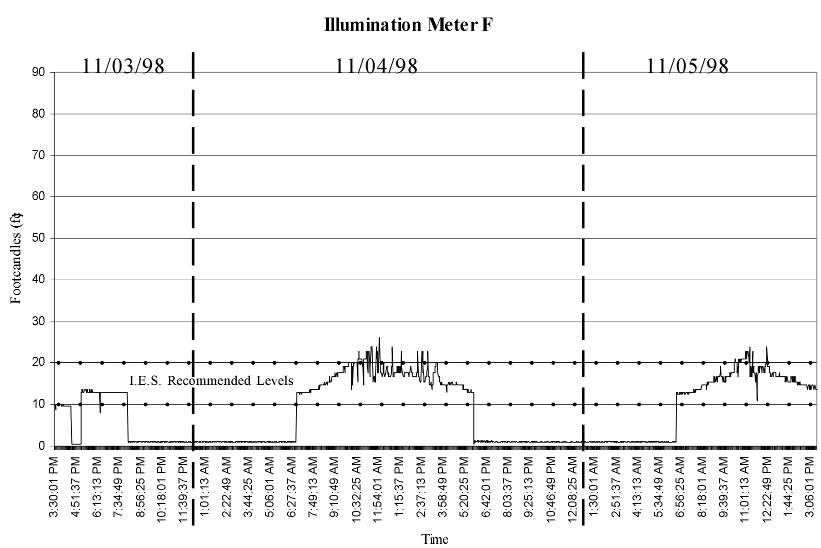


Fig. 23

Fig. 23
Data from test 2-Meter F
(I.E.S. recommended illumination level for corridor space is 8-10 fc)

5- *Nighttime Measurements*

Using the Sylvania light meter, we found the lighting levels to be 10-15 footcandles, as indicated on the sections shown in Figs. 24-25. By subtracting the average nighttime illumination levels from the average day time illumination levels we were able to figure the average diffuse light entering the corridors on a typical day. On a sunny day, we found that the average daylight component was 50 footcandles for the portrait wall and 35 footcandles for the wall opposite the portraits. On a cloudy day, we found that the average daylight component was twenty footcandles for the portrait wall and six footcandles for the wall opposite the portraits.

6 - *Section of Analysis of Light Levels*

Sections of the corridor space were produced from data collected with the instantaneous meters in previous procedures. Measurements were taken during three sky conditions to get the best representation of the lighting levels.

The first section (See Fig. 24) shows the existing illumination condition in the balcony corridor. The section was cut facing the portrait wall and instantaneous illumination measurements were taken at one foot intervals directly on the wall, 36 inches above floor level. This section shows there is an inconsistency in the placement and distribution of lighting in the balcony corridor. The light levels remain at an already high range of 50-77 footcandles in the middle zone of the space, but at the ends of the space the reflected light from the conservatory produces light levels as high as 145 footcandles. Because of the fact that the natural light can fluctuate drastically on sunny and partly sunny days, there should be some sort of operable control to adjust for the influence of the daylight factor.

The second section (See Fig. 25) was cut facing the wall opposite the portrait wall. Instantaneous illumination measurements were taken at one foot intervals directly under the row of lights, 36 inches above floor level. By looking at this section, it is obvious that the diffuse light from the conservatory was lower than shown in the first section because this is reflected light off the portrait wall. The light levels range from 23-45 footcandles at the ends of the space facing the balconies and from 41-49 footcandles in the middle zone of the space.

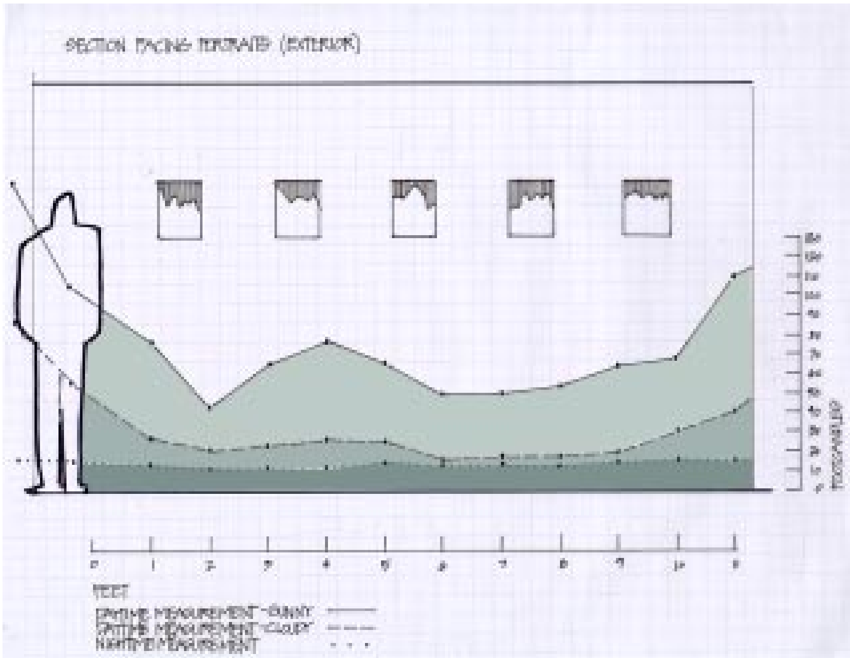


Fig. 24

Fig.24
Section showing portrait wall and illumination in footcandles at one foot intervals

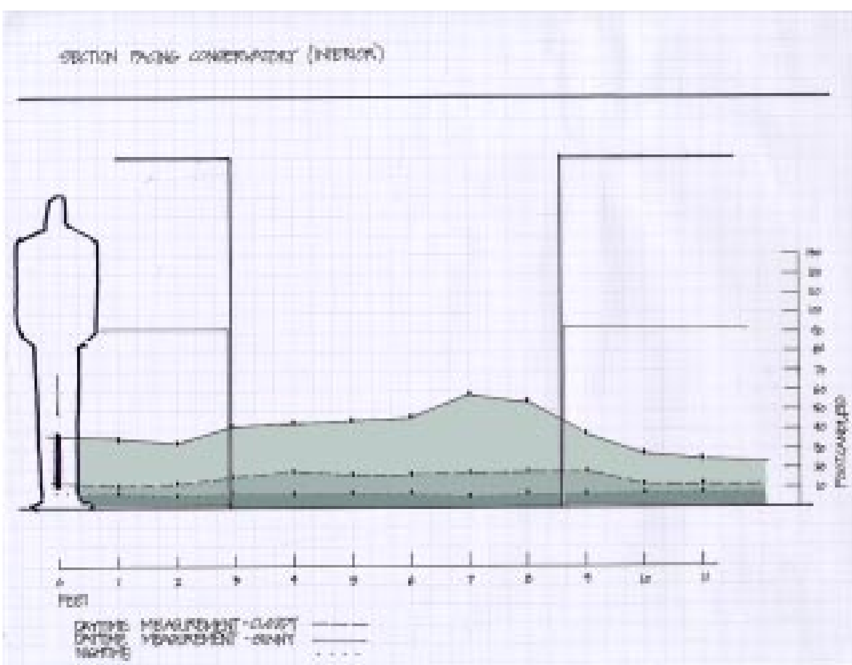


Fig. 25

Fig. 25
Section facing conservatory showing illumination in footcandles at one foot intervals

7 - *Portrait Wall Spot Measurements*

Figure 26 shows an image taken of the portrait wall surface. The image was converted into a gray scale image to enhance the varying constrast levels of light projected onto the wall during a sunny day. The spot measurements collected were plotted on cordinates and contour lines were drawn to delineate different illumination levels. This image shows the inconsistency of light arriving at the wall surface. The highest levels are those closest to the balcony spaces which are directly affected by light entering from the conservatory. The lower levels in the middle of the image are directly opposite the column wall and little light from the conservatory is affecting the area.

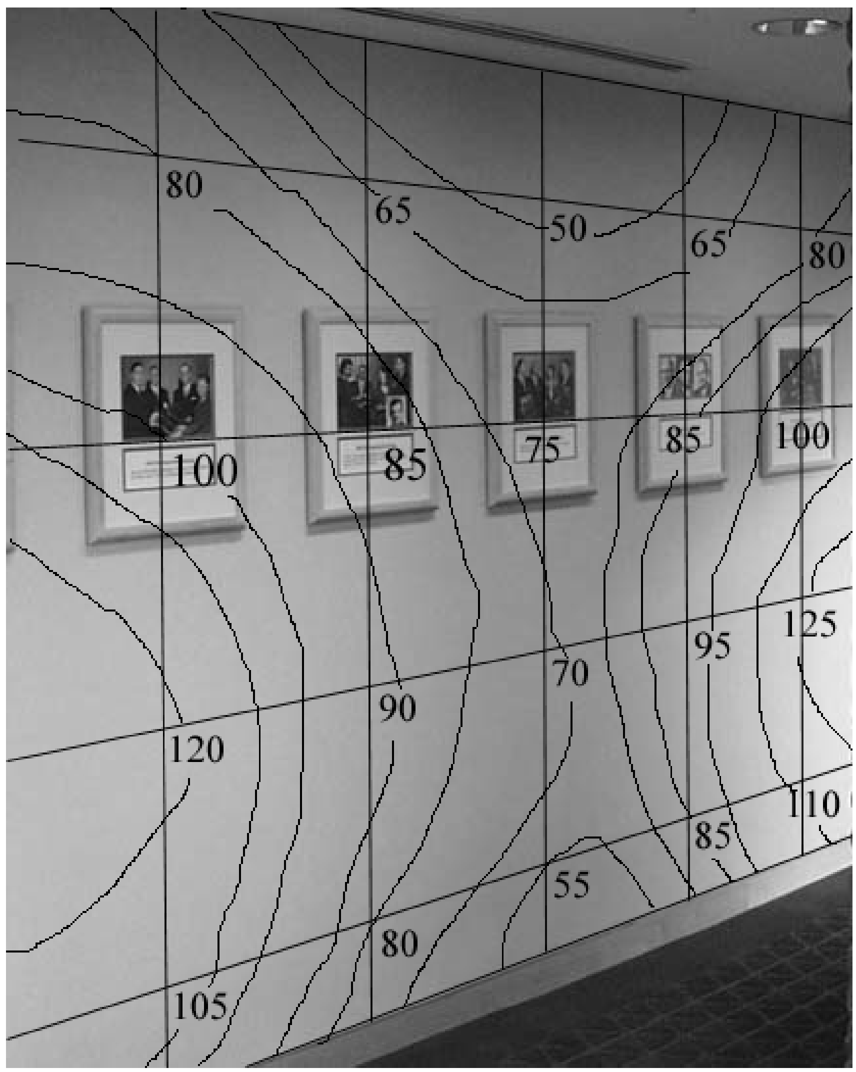


Fig. 26

8 - *Conservatory Cross-Section Analysis*

This section of the conservatory space (See Fig. 27) shows the effect of the conservatory illumination conditions on the balcony corridor space during a sunny day at 3:00 P.M. Instantaneous illumination measurements were recorded at four foot intervals from the start of the stair to approximately 64 feet into the conservatory. The high illumination levels (up to 570 footcandles) in the center of the atrium diminish to 200 footcandles just beyond the balcony on the second level. The reflected light that enters the balcony accounts for readings as low as 45 footcandles in the center of the corridor space behind the column and as high as 135 footcandles on the ends of the balcony corridors. This shows the uneven distribution of light in this space caused by the adjacency of the corridor to the atrium.

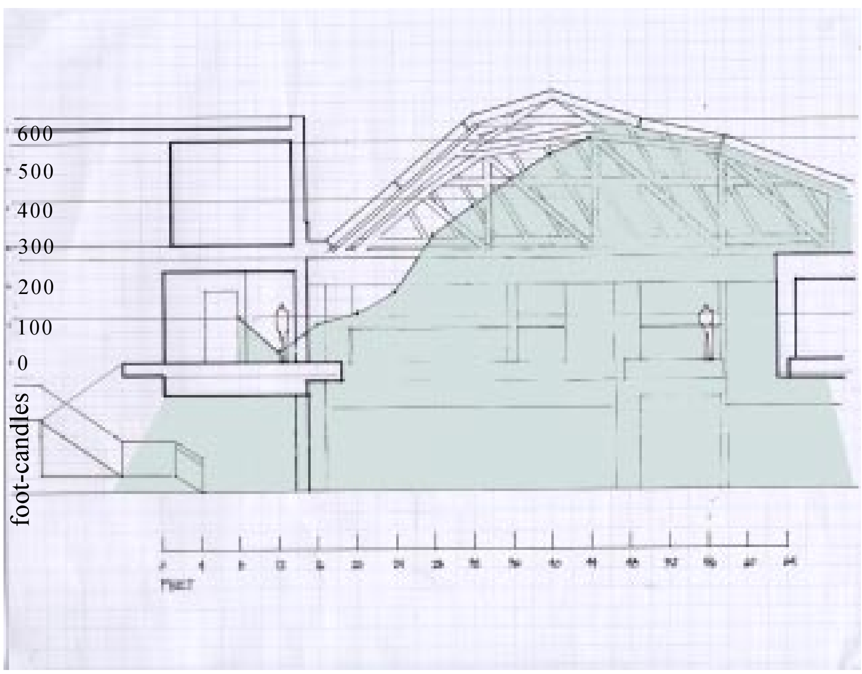


Fig. 27
Section of conservatory space that cuts through the balcony corridor space on the second level and through the main stair.

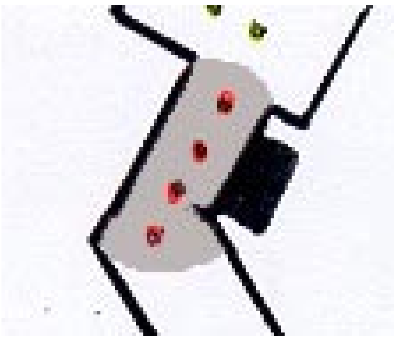


Fig. 28
Lighting density= number of fixtures x wattage / square footage

7.655 w/sq. ft. = $\frac{\text{4 fixtures x 100-watt}}{\text{52.25 sq. ft.}}$

9 - <u>Lighting Energy Assessment</u>

To assess the energy use, the lighting density was calculated by taking the number of fixtures in a balcony corridor multiplied by the lamp wattage and then divided by the square footage of the balcony corridor. In each of the six corridors, there are four wall washer fixtures with 100-watt bulbs. The area of a single corridor is 52.25 square feet. Therefore the lighting density of each corridor is 7.655 watts per square foot. According to <u>Mechanical and Electrical Equipment for Buildings</u>, the electric lighting power density for a corridor is one watt per square foot *(See Fig. 28)*.

Next the energy costs were assessed by taking total wattage of all lamps in each corridor (converted to kilowatts) times hours of operation times days used. From our six data loggers used in method four, we determined that the lights were turned on around 6:00 am and then turned off around 9:00 pm which totals fifteen hours of operation. We also multiplied that by the total days of operation in a month which we estimated to be 20 days.

6 corridors x (4 fixtures x 100-watts) / 1000 = 2.4 kw

2.4 kw x 15 hrs x 20 days = 720 kw/hrs

In a telephone interview with Jim Lowe, Facilities Assessment Engineer at Ball State University, we found that the voltage rate for the Alumni Center to be four cents per kilowatt-hour. This a large voltage rate based on peak demand. The energy costs for one month were calculated from the total kilowatt hours multiplied by the cost per kilowatt-hour.

720 kw/hrs x $.04 = $28.80 per month.

Both energy and cost could be reduced by reducing lamp wattage or alternative lighting solutions, such as occupancy sensors, discussed in the conclusion section.

10 - *Daylight Test Without Electrical Lighting*

On December 4, 1998, at 10:30 am, the lights in the balcony corridors were turned off for approximately thirty minutes. The sky conditions were overcast allowing the least amount of day light into the balcony corridor space. Instantaneous measurements were taken on the interior wall opposite the photos and at the center of the wall displaying the photos (the same location the data loggers were placed for the 48 hour test). The measurements taken on the interior wall were found to be one footcandle at all locations and the photo wall were at two footcandles. This indicates that on overcast days, it is necessary for supplemental electrical lighting. (Time did not permit a second trial on a sunny day.)

11 - *Occupants Response to Daylight Test*

During the test taken in procedure 10, several employees were interviewed regarding their response to the lighting level of the corridor with no electrical lights on. The employees were asked the following questions:

- If they noticed a difference in the balcony corridor space?
- Did they feel that it was too dark in the space?
- Did the space feel different to them?
- On a sunny day, if we shut the lights were shut off, would they have noticed a difference?
- Do you think the lights should be turned on everyday?

Responses varied from person to person, but everyone noticed right away that the lights in the balcony corridor had been turned off, including one employee noticed the lights being off from the lower level of the conservatory space. The employees all also agreed that it was too dark in the space without the lights on. When asked if the space made them feel different with the lights off, they all noted that it seemed more gloomy or depressing which was consistent with the overcast sky conditions. When asked if on a sunny day they would notice the lights being off, some responded that they would probably notice the lights being off and others responded that they probably would not notice whether the lights were on or off.

CONCLUSION

Fig. 29
Ball State Alumnus viewing portraits in balcony corridor space.

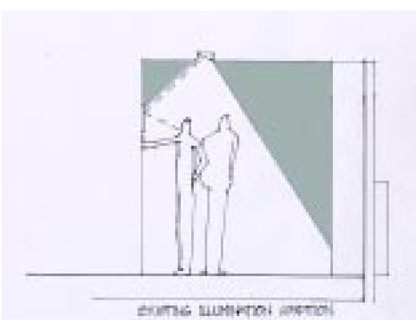


Fig. 30
Existing illumination condition in the second level balcony corridor space.

This report presented research and investigation findings of lighting levels in the balcony corridors conducted at the Ball State University Alumni Center. During the process of this investigation, we found the corridors to serve dual functions of both circulation and exhibition. This insight led us to different design recommendations that separate the two functions and leaves a more efficient and qualitative space.

The team collectively gathered data, studied the results of the procedures previously listed, and individually drew conclusions based on multiple subjective observations of the second level balcony corridor spaces. There are several possible standards on which to base the conclusion of this case study. The hypothesis is intended to prove that based on the architect's design of these spaces and by the recommended illumination levels given by the I.E.S. for this function, the existing electric lights are not necessary during daylight hours. From a scientific standpoint, and based on the sections produced through the space, it is possible to assume that the electric lights could be eliminated on sunny days. However, because daylight is so dynamic and the illumination levels can fluctuate so much on partly cloudy and cloudy days, there is still the need for some artificial illumination in these spaces.

The team originally attempted to conduct light intensity measurements over several days with the electric lights turned off. The team believed that this step would prove that the lights were not necessary based on levels above the I.E.S. recommended average of 15 footcandles for circulation spaces. Unfortunately, this procedure could not be carried out because of the circuiting of the lights, fire and safety codes, and the scheduling logistics involving the users. The team was able to study the effects of the space without artificial light for thirty minutes on a cloudy day. Several people were questioned about the lights being off. It was evident after conducting this survey that there are two distinct purposes of the electric lights. The first and obvious reason is for the illumination of circulation paths. The second purpose, which is separate and distinctly different in nature, is for the illumination of the portraits. Due to the fact that there are two distinct illumination functions (circulation and display), there is an inconsistency in the light levels of this space. Because of the placement of the lights, the portraits receive a veiling reflection that makes viewing the images difficult to see unless they are viewed from an angle *(See Fig. 30 for existing illumination condition)*.

Based on this discovery, the team believes that there is the need to separate the two lighting functions (circulation and display) in order to maintain a consistent illumination level and to implement some form of operable control for this system.

Figure 31 shows a possible solution to the problem that exists in the current illumination condition in the second level balcony corridor space. The movement of the existing wall washer closer to the wall would cause the angle of reflection to change and thus eliminate the veiling reflection that is sometimes present on the portraits. In addition to this, a lower level lighting fixture that would act to illuminate the floor and reflect light from a thin metal panel up to the portraits would be introduced. This system would be on a different circuit to allow two separate lighting conditions to occur independent or in unison depending on the effect of light entering from the conservatory.

Figure 32 shows a second possible solution to the problem that exists in the current illumination condition in the second level balcony corridor space. This system would also move the existing wall washer lights in closer to the wall to eliminate the veiling reflection problem. Rather than having a fixture that worked to illuminate both the portraits and the floor surface, this system would introduce lower level lighting fixtures that illuminated only the floor. Similar to the first proposed condition, this system would also work on a different circuit to allow for flexibility in response to the lighting conditions in the conservatory. In addition to the afore mentioned recommendations, these lights could also be controlled by occupancy or photo sensor controlling devices to maintain consistent illumination levels and reduce energy consumption.

In conclusion, the team believes that not only the illumination levels are too high in these spaces, but the range in footcandles is too broad and inconsistent. Therefore, we believe that the propsed alternatives would help to maintain more controlled task specific lighting levels.

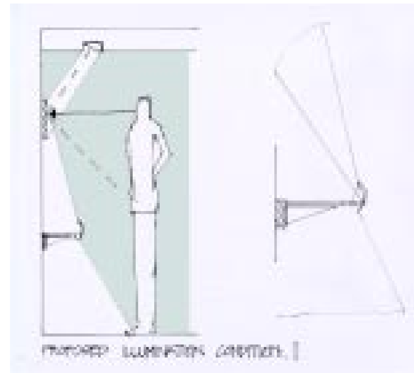


Fig. 31
First proposed illumination condition in second level balcony corridor space.

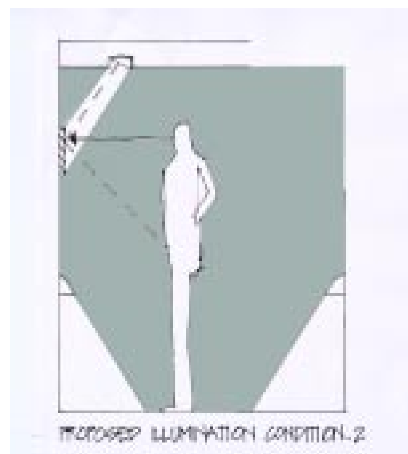


Fig. 32
Second proposed illumination condition in second level balcony corridor space.

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ACKNOWLEDGEMENTS

This report was compiled and produced by:
Jason Brown - First year architecture student
Cory Calvin - Second year business student
Barbara Charlton - Third year architecture student
Jake Plummer - Fifth year architecture student

The team would like to express gratitude to the visiting guest lecturers: Bruce Haglund, Alison Kwok, Joel Loveland, Jeff Sailer, and Marc Schiler. See Appendix B for the contributions of the lecturers. We would also like to thank Matt Stevenson of the Alumni Center, and finally the CERES Administrators: Jeff Culp, Professor Robert Fisher, and Professor Robert Koester for their contribution to our case study.

APPENDIX A

This appendix includes personal narratives of each group member on their intial thoughts and observations about the Alumni Center. This information was used in determining our hypothesis.

JASON BROWN

FIRST YEAR ARCHITECTURE MAJOR

Upon my entry into the Alumni Center, I found that it is an impressive building. The building itself has an interesting style, which is composed of angles and natural lighting. The atrium space creates a large social area with vast amounts of natural light. This light helps to create a warm and inviting space. After noticing the light in the atrium, I focused my attention to how the light was entering and how its effect on the rest of the building spaces. The Boardroom, a very impressive room with a large oval table and video screens for presentations and teleconferencing, was the first room to catch my attention. The Boardroom is illuminated with both electrical lights and daylight from windows on the south wall. The electrical lights include small perimeter accent lights, small spotlights above each chair of the boardroom table, and a hanging fixture above the center of the table. My initial thought was to test this room for glare discomfort levels. I later concluded if this problem existed, board members would have already addressed it. The overall design of the Alumni Center appeared to be very well laid out for the workers needs and for the overall optimum performance of its duties.

CORY CALVIN

SECOND YEAR BUSINESS MAJOR

During my initial visit to the Alumni Center, I observed the building from a structural and design standpoint, noticing the use of triangles and hexagons throughout the entire building. The space that initially caught my attention was the Board Room. The large maple table was very impressive, and this prestigious room gave me a feeling of importance while sitting at the table.

My second visit consisted of observing four main areas of interest: Assembly Hall, Alumni Room, Atrium space, and the Board Room. In Assembly Hall and the Board Room, I changed lighting levels in each room to see the affects in the room and on work surfaces. My attention was still focused on the Board Room. As I was "playing" with the lighting, I noticed when the small spotlights were on directly over the work surface, shadows were created when leaning over the work on the table. I put my hand one foot above the table surface and sketched the shadows produced on the surface.

A third visit was made as a group and we all discussed our areas of interest. From viewing each of these areas, we collectively agreed on an area that would give us the best testable hypothesis and outcome.

Barbara Charlton
Third Year Architecture Major

I experienced the Alumni Center for the first time on a very bright, sunny day. I was impressed with the overall daylighting effects of the central atrium space, but somewhat disturbed by the lack of natural light in the office cores, where the support staff is located. Another observation was the extensive use of electric lights in the corridor space of the balcony area. Although the walls are used to exhibit alumni photos, it seemed overly bright when combined with daylight and that the arrangement of one light per photo was excessive.

Jake Plummer
Fifth Year Architecture Major

My first impression of the Alumni Center was that the overall lighting design was well implemented with the overall building design. I was interested specifically in the conservatory and the quality of light that enters the space. It seemed that there were ample opportunities in this space, because of the variety of types of lights and the way that they were complementing the natural light in the space. Initially I wanted to study the effects of the high wattage lights on the palm trees and if they worked correctly and efficiently. Another idea that came from the conservatory space was to study the translucent glass in the overhead skylight to determine whether the opacity of the glass was sufficient to block unwanted glare and maintain a tolerable comfort level. Working with the other team members, we pooled our ideas to determine which proposal had the most potential for developing a testable hypothesis. The current hypothesis developed from one of the team members' observations of the second level balcony spaces. The concept initially dealt with studying the usage of the second floor balcony, corridor, and vestibule spaces that surround the conservatory to determine whether the can lights were necessary. The team decided that it would be feasible to measure the lighting levels to see if the light that illuminated the portraits was above recommended levels. The three most important issues in the initial stages of the case study are: determining from the architect, or someone directly involved in the planning, the exact intended use of the balcony space, the cost of the light per kilowatt hour, and the hours of operation. As the study continued, each team member added their own criteria to evaluating the space in terms of light quality and illumination efficiency.

APPENDIX B

This Appendix lists the contributions of each of the visiting lecturers who presented to the class during the semester. Each team had individual meetings with the lecturers. In each case, the guest lecturers gave the class a different perspective from which to view the process of scientific research.

BRUCE HAGLUND

PROFESSOR, UNIVERSITY OF IDAHO

During our team discussion with Mr. Haglund he told us about the structure of the case study. He said that there were three major parts of the case study including the indicative, the investigative, and the diagnostic. Mr. Haglund explained the reason behind doing each portion of the report and what could be learned from those sections. According to Mr. Haglund, the indicative section gives both the researcher and the reader the awareness of the importance of the area being studied in terms of what exactly the goal of the research is. The indicative deals with all of the parameters of the research and the who, what, when, where, and why of the report. The investigative section of the case study deals with immersing oneself into the factual data and the information that will be used to prove or disprove the hypothesis. This could be through surveying the occupants of the space or by measuring the light intensity, illuminance, or luminance of the space. The Diagnostic portion of the work deals with actually taking the data that has been generated and pulling out the critical information that can be directly tied to the hypothesis. The diagnostic phase of work proves the ability of the researcher to compile all of the data into a concise format that proves or disproves the hypothesis. Mr. Haglund explained the importance of understanding each of these phases and the types of activities that need to be performed in each one. His expertise in leading students in case study work at three Museums in Seattle brought him to Ball State to share the findings of their case studies. Through examining the light quality of the different museums and combined with the architect's design intent, Mr. Haglund's class was able to make recommendations based on three-dimensional computer models that tested the orientation of the building and solar angles.

Alison Kwok, Ph.D

Associate Professor, University of Oregon

Dr. Kwok's lecture focused on how to begin a case study and develop a hypothesis. She broke the case study into its most essential parts in terms of observation, testing, and drawing conclusions based on the findings of experimentation. She told the group to first observe the spaces in the Alumni Center and take notes, photographs and quick sketches to develop a base on which to work. She also said to find out early what the architect's goals were for the spaces that we were interested in studying. From that, Dr. Kwok encouraged the group to use the senses that we as humans possess first and foremost as a tool in testing our hypothesis. According to Dr. Kwok, it is sometimes necessary to use scientific methods and tools to support and enhance the human senses. This would be the case in taking digital measurements of illuminance and luminance in the selected space. As a class we received the benefit of a better understanding of the purpose and methodology of the case study. Her knowledge and expertise in architectural building science and especially natural ventilation, air quality, occupant thermal comfort, and energy use/ conservation contributed greatly to helping the team develop a way-of-thinking about analyzing the built environment. Furthermore, Dr. Kwok's experience teaching a similar course at Cornell University served as an example of the entire process of conducting a case study from initial observation through final conclusions.

Joel Loveland

Professor, University of Washington

In his lecture Mr. Loveland talked about the unpredictability of nature with regard to daylighting in buildings. He stated that through history there has been a paradox between the ideal (mind/spirit/reason) and the place of reality (experience). To truly understand light, he said, we must first understand darkness and how we perceive the absence of light. Mr. Loveland discussed the changing requirements for energy efficiency in buildings for the next century. He said that there will be an 80% reduction in energy consumption in buildings eventually and that today we are nowhere near capable of meeting those needs because of our reliance on fossil fuels as a primary energy source.

During our team discussion with Mr. Loveland he encouraged us to use our senses as a primary tools in interpreting the light qualities that we are studying in the Alumni Center. Mr. Loveland continued to explain how the human eye is capable of adapting to light levels in a much greater range than other digital sensors. He also talked about how the space was experienced in terms of light quality for the occupants. Mr. Loveland encouraged the team to take readings of the circulation space with the lights turned off for several days and then to survey the occupants to see if they noticed the difference. He further discussed how the lights in the circulation spaces were left on throughout the day despite the ample residual light that filtered in from the conservatory. He believed that the architect really did not care about natural light in the building and the light quality in general.

Jeff Sailer

Graduate Student, University of Florida

Mr. Sailer was a zoology major at Ball State University and was a student in Vital Signs 1. He said that when he signed up to take the class as an elective, he doubted that he would learn much as it was unrelated to his major. Upon graduation, Mr. Sailer took a position working with animals and studying how they respond to the environment around them through their metabolic and physiological processes. His lecture to the class focused on how he used the information that he learned while taking the Vital Signs class in conducting research on animals in the field and in scientific experimentation.

Marc Schiler

Associate Professor, University of Southern California

Mr. Schiler lectured on the aspects of glare in the architectural environment. His examples of buildings and spaces that he has studied gave the class insight on how to eliminate unwanted glare and reflections on surfaces. Mr. Schiler explained on a more general basis the difference between illuminance and luminance and that luminance was what actually caused glare due to the fact that light was leaving the surface. In each case he said that adaptation of the eye between the source and the background was critical in the level of glare that was produced.

Mr. Schiler referred to the Alumni Center in our team discussion with him. He said that the wall washers (the lights in the circulation spaces) should be a minimum of 2-3 feet from the wall and at least that far from each other. He said that it really would not be possible to reduce the number of fixtures, but that it is feasible to use a photo dimmer to dim the lights when it is too bright in the area. According to Mr. Schiler, another possibility would be to incorporate an occupancy sensors or combined photocell/occupancy sensors to help increase the energy efficiency of the lights.