A SIMPLELIFESTYLES STUDY IN EARTHFRIENDLY DESIGN

Direct Beam Radiation

A Comparative Analysis of The Southern Fenestration of The Hall of Champions & Office Wing Of The NCAA Headquarters

Indianapolis, Indiana

VITAL SIGNS VI

Fall 2001

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Interior Illuminance, Daylight Control and Occupant Response

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A Direct Beam Radiation Comparative Analysis
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for all of his invaluable contributions of
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Robert Fisher - Professor of Architecture, Resident Fellow

Ron Fisher - Managing Partner from Schmidt Associates, Architect of Record, who provided us with insight into the architects design intention.

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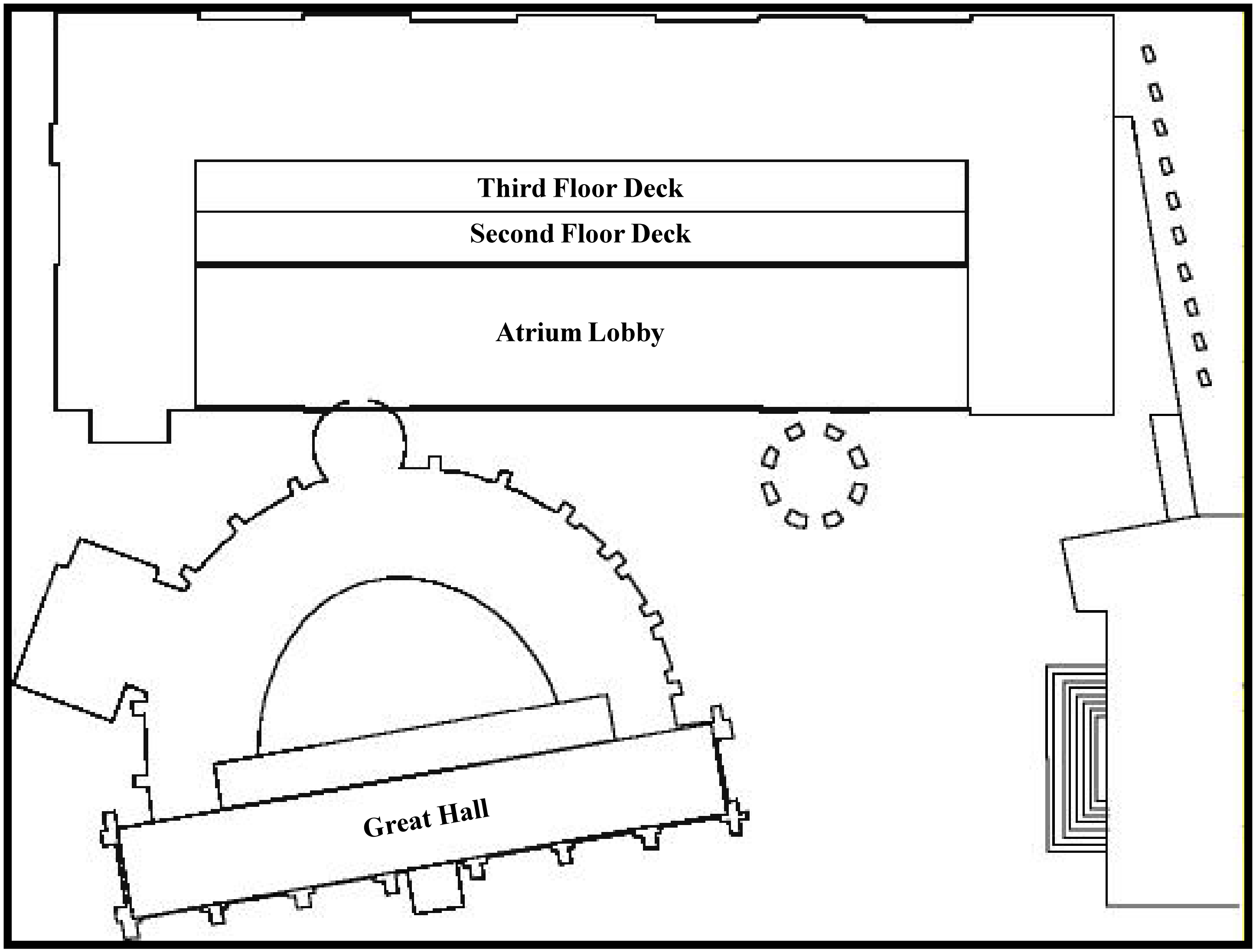
Keymap of the NCAA Office Wing and the Hall of Champions



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"Architecture is the masterly, correct and magnificent play of masses brought together in light"

Le Corbusier, 1927

ABSTRACT

In the fall of 2001 the Center for Energy Research/Education/Service (CERES) selected the NCAA Headquarters and the Hall of Champions campus for a post occupancy evaluation of the lighting environment as the research subject for a course structured around the national Vital Signs program.

These signature buildings, designed by world renowned architect and AIA Gold Medal winner Michael Graves, are located in White River State Park in Indianapolis, Indiana. Opening for business on March 29, 2000, the two buildings each have 80% south facing fenestration, allowing for full direct beam radiation to enter the adjacent atria spaces.

Our team chose to study the effects of this direct beam radiation in the atrium spaces following the protocol of an instrumented field study utilized by CERES, among others. This protocol uses indicative, investigative, and diagnostic procedures for research topic identification, data gathering and analysis.

Our introductory visit to the NCAA Headquarters and the Hall of Champions was a guided walk-through led by the staff of REI Real Estate, the firm responsible for the operation and maintenance of the buildings. The tour included the renovated Superintendent building, an historic building on site. The physical characteristics, layout and lamping of all three spaces were explained to us by the building management team. Informal interviews were conducted with the occupants of the work spaces.

Indicative Process

The group then split into teams, with our team choosing to investigate the effects of direct beam radiation on the atrium spaces of the two main buildings. Discomforting glare was present in the two spaces, a fact made evident by many informal remarks made by the employees during the first visit, as well as our own observations.

Fig 6-a Downtown Indianapolis, White River State Park

Investigative Process

In our investigative process, we took steps to gather some initial technical information

- Instantaneous illumination measurements.

These readings were taken at the finished floor level, surface level, and eye level to gain a better understanding of the illumination patterns within the spaces.

- Digital and 35mm photography

Pictures were taken to document our study as well as for use in photometry analysis. Points of high illumination and reflectance, deep contrast ratios and veiling and reflecting glare patterns were pinpointed and recorded.

- Contour mapping

Using a reference grid pattern of 4ft., instantaneous illumination data were gathered and recorded. Isolux diagrams of the light distribution of the entire space were constructed from this data.

- Long term illumination measurements

Stowaway and HOBO data recording loggers were set up to measure changes in illumination over a period of time.

- Computer modeling

AutoCAD models were set up to simulate light patterns and their distribution throughout the spaces in a format that would be easy to use to convey information about direct beam radiation and its penetration into the perimeter of the building.

Diagnostic Process

In our diagnostic process, the data gathered from our investigation was condensed and evaluated. The isolux charts, area graphs and photometric analysis generated by our investigation gave us the necessary information with which to assess the performance of the spaces.

Research into the factors involving visual discomfort, and the characteristics of glare in particular, was necessary for us to be able to evaluate the information and test our hypothesis.

Comparative Analysis

We used the information gathered from our diagnostic methods and compared the results of the two spaces. Our comparison used the following criteria:

- Standard Illuminating Engineering Society (IES) guidelines

Recommended IES illumination standards for space and task related to atrium, lobby and path, seated areas and reception desk

- Design team intent

  The aims of the design professionals working together on this project regarding daylighting and glazing in the atrium spaces.
- Factors in visual accuity

  Specifically the factors involved with direct glare, veiling glare and reflecting glare

- Aesthetic considerations

  A survey was taken to see how the occupants of the buildings felt about the daylighting of the atrium spaces.

Conclusions

Based upon our research, we concluded that visual discomfort exists part of the year in the atrium spaces of the two buildings due to direct beam radiation.

Recommendations

Analysis of daylighting principles and comparison with successful daylighting designs led us to recommend strategies for mitigating visual discomfort and heat gain in this facility, such as:

- Light shelves
- Glazing treatments
- Shading devices, such as blinds

It is our recommendation that the interior lighting be turned off during the daytime, as the daylighting provides enough light to meet the needs of the buildings occupants. Ideally, the lighting should be integrated with controls that turn the electric lighting off and on, depending on the illumination of the space.

INTRODUCTION

CERES Vital Signs

This lighting study of the NCAA Headquarters and the Hall of Champions was conducted through the course **Vital Signs VI**, offered by **CERES** (Center of Energy Research/Education/Service) in the fall of 2001, at Ball State University. CERES is an interdisciplinary academic support unit, focusing on issues related to energy and resource use.

The Vital Signs project, funded by **Pacific Gas and Electric**, the **National Science Foundation** and the **Energy Foundation**, is an interdisciplinary curriculum designed to enable students to research, postulate an hypothesis and write a technical report based on their findings. It is coordinated through the Center for Environmental Design Research at the University of California in Berkeley. We are especially indebted to Wayne Leonard, CEO of Entergy, for his companys endowment of the Ball State University CERES Vital Signs Project in support of the student scholarship documented in this report.

Our project worked under the supervision and direction of the architectural faculty and professional staff at **CERES**.

An interview with Ron Fisher, the managing partner from Schmidt Associates, the Architect of Record, was conducted via teleconference.

Observations

With clear skies, the NCAA Headquarters and the Hall of Champions receives high illumination values from the southern glass facade. The incoming light casts more deeply into the space in the winter months due to the sun's lower angle in the sky.

Comparative Study of Direct Beam Radiation

Based upon our indicative visit, our team chose to do a comparative study of the southern fenestration of both buildings. We were concerned with the problems associated with direct beam radiation entering into such large facades of glass, and we wanted to compare the functionality and effectiveness of the two spaces.

We noticed the significantly high levels of direct beam radiation on our initial visit, with higher ilumination inside the Great Hall in the Hall Of Champions. The administrative building seemed to have better control and was able to utilize the incoming direct beam radiation much better.

Fig. 8-1 Reception area inside the NCAA Administration Building recieves high levels of illumination from direct beam radiation entering the large south-facing glass facade.

NCAA Administrative Building

The NCAA Headquarters Administration building encounters problems with direct glare and veiling reflections during the early fall to early spring months.

The first floor lobby is a minimal-use space, used partly as a reception area and mainly as a transition space to access the grand stairway and the offices and rooms off of its main axis.

The main difficulty on the first floor is with direct beam radiation entering the reception seating area in the mid-morning hours from roughly around 9:30am to noon.

The early morning sun is shaded by the Superintendent Building to the southeast, while the afternoon sun is shaded by the entranceway to the southwest.

Open Decks

The open deck of the second floor, and somewhat the third floor, are affected more by direct glare caused by the incoming direct beam radiation, especially the seating areas known as the "sidewalk bistro" by the workers who eat their lunch there. The lounge areas at the east and west ends of these decks are also affected.

The second floor deck, the largest open area seating in the atrium, recieves the most intense direct beam radiation levels of the three floors, with higher illumination values and deeper penetration in the mid to late afternoon in the early fall to early spring months.

The penetration of space by direct beam radiation changes over the period of the day in the months noted , from early fall to early spring. In the morning, it stays clear of the tables, climbing up the carpet. In the afternoon, it moves up to the tables and the wall.

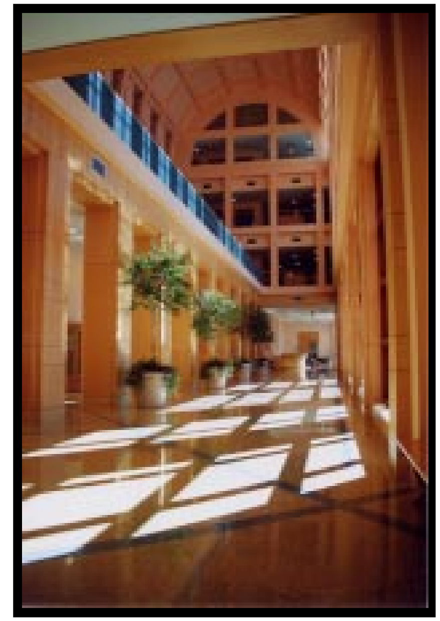


Fig. 9-a First floor, NCAA Administration Building.

Fig. 9-b Reception area seating

Fig. 9-c The "Sidewalk Bistro" second floor open deck

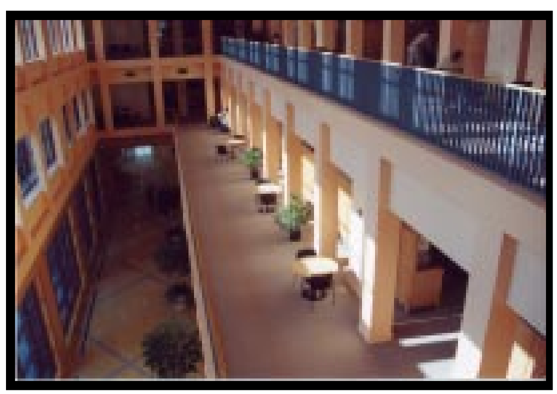


Fig. 9-d The lounge area, second floor open deck

Hall Of Champions

The Hall of Champions experiences some of the highest illumination readings of the two buildings. The entryway space known as the Great Hall was designed to be an indoor/outdoor space, a transition from the outside park to the inside gallery and exhibit spaces.

The open facade was designed for maximum viewing from the outside, to attract people and bring them into the building during the day. At night, the design intent of the architect was to have the Great Hall acts as a lantern, illuminating the space within and casting a glow across the parkway.

Fig. 10-a Hall of Champions

The 20’ x 45’ foot tall windows allow significant illumination levels into the interior space, some as high as as 4000 footcandles. The windows were not treated with low-emissivity coatings or films that would help mitigate heat gain, nor were they designed to mitigate transmittance, so that the viewability of the interior from the outside and the illumination of the lantern effect at night would not be compromised.

Interior

The interior atrium of the Great Hall is finished with light colored, highly reflective materials such as the terrazo tile floors and the yellow ochre reception desk laminate surfaces. The walls are made of red clay brick and a deeply saturated pastel blue brick that serve to tone down the reflectance somewhat. While the highly reflective surfaces aid in the lantern effect at night, they serve to create high luminance reflectance during the daytime operating hours, creating veiling and reflected glare.

Fig. 10-b The Great Hall

Daylighting in Design

Daylighting is receiving more attention now. and being explored more by architects, engineers and designers now than ever before. The key to incorporating daylighting into design is how to do so without undesirable effects.

The horizontal directionality of daylight entering a window (sidelighting) provides excellent vertical illumination and good modeling of shadows with minimum veiling reflections.[1] This, coupled with the visual contact with the outside, is why there is a demonstrably marked preference for daylight over any other lighting options.

Other factors in favor of daylighting stems from the issues of energy efficiency and the conservation of precious natural resources. Legislative attempts to encourage lighting energy effectiveness, such as the Energy Policy Act (EPACT) of 1992 and the EPA's Green Lights program work toward creating an awareness of the importance of these issues in the design and construction of the built environment.

World wide standards consider electric lighting as supplementary to daylighting. Their design approach, such as the British technique Permanent Supplementary Artificial Lighting, Interiors (PSALI) recognize that sufficient daylight is available during the time when non-residential interior load dominated building demand is the highest, during the day, and that daylighting can meet most needs. The high cost of energy in Europe, as well as the rest of the world, has made PSALI a universally applied standard across the continent.

One of the most prominent characteristics of daylighting is its **continual variation**, providing gradual and continually changing patterns of illumination that the eyes can easily adapt to. It provides excellent vertical surface illumination, some of the most important surfaces to be lit because the vertical surfaces occupy our field of view more than the horizontal surfaces. This is typically ignored in lighting design, where the focus is on horizontal footcandles on work surfaces and average footcandles within a space. In reality, we spend very little time looking at horizontal surfaces.

Drawbacks

The drawbacks to daylighting design are[2]

• The influence of windows on the thermal balance of the building.

This depends on whether the building is load dominated or envelope dominated. Load dominated buildings consume most of their energy in electric loads associated with cooling of waste heat produced by lighting and powered equipment. For daylighting to be an effective alternative to electric lighting, it must reduce lighting and cooling energy costs more than it increases energy costs from heating, solar gains on the glazing and from envelope loads.

• Variability of conditions beyond occupant control (sunny, partly sunny, partly cloudy, overcast).

Careful consideration of the design should include daylight factor, the amount of light contributed from the ambient light of the sky vault on a cloudy day, establishing a best-case design use of a readily available no load illuminate that electric lighting can complement when necessary.

• Visual discomfort from direct and/or reflected glare.

This occurs with direct beam radiation, the sun entering the building at the right angle can cause these glare conditions.

1 and 2 See footnotes in bibliography at the end of this report

HYPOTHESIS

Our hypothesis states that visual discomfort exists in the open atrium spaces of the NCAA Headquarters and the Hall of Champions. This is the result of multiple factors including:

- direct beam radiation.
- high illumination levels
- material reflectance
- brightness contrast in the field of view

Direct Beam Radiation

This study of the signature buildings of Michael Graves focuses on the problem of direct beam radiation. The entrances and atrium spaces to both the NCAA Headquarters Office Wing and the Hall of Champions are transition spaces, providing access to other parts of the buildings. They both have south facing facades made up of over 70% glass fenestration that receive direct sunlight, with deeper penetration in the winter months when the sun is at a lower angle.

Glare

Glare is defined as excessive luminance and/or excessive luminance ratios in the field of vision. Discomfort or direct glare is caused by light sources in the field of vision. From September through April, the sun is low enough in the sky to enter into the field of view of the occupants. The southern fenestration receives direct beam radiation from the sun, with readings as high as 4000 footcandles inside the space, producing direct glare. The reflectance of the light colored materials produce high luminance values, resulting in reflecting and veiling reflections.

In our research we discovered that, in order to determine the overall performance of the spaces, there are other aspects to consider besides the strictly technical IES recommended guidelines, which focus primarily on a quantitative analysis of the amount of illumination a space receives.

Other factors of visibility include things such as[3]

- Contrast
- Luminance ratios
- Exposure time
- Chromaticity
- Adaptation levels of the observer (differs with age)

as well as other subjective factors like

- Subjective impressions
- Psychological reactions

We focused on one major time period during the normal workday, from mid-morning through mid- afternoon, when the direct sun had its most significant impact. Sunny and overcast conditions were measured for comparison.

Greetings

Reception Desk, Office Wing of the NCAA Headquarters

Vital Signs Protocol

The methodology of this report follows the protocol of an instrumented field study as developed by Wolf Preiser and used by CERES.

Introductory Visit

While we were being instructed in the tools and procedures of an investigative field study, the group made an initial visit to the site in early September. We were given a full tour of the facilities and a brief introduction to the lighting systems by the REI Real Estate management group, the ones responsible for maintaining the building. After this visit, we formed into teams.

Indicative Visit

This assessment reinforced the preliminary visit to the facility, allowing the team to frame an awareness of the design and search for opportunities for investigation.

Our team returned in mid October, walking through the facility, looking for areas to begin our investigation. We focused on the southern facades of the two main buildings with large glass fenestrations. These areas included

NCAA Administrative Building
- first floor lobby atrium,
- second floor open deck
- third floor open deck

Hall of Champions
- Great Hall entranceway

Investigative Procedure

This step was used by the team for more detailed fact-finding, using short term instrumented sampling to gather our initial field-measured data. With digital and 35mm photography, we pictorially documented several key areas of concern, such as the Administration lobby reception area and the second floor open deck tables, the Sidewalk Bistro.

Using light meters, the Sylvania digital light meter, model DS-2000 and the General Electric analog light meter, model 217, we took instantaneous illumination measurements in adjacent areas of high and low luminance and areas of direct beam radiation

Sylvania DS-2000

General Electric 217

Subsequent visits enabled us to gather long term illumination values with Stowaway and HOBO light intensity data loggers, manufactured by Onset Instruments. Measurements are recorded in lumens/ft^2 and later downloaded into a computer using Boxcar Pro version 3.51.

Stowaway Light Intensity Data Logger

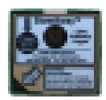
24 Hour Lighting Cycle

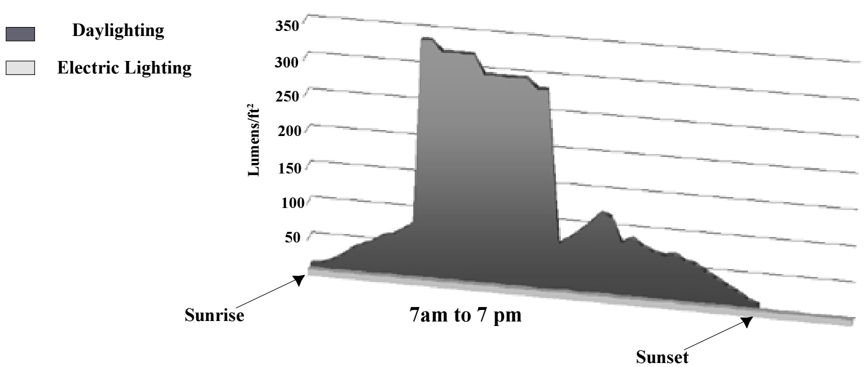
Our team worked in coordination with the other teams and the staff at the NCAA campus to place data loggers in selected areas. Illumination values were logged for a 24 hour period. These values were taken into the Boxcar software program and converted into Microsoft Excel spreadsheet formatting to create graphs of these values.

The data loggers were programmed to measure in fifteen minute intervals, and placed at key points. The building management group coordinated with our teams in this effort, leaving the lights on in the spaces for the duration of the 24 hour period. This allowed us to make assessments of these spaces without daylight. This information was important in determining the amount of light contributed by the designed lamping systems, and, by extrapolation, the amount contributed by the sun without the lamping.

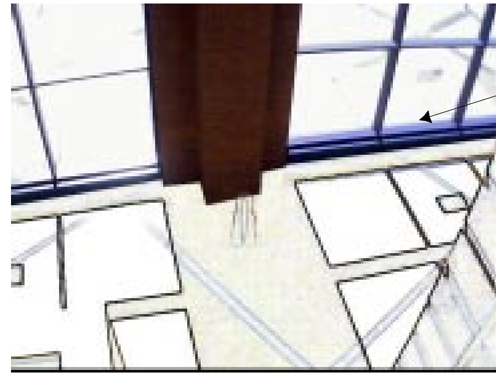
NCAA Administration Office Wing

Data logger placed here

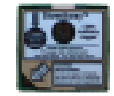


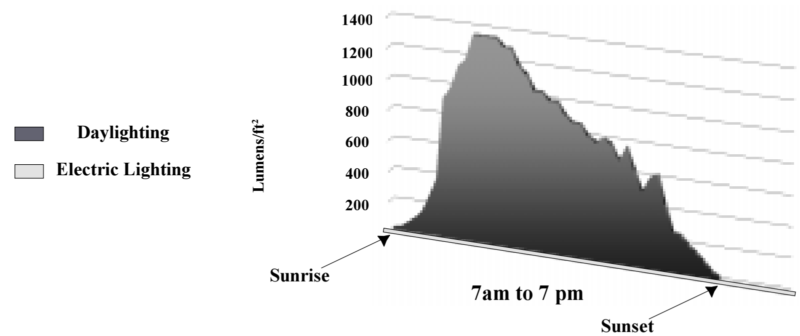


Hall of Champions Great Hall



Data logger placed here





These values show the dynamic patterns of illumination by direct beam radiation over the period of one day, from sunrise to sunset on October 30.

In the administration building, we were able to identify the effect of shading by the two buildings on the southeast and southwest corners.

In the Great Hall, in the Hall of Champions, we can observe the pattern of daylighting that comes from its orientation to solar noon or true south. The sharp rise to peak at local noon, around 12:28 local time, and the gradual decline of the afternoon sun show the typical pattern of a passive solar design oriented to maximize the direct beam radiation of the sun.

Isolux Illumination Diagrams

We laid out a grid in our spaces, taking instantaneous illumination measurements every four foot along the long axis, in two foot increments along the short axis. We entered this data into the Excel Spreadsheet software program, enabling us to generate isolux illumination contour maps of constant illumination values. This gave us an idea of the spread of illumination over the entire floor plan

Fig. 16-a The Sidewalk Bistro, second floor

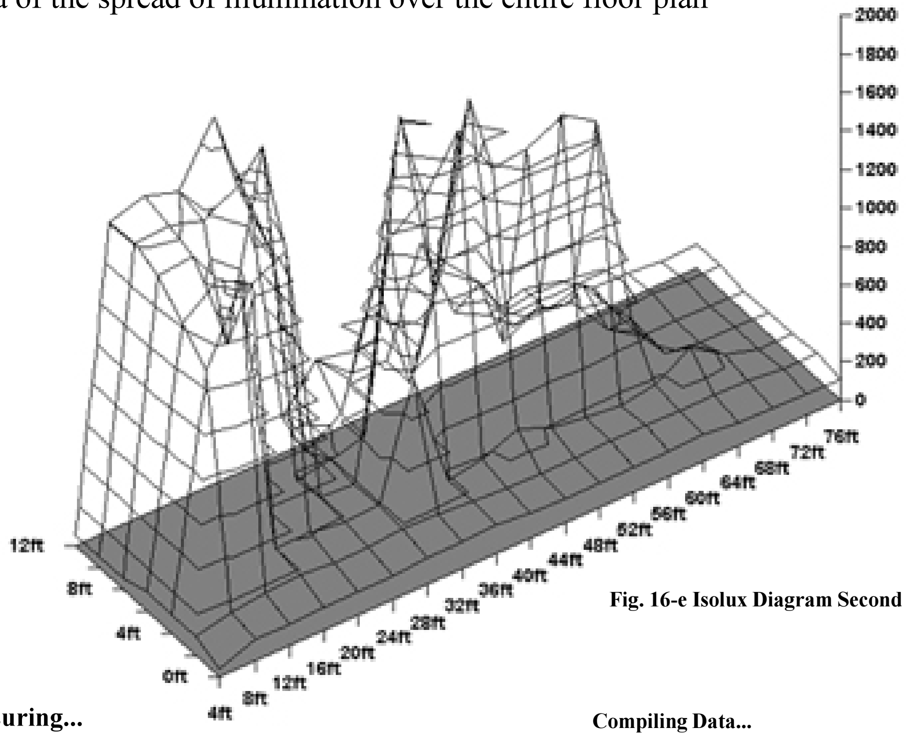


Fig. 16-e Isolux Diagram Second Floor Bistro

Measuring...

Fig. 16-b

Compiling Data...

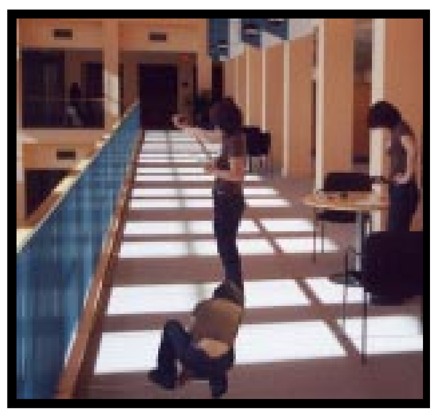


Fig. 16-c

Taking and Recording Measurements

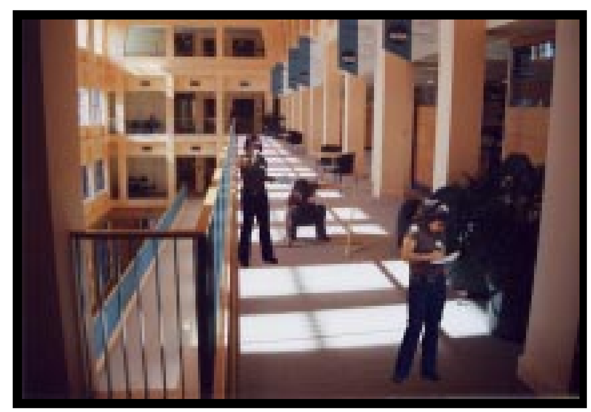


Fig. 16-d

Photometric Analysis

Photographs were taken of the areas with high brightness contrast ratios and direct beam radiation. These image was taken into the Photoshop graphic editing software and the contrasting luminance areas highlighted.

We took the printouts of our grayscaled images back to the NCAA campus, along with the Minolta direct-reading, narrow angle spot type luminance meter and took luminance measurements.

Fig. 17-a High brightness constrast ratio

Fig. 17-b Minolta Luminance Spot Meter LS-100

Fig. 17-c High brightness constrast ratio

Through digital imaging, the photographs are manipulated to bring out the contrast ratios by defining the edges in greyscale mode and reapplying those edges to highlighted contours, making the boundaries stand out.

The numerical readouts locate the center of the areas of different luminance values. These areas pinpointed exactly where luminance measurements needed to be taken.

By using approximate time and sky conditions, we measured the luminance readings at the same locations to gather our information. These readings were used to measure the brightness contrast ratios, enabling us to determine whether or not significantly high contrast existed for visual discomfort.

Diagnostic Research

Utilizing our collected data, we continued our investigation with substantiating research that would allow us to make our determinations based on the work that had preceded us. The work of the previous Vital Signs teams were invaluable in gaining an insight into our own investigations, and having access to this work via the Web postings proved to be very beneficial.

In order to analyse our data and draw our conclusion based on precedent, we needed to draw together sources of information on various topics including the following:

Physiological Properties of the Eye

- Physical makeup of the human eye
- Factors in visual acuity
- Reaction process involving visual discomfort
- Adaptation to light levels

Light Characteristics and Qualities

- Illumination vs. luminance
- Units in light measurement (footcandles, footlamberts, etc)
- IES quidelines for recommended task perfomance
- Issues beyond IES guidelines

Visual Discomfort

- Direct glare, reflected and veiling glare
- Brightness contrast ratios
- Contrast grading

Luminaire Properties

- Sources
- Quality
- Quantity
- Size
- Location

Atrium Design

- Design characteristics
- Advantages and disadvantages

Daylighting Design

- Daylight use and issues
- Natural vs. artificial light
- Integration with artificial light
- Negative qualities and problems

Energy

- Load vs. Envelope dominant buildings
- Cost analysis
- Building codes
- Legislative regulations

Network Resources

A very important part of our investigation included networking and collaboration with key members of the design community. A teleconference with Ron Fisher, the main partner with Schmidt Associates, the Architect of Record for the project, was set up. Questions pertaining to the design were posed and many important details were discovered through this discussion, such as design intent, problems in development and execution, financial considerations and limitations, and construction documentation

Nick Rajkovich, a member of the Vital Signs community, came to Ball State and gave a presentation of his investigations. He also met with the individual teams, one on one, offering help and advise from the perspective of passing along information and techniques developed in the field.

INVESTIGATION

Office Wing Investigation

Our investigation got underway in mid October in the mid morning with clear skies and full sun overhead. We began by taking instantaneous illumination measurements in the lobby of the administrative building, around 10:30 in the morning.

Using formZ modeling software, we calculated the solar altitude of the sun to be at 33.66° above the horizon at a solar azimuth angle (bearing angle) of 0° east of true south when we began our readings.

We targeted adjacent areas of contrasting luminance, such as

- the areas lit by direct beam radiation next to areas in shadow
- light surfaces next to dark surfaces
- areas receiving high illumination from direct beam radiation.
- high occupant use areas (reception area, sidewalk bistro and seating areas of the second and third floor decks

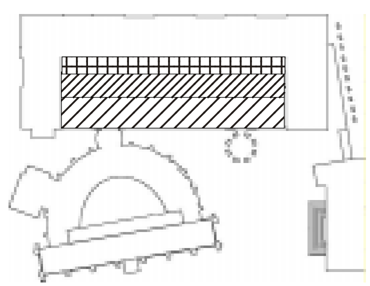


Fig. 20-c NCAA Administration Building
First floor lobby, second floor deck and third floor deck

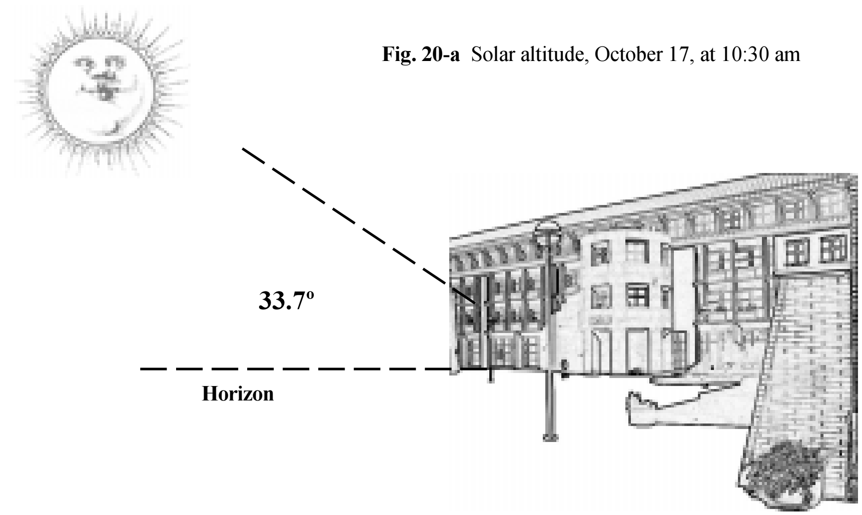
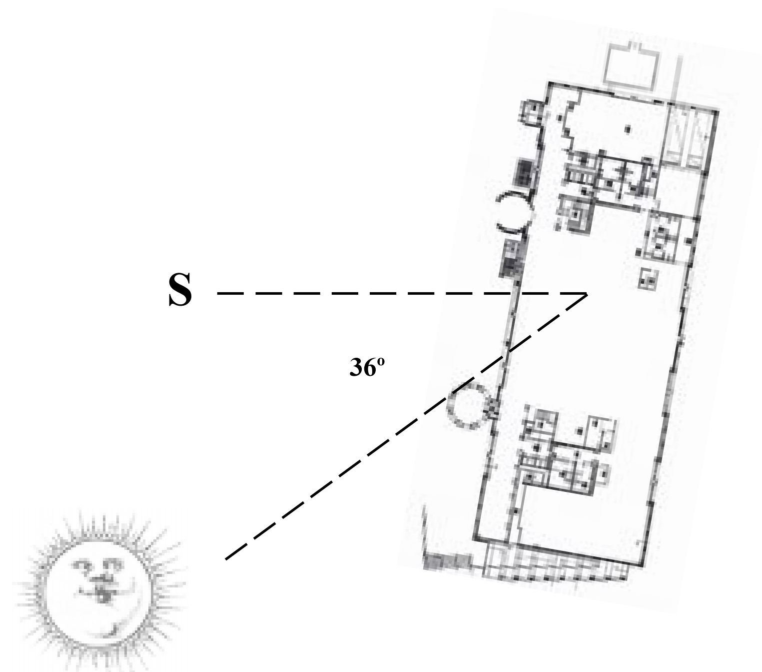
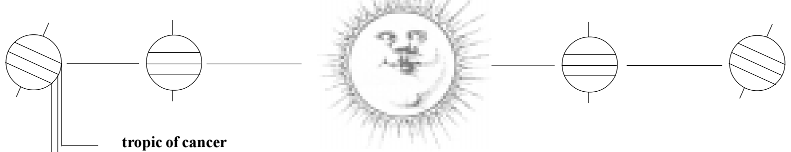


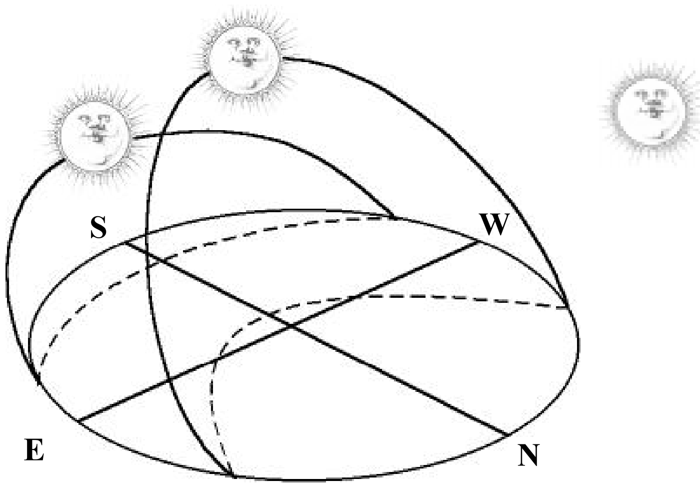
Fig. 20-a Solar altitude, October 17, at 10:30 am

Fig. 20-b Solar azimuth, October 17, at 10:30 am



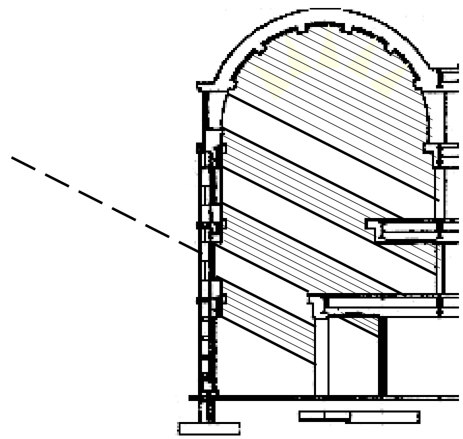


Solar Altitudes and Seasons of the Year



Winter Solstice SolarAltitude 26.81°

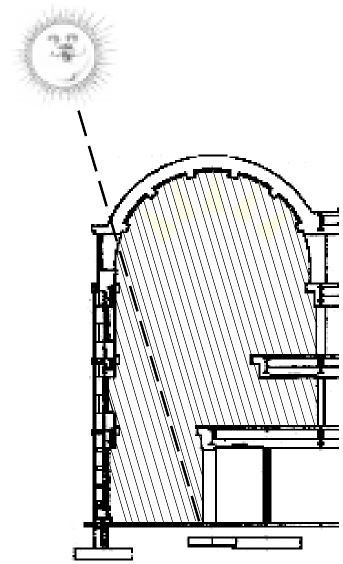
December 21 at 12:43 pm local time



Maximum Penetration of Direct Beam Radiation

Summer Solstice SolarAltitude 73.68°

June 21 at 12:46 pm local time

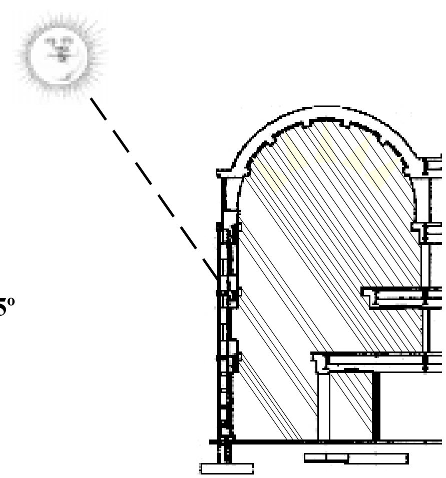


Minimum Penetration of Direct Beam Radiation

Solar Altitude and Azimuth

The earth's tilt of 23.47° from a vertical to the ecliptic (the earth's path around the sun) causes the relative solar altitude variations throughout the year. These illustrations show maximum and minimum solar altitudes for the NCAA campus site in Indianapolis, Indiana.
Between September 8 and April 2, the sun is below a 55° solar declination, entering the field of view of the occupant/user and becoming a source for direct glare inside the buildings.

September 8 - April 2
Solar Atlitude below 55°



Daylighting Data

Indianapolis, Indiana Lat(N): 39.73 Long(W): 86.28 * Elev(m): 246 * Pres(mb): 988

For southfacing fenestration used in sidelighting

Flat-Plate Collector Facing South at Fixed Tilt=90

Solar Radiation, kWh/m^2/day **Percentage Uncertainty: 9**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average	**3.0**	**3.5**	**3.2**	**3.0**	**2.7**	**2.6**	**2.7**	**3.1**	**3.5**	**3.6**	**2.8**	**2.5**	**3.0**
Minimum	**2.1**	**2.4**	**2.5**	**2.5**	**2.4**	**2.4**	**2.5**	**2.7**	**2.9**	**2.6**	**1.8**	**1.6**	**2.8**
Maximum	**4.1**	**4.6**	**3.8**	**3.6**	**3.1**	**2.8**	**2.9**	**3.5**	**4.1**	**4.4**	**4.1**	**3.7**	**3.3**

Conversion Formula

To convert kWh/m^2/day over to Btu/sq.ft./day

November Average 2.8 kWh/m^2/day

2.8 kWh/m^2/day x 317 = 887.6 Btu/sq.ft./day

Btu/sq.ft./day imported into Excel speadsheet to convert over to Btu/sq.ft./hour

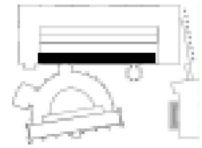
November 15, Thursday, 2001 @ 10:30 am 138.75 Btu/sq.ft./hour
Assuming an efficacy of 27.25 lumens per Btu/h:

The transmittance factor of the windows in the NCAA Administrative Building is 57%

138.75 Btu/sq.ft/hour x 27.25 lumens per Btu/h = 3780.94 lumens/sq.ft

Exterior Illumination @ start (10:30am) 2373.475 fc
Exterior Illuminanation @ finish (12:00pm) 4731.7 fc
Average I_e = 3552.6 fc
Interior Illumination 2000 fc

First Floor Atrium Lobby, Office Wing



- **A** 12” inside southfacing window @ floor level
- **B** 12” inside southfacing wall @ floor level
- **C** 16” above floor level @ coffee tables
- **D** floor level @ coffee tables
- **E** 52” above floor level @ Front Desk
- **F** 5’ in from south wall @ 30” above floor level working plane
- **G** 10’ in from south wall @ 30” above floor level working plane
- **H** 20’ in from south wall @ 30” above floor level working plane

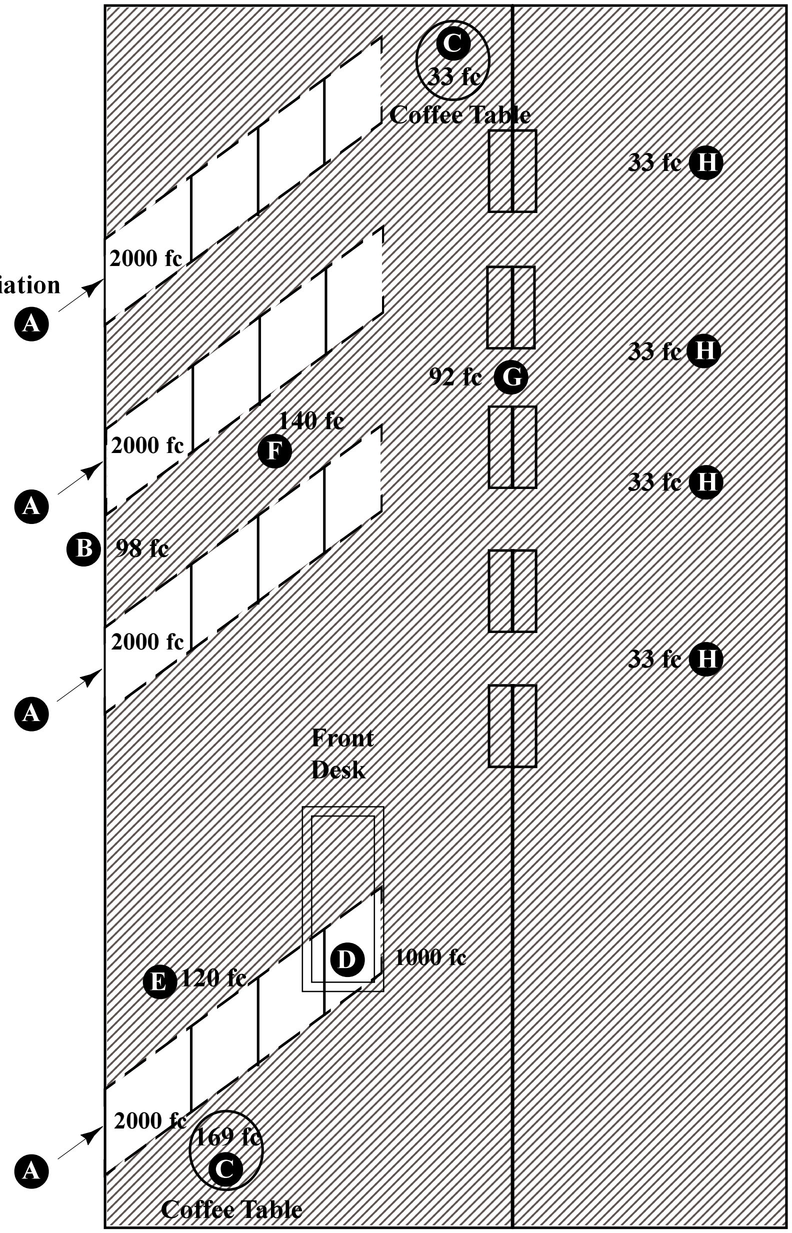
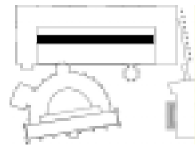


Fig. 23-a
First Floor Atrium Lobby
Office Wing

Second Floor "Sidewalk Bistro"



The second floor deck is known as the Sidewalk Bistro by the employees who work here, as this is where a lot of employees like to have their lunch. We measured the following areas:

- I the tables @ 30" above finished flooring
- J at finished floor level by the handrail
- K at 2ft increments back into the hall toward the offices

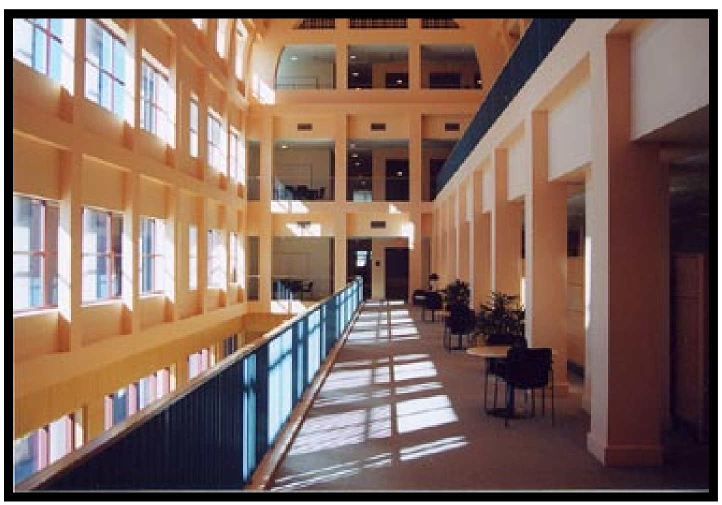
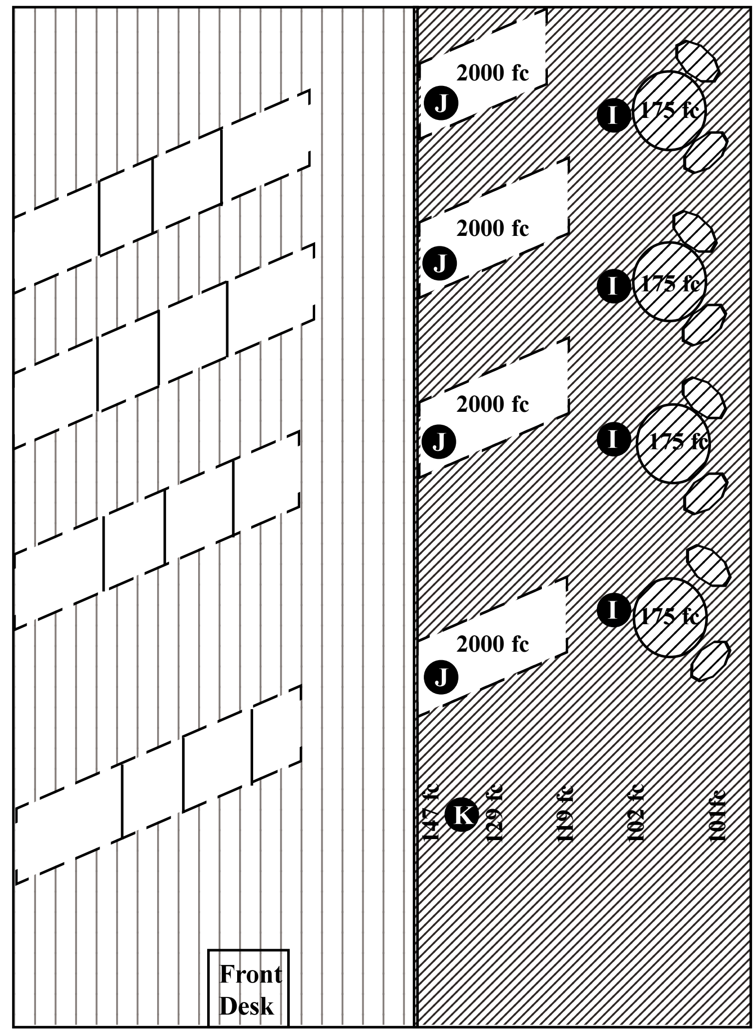
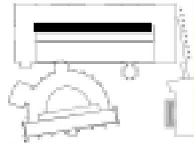


Fig. 24-a
Second Floor
Sidewalk Bistro



Lobby Level **Second Floor Deck**

Third Floor "Sidewalk Bistro"



The third floor deck also has a Sidewalk Bistro, and the lighting is much more even, with much lower illumination levels than the first or second floors.

- **L** the tables @ 30" above finished flooring
- **M** at finished floor level by the handrail
- **N** at 2ft increments back into the hall toward the offices

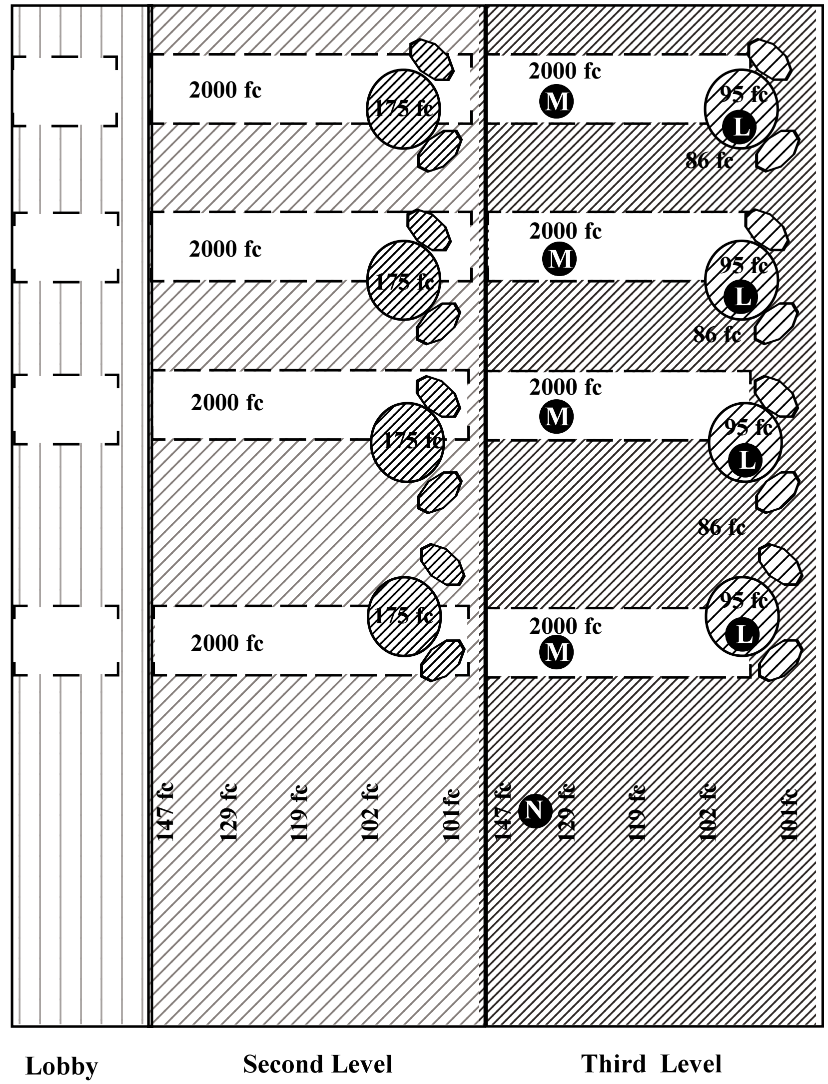


Fig. 25-a
Third Floor
Sidewalk Bistro

Office Wing East Lobby

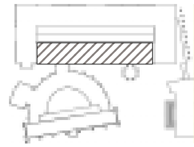
Illumination measurements for October 31st

Administration Building Reception Area East

Sunrise 7:10am **Sunset** 5:40pm

Maximum Solar Altitude 36.1° @ 12:26pm

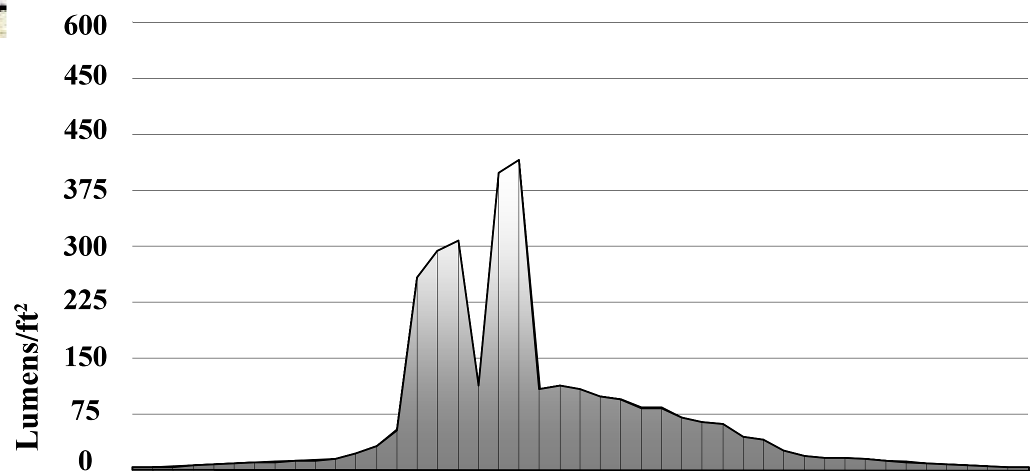
Partly Cloudy Skies



The early morning sun is shaded by the Superintendent building until after 10 am. The afternoon sun is shaded by the entryway after noon.

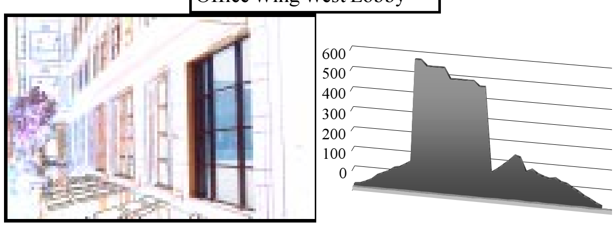
Illumination Over a Nine Hour Period

Data points at 15 minute intervals

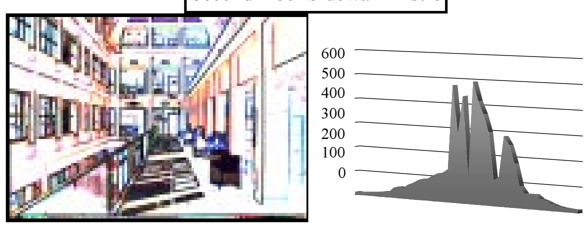


Direct Beam Radiation	6:55 AM	10:09 AM	10:24 AM	10:39 AM	10:54 AM	11:09 AM	11:24 AM	11:39 PM	2:55 PM	3:55 PM	4:55 PM	5:55 PM
Illuminance	4.16 fc	54 fc	258 fc	297 fc	307 fc	113 fc	398 fc	416 fc	26.9 fc	15.4 fc	8.34 fc	87 fc

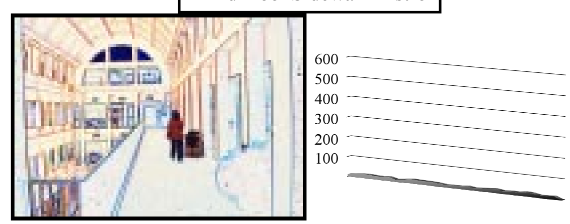
Office Wing West Lobby



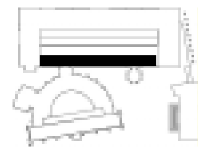
Second Floor Sidewalk Bistro



Third Floor Sidewalk Bistro



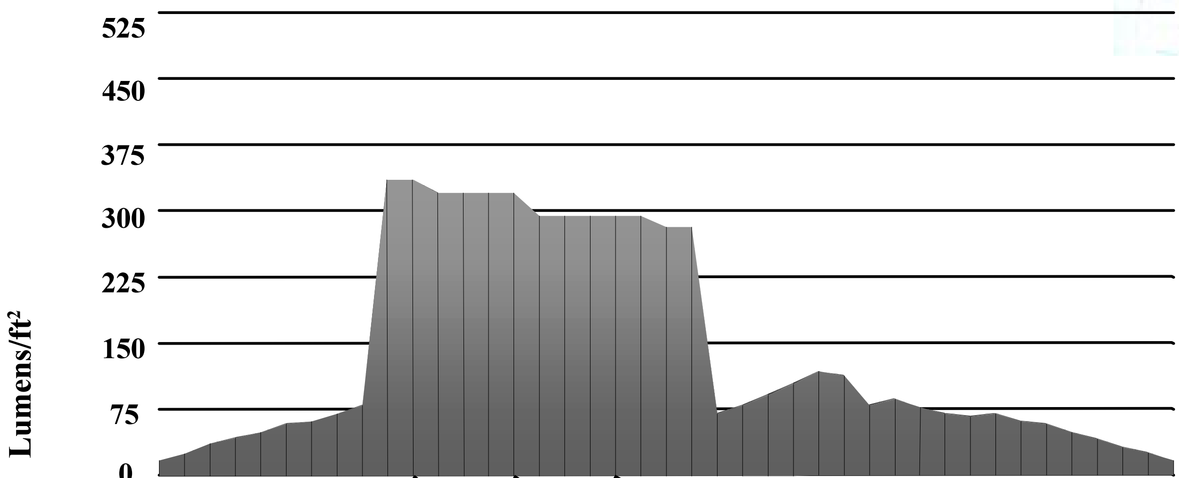
Illumination measurements for October 31st
Administration Building Lobby Area West
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1° @ 12:26pm
Partly Cloudy Skies



Office Wing West Lobby

Illumination Over a Nine Hour Period

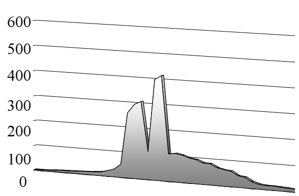
Data points at 15 minute intervals



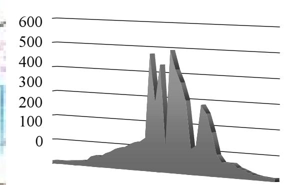
The early morning sun is shaded by the Superintendent building until around 9:30 am. The afternoon sun is shaded by the Hall of Champions after 12:30 pm.

6:55 AM	7:55 AM	8:55 AM	9:55 AM	10:55 AM	11:55 AM	12:55 PM	1:55 PM	2:55 PM	3:55 PM	4:55 PM	5:55 PM	**Direct Beam Radiation**
9.9 fc	36.5 fc	61.8 fc	335 fc	320 fc	294 fc	70.2 fc	118 fc	76.8 fc	61.8 fc	32 fc	9.12 fc	**Illuminance**

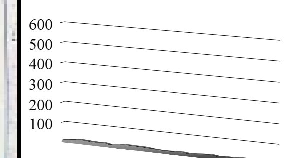
Office Wing East Lobby



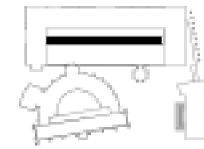
Second Floor Sidewalk Bistro



Third Floor Sidewalk Bistro



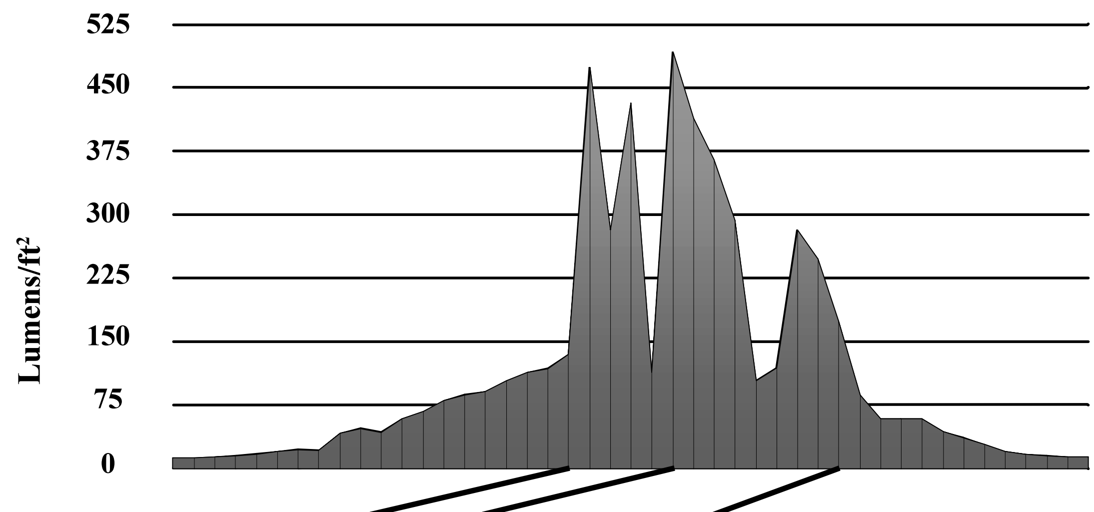
Illumination measurements for October 31st
Administration Building
Second Floor Sidewalk Bistro
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1° @ 12:26pm
Partly Cloudy Skies



The table where this data logger was placed shows that the light begins projecting onto the table right around lunch time, when this area gets used the most. The spikes represent shadows cast by the mullions and wall components across the space, reducing illumination levels to daylight factor minus direct beam radiation.

Illumination Over a Nine Hour Period

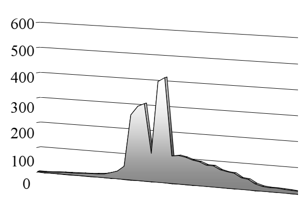
Data points at 15 minute intervals



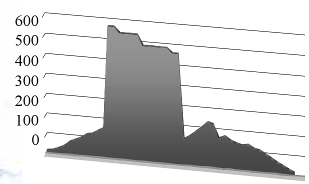
Direct Beam Radiation

	6:55 AM	7:55 AM	8:55 AM	9:55 AM	10:55 AM	11:55 AM	12:55 PM	1:55 PM	2:55 PM	3:55 PM	4:55 PM	5:55 PM
Illuminance	12.9 fc	17.5 fc	41.4 fc	67.2 fc	104 fc	474 fc	492 fc	104 fc	175 fc	58.8 fc	19.9 fc	12.9 fc

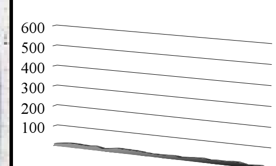
Office Wing East Lobby

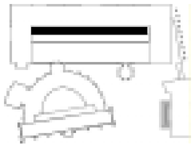


Office Wing West Lobby



Third Floor Sidewalk Bistro

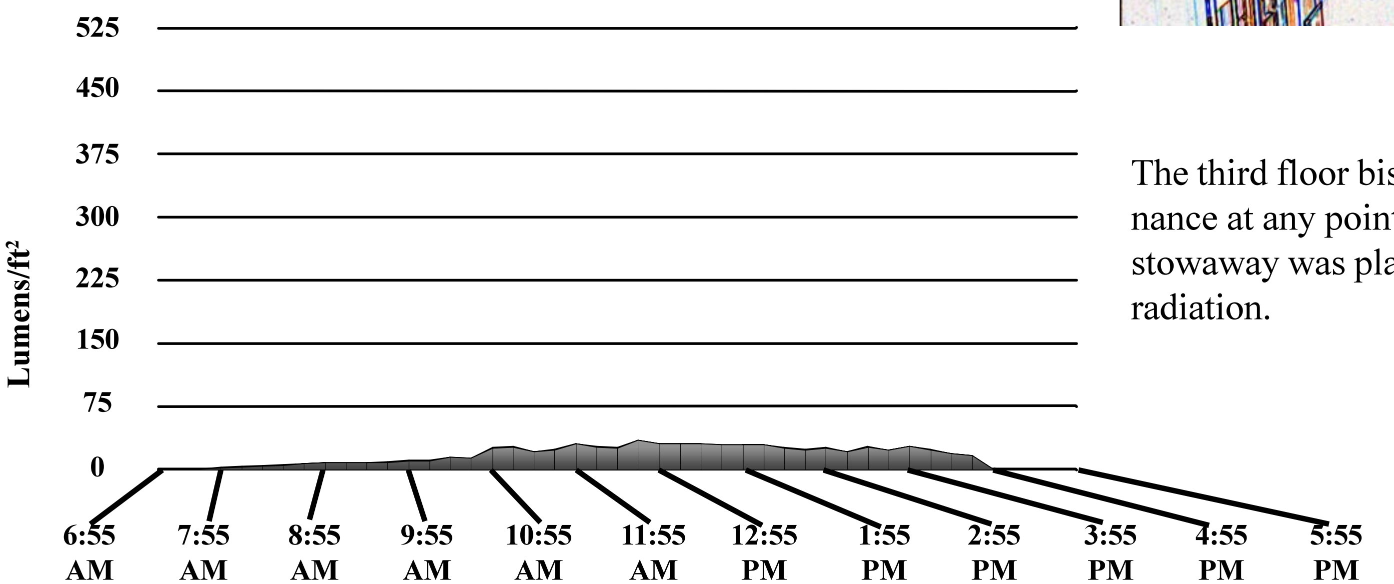




Illumination measurements for October 31st
Administration Building
Third Floor Sidewalk Bistro
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1° @ 12:26pm
Partly Cloudy Skies

Illumination Over a Nine Hour Period

Data points at 15 minute intervals



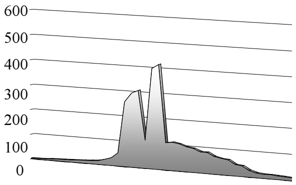
No Direct Beam Radiation

0.2 fc	**3.5 fc**	**7.98 fc**	**10.9 fc**	**25.8 fc**	**30.7 fc**	**30.7 fc**	**29.4 fc**	**25.8 fc**	**27 fc**	**0.6 fc**	**0.32 fc**

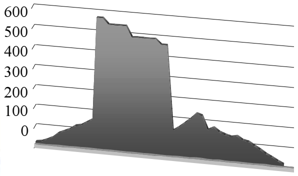
Illuminance

The third floor bistro is not subject to over illuminance at any point in the day. The table where the stowaway was placed received no direct beam radiation.

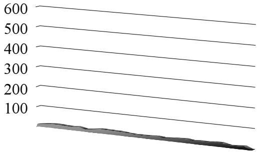
Administration West Lobby



Second Floor Sidewalk Bistro



Third Floor Sidewalk Bistro



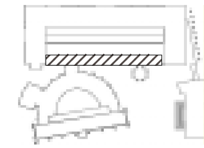
Illumination Across the Lobby

Data points at 15 minute intervals

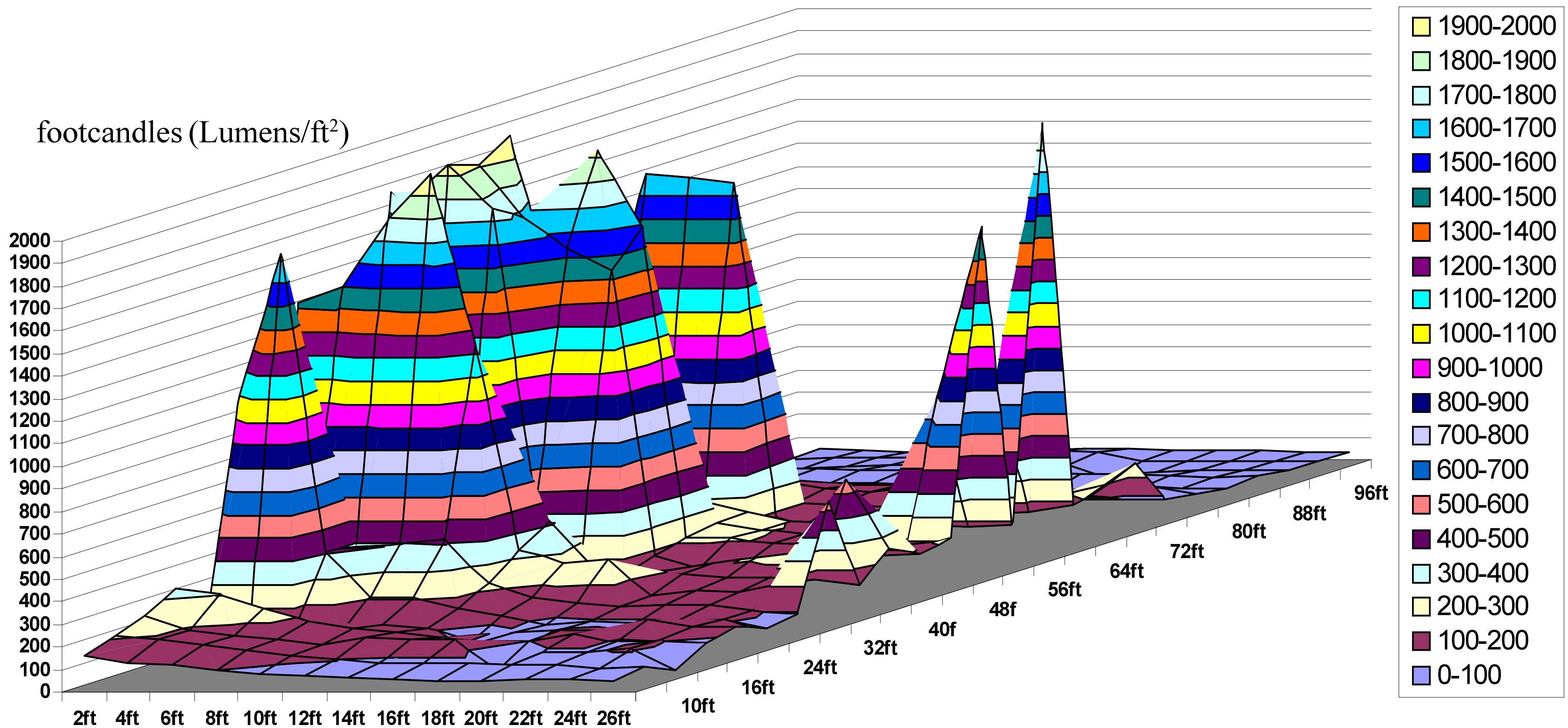
IES Illuminance Catagories and Values for Generic Type Activities

Type of Activity	Illuminance Catagory	Ranges of Illuminance
Working spaces where visual tasks are only occasionally performed	C	10 - 15 - 20 (fc)
	Measured levels	40 - 1000 - 2000 (fc)

Isolux diagram for November 14
11:00am to 12:00pm
Office Wing Lobby
Altitude 28.39° to 31.63°
Azimuth 24.29° to 8.46°
Maximum Solar Altitude 32.04 @ 12:29pm
Partly Sunny Skies

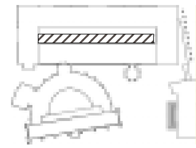


Less than 4% of the total light distribution falls into the catagory below 100 footcandles, and all values are above the recommendations of the IES.



Illumination Across the Second Floor Bistro

Data points at 15 minute intervals

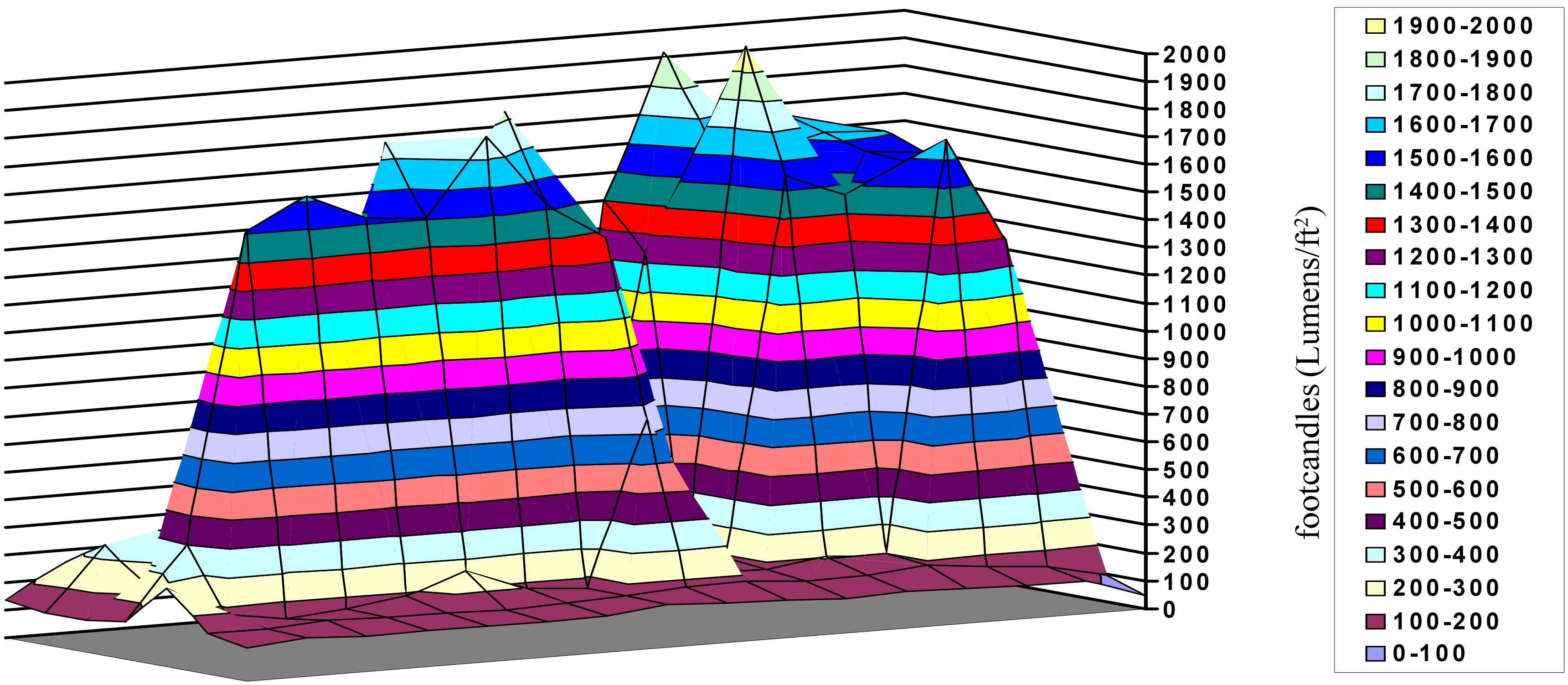


Isolux diagram for November 14
12:00pm to 1:00pm
Sidewalk Bistro Second Floor Deck
Altitude 31.63° to 31.61°
Azimuth 8.46° to -8.29°
Max. Solar Altitude 32.04 @ 12:29pm
Partly Sunny Skies

IES Illuminance Catagories and Values for Generic Type Activities

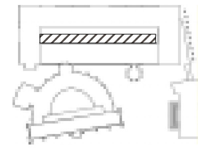
Type of Activity	Illuminance Catagory	Ranges of Illuminance
Working spaces where visual tasks are only occasionally performed	C	10 - 15 - 20 (fc)
	Measured levels	40 - 1000 - 2000 (fc)

Less than 4% of the total light distribution falls into the catagory of less than 100 footcandles, and all values are above the recommendations of the IES.



Illumination Across the Third Floor Bistro

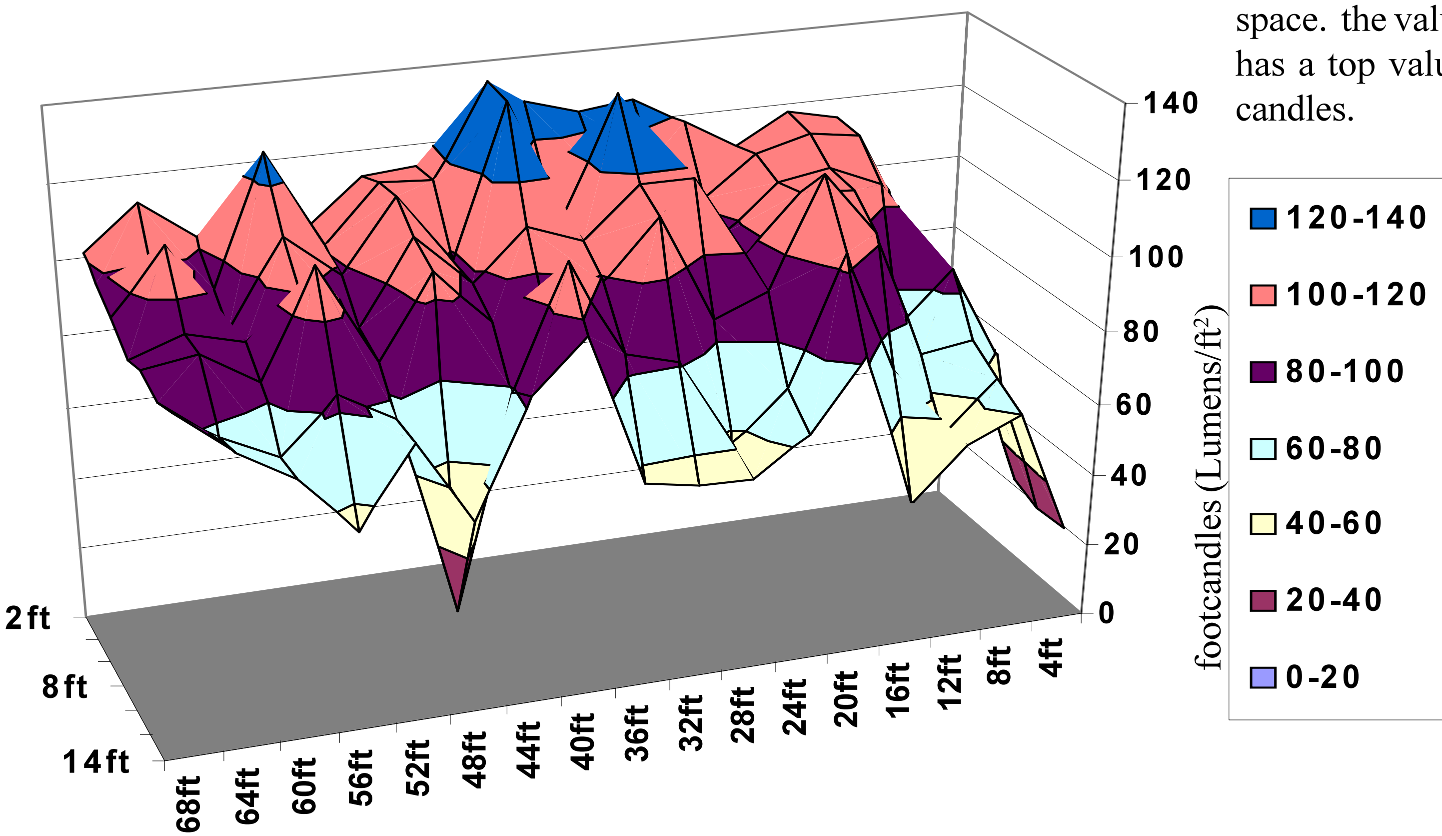
Data points at 15 minute intervals



IES Illuminance Catagories and Values for Generic Type Activities		
Type of Activity	Illuminance Catagory	Ranges of Illuminance
Working spaces where visual tasks are only occasionally performed	C	10 - 15 - 20 (fc)
	Measured levels	40 - 80 - 140 (fc)

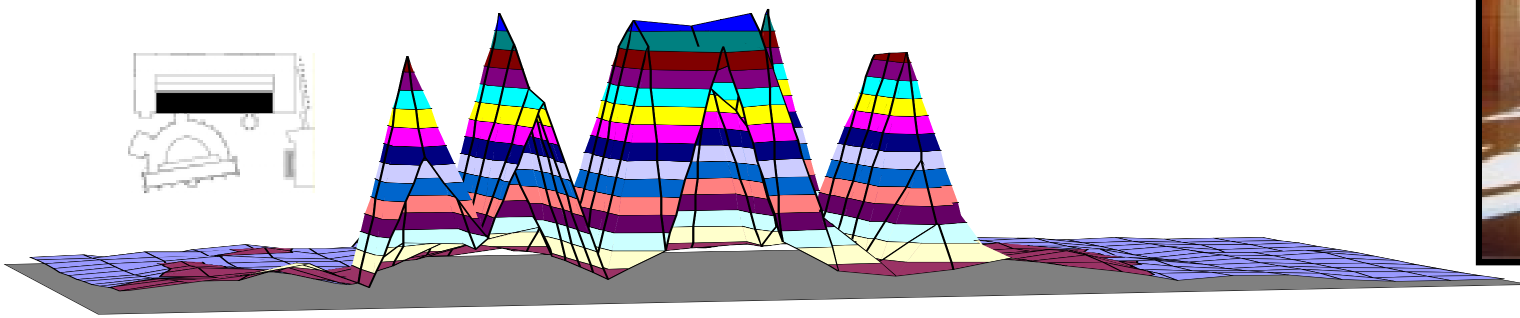
Isolux diagram for November 14
1:00pm to 2:00pm
Sidewalk Bistro Third Floor Deck
Altitude 31.63° to 31.61°
Azimuth 8.46° to -8.29°
Maximum Solar Altitude 32.04 @ 12:29pm
Partly Sunny Skies

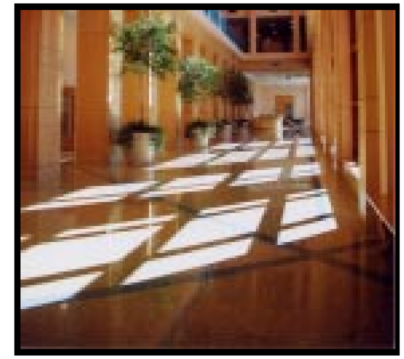
Unlike the other spaces, with illumination levels reaching 2000 footcandles, the third floor Bistro Sidewalk recieves much lower illumination across the space. the values of the third floor deck has a top value of less than 150 footcandles.



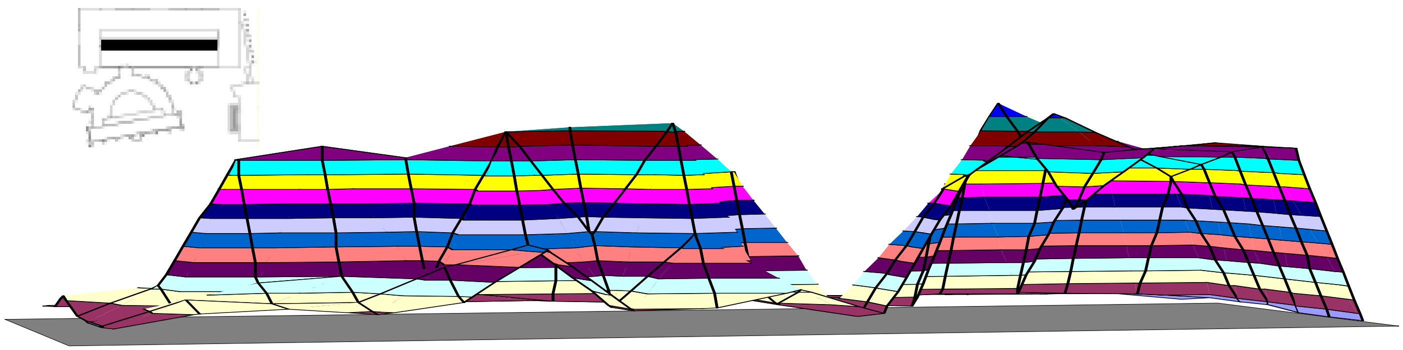
Daylighting Data

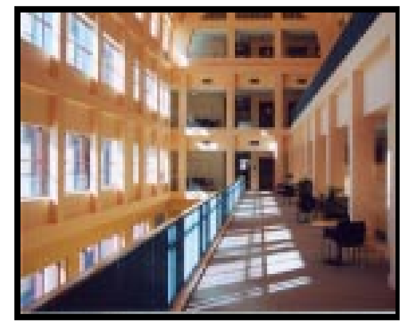
First floor lobby
0 - 2000 footcandles



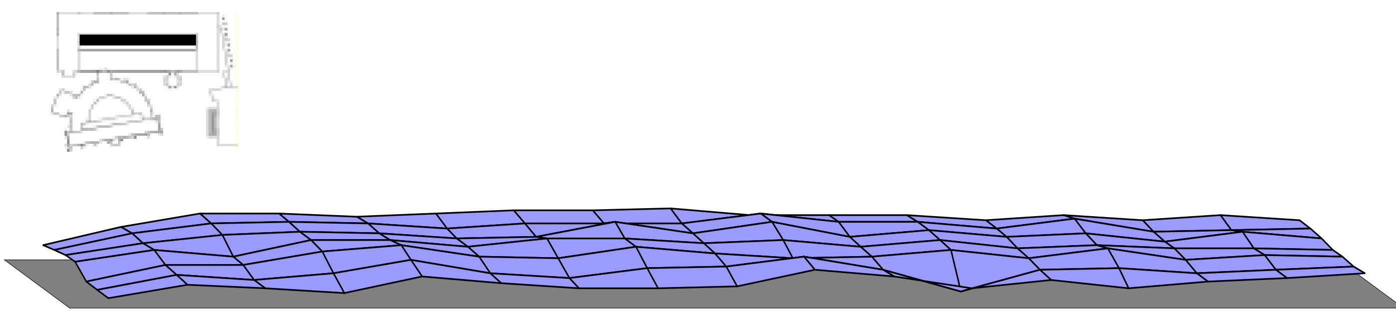


Second floor bistro
0 - 2000 footcandles





Third floor bistro
0 - 2000 footcandles



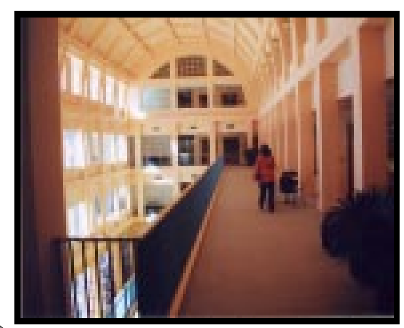


Fig. 32-a Hall of Champions Great Hall

Fig. 8 The south facing facade recieves light from a 40º bearing angle from the October sun. The lower angle allows for a deeper penetration into the space, but the lower angle means there is more atmosphere for the sun to have to penetrate, reducing the illumination level and IR (infra-red) radiation coming into the space.

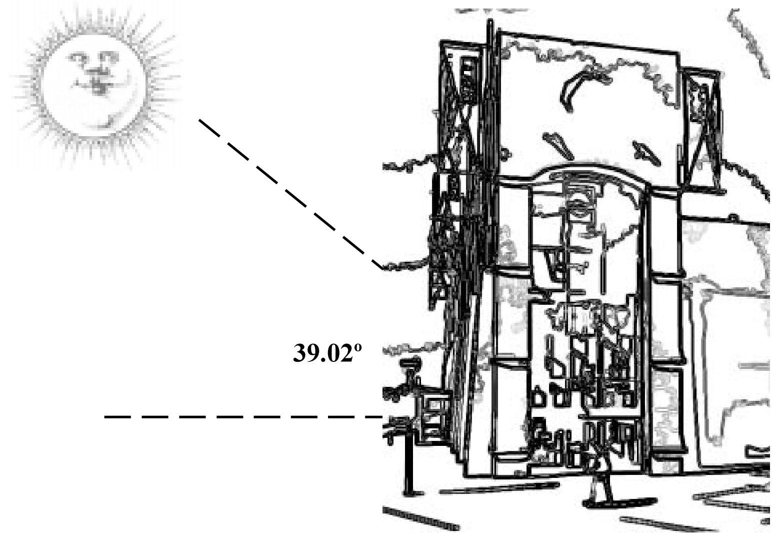


Fig. 34-a Solar atltitude, October 17 @ 11:30AM

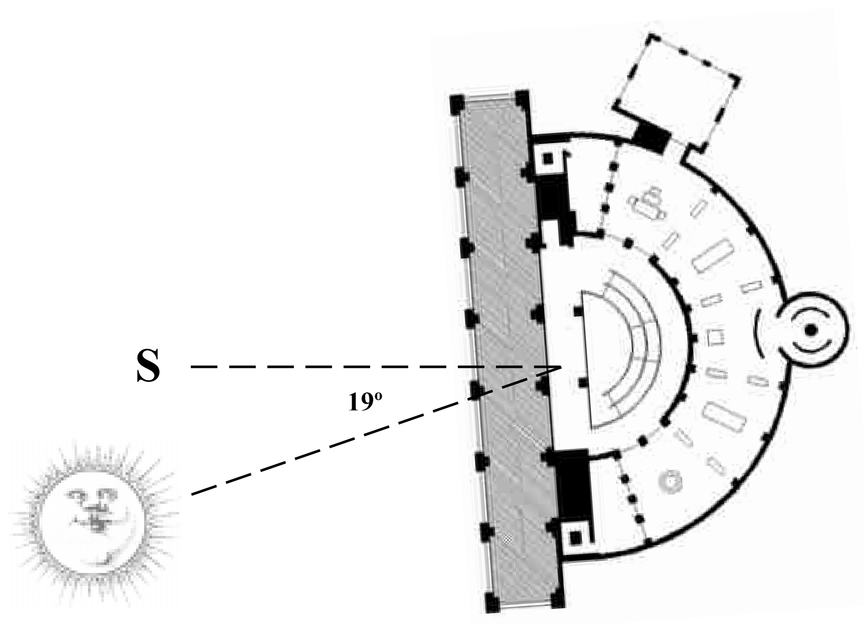
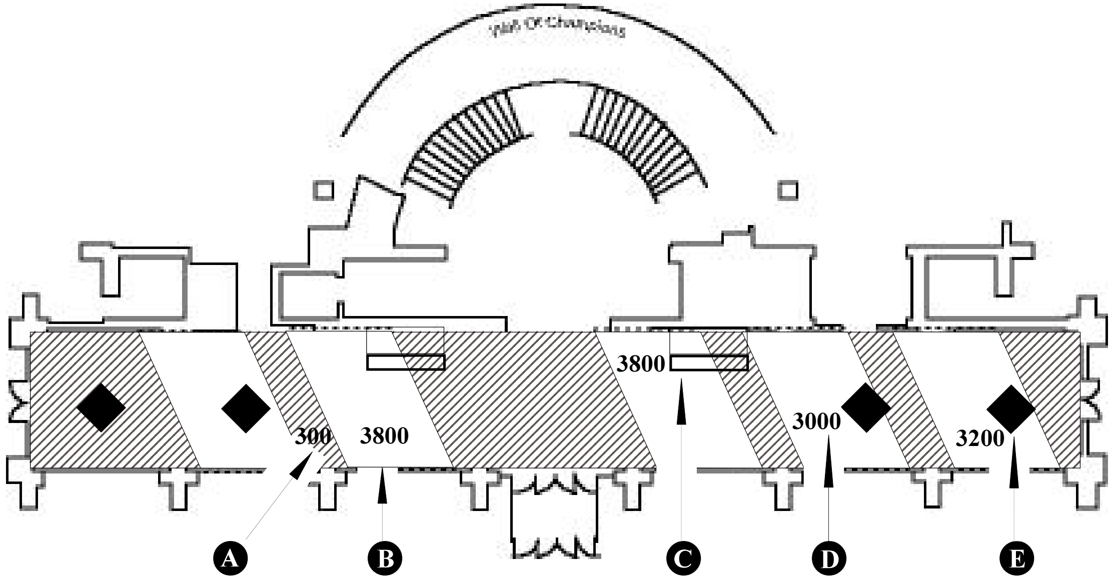


Fig. 34-b Solar azimuth, October 17 @ 11:30AM



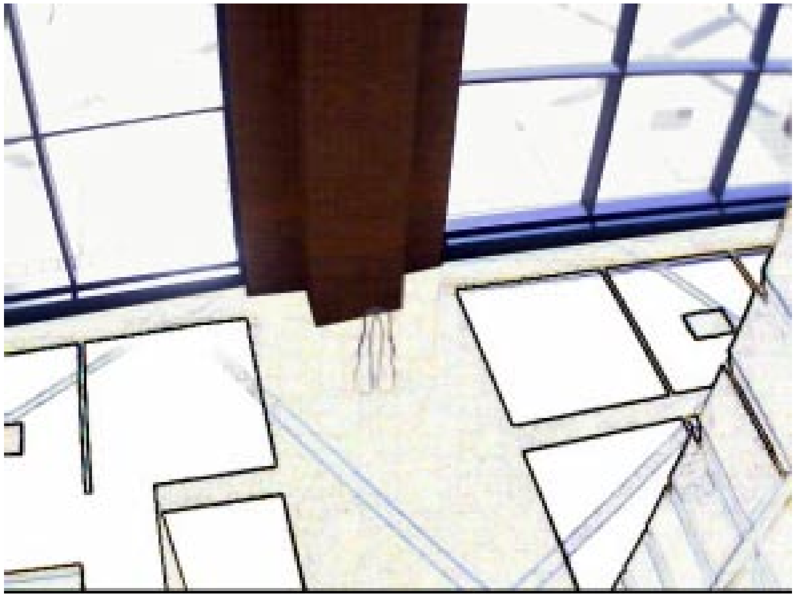
A **300 fc @ finished flooring (shaded)**

B **3800 fc @ finished flooring (direct beam)**

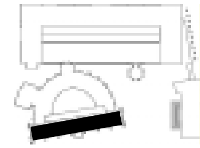
C **3800 fc @ reception desk(@ 30" above finished flooring)**

D **3000 fc @ window (@ 30" above finished flooring)**

E **3200 fc @ display (@ 30" above finished flooring)**



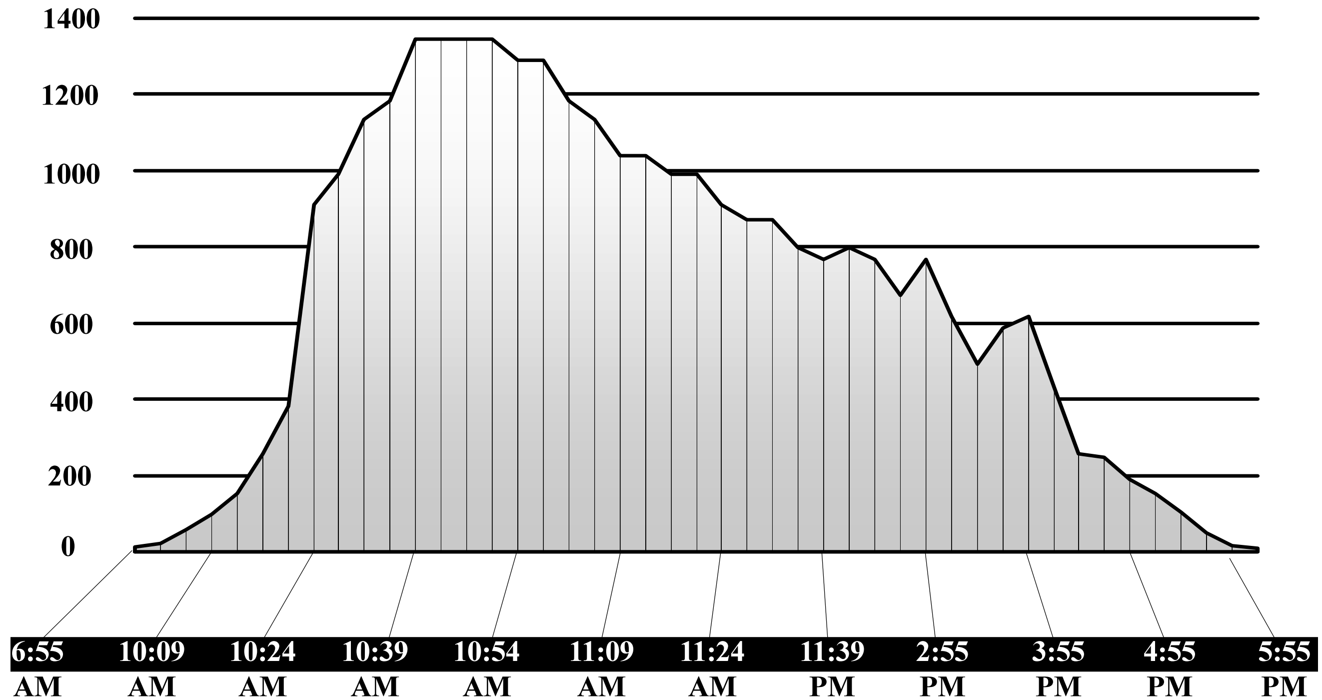
Illumination measurements for October 31st
Hall of Champions Great Hall Atrium
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1° @ 12:26pm
Partly Cloudy Skies



The Great Hall Atrium of the Hall of Champions is well lit by direct beam radiation through the entire day, with open fenestration on the east, south and west facades. The single glazing ensures an 85% transmitance of the incident light, comparable to the outside. It was the architects intent that this space be a transition from the outside to the inside.

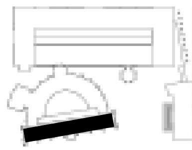
Illumination Over a Nine Hour Period

Data points at 15 minute intervals



Direct Beam Radiation

Illuminance	11 fc	154 fc	990 fc	1344 fc	1290 fc	1038 fc	870 fc	798 fc	618 fc	432 fc	154 fc	10 fc



Illumination measurements for October 31st

Hall of Champions Agents Booth East

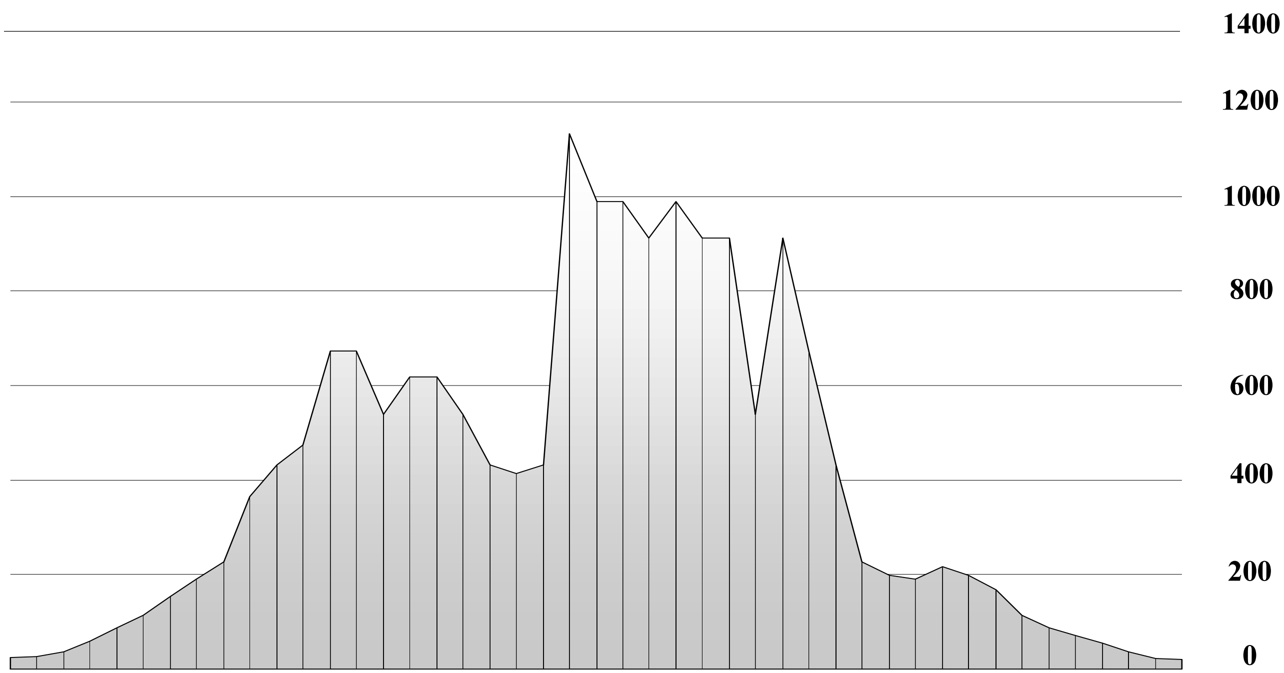
Sunrise 7:10am **Sunset** 5:40pm

Maximum Solar Altitude 36.1° @ 12:26pm

Partly Cloudy Skies

Illumination Over a Nine Hour Period

Data points at 15 minute intervals



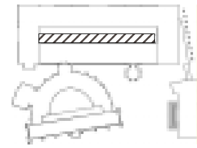
The data logger was placed on the agents booth in the Great Hall. The booth stands in line of the direct beam radiation all day, picking up very high illumination levels throughout the mid morning and carrying them through till twilight.

6:55 AM	10:09 AM	10:24 AM	10:39 AM	10:54 AM	11:09 AM	11:24 AM	11:39 PM	2:55 PM	3:55 PM	4:55 PM	5:55 PM	
11 fc	154 fc	990 fc	1344 fc	1290 fc	1038 fc	870 fc	798 fc	618 fc	432 fc	154 fc	10 fc	**Illuminance**

Direct Beam Radiation

Illumination Across the Great Hall

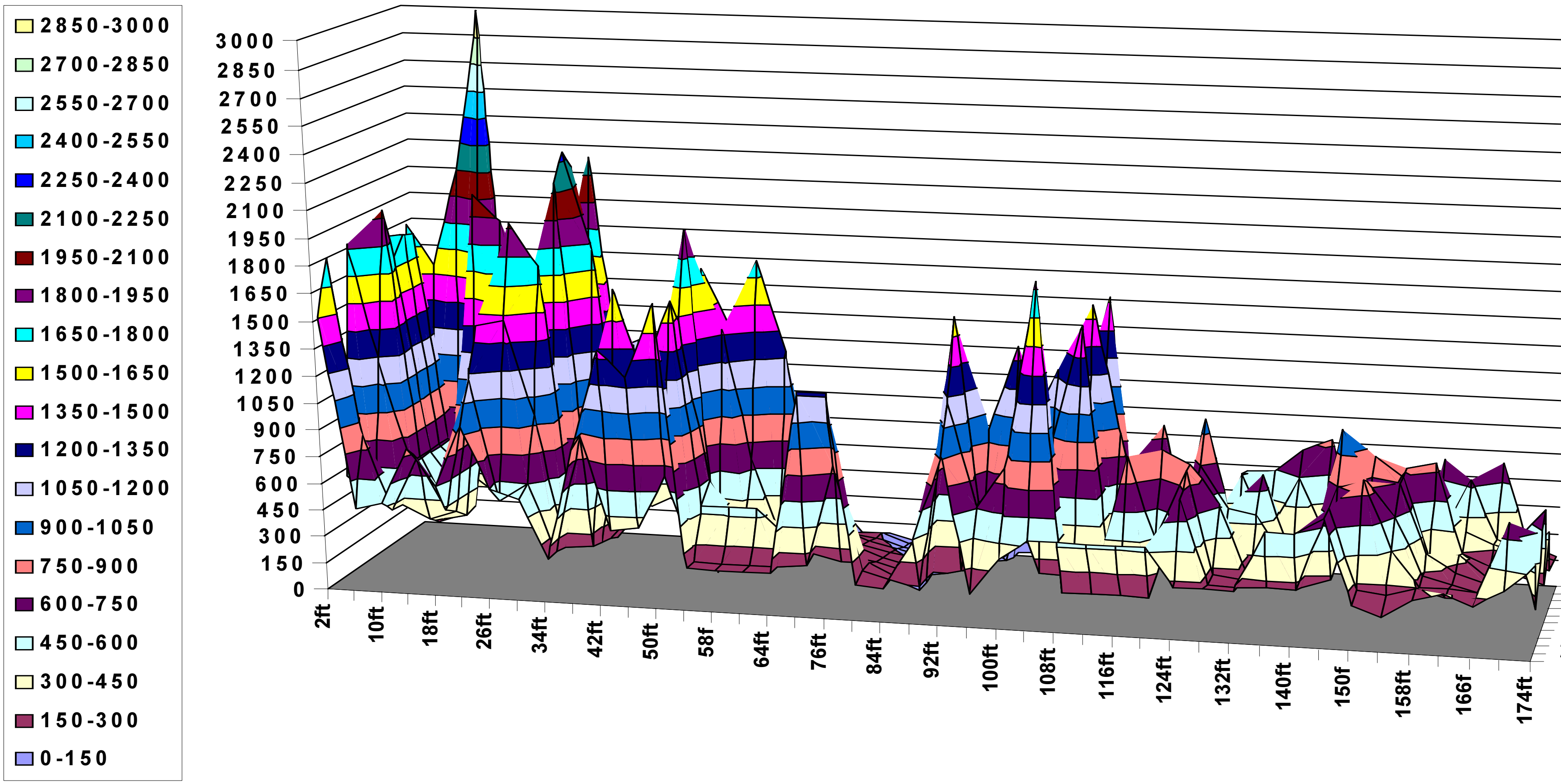
Data points at 15 minute intervals



Isolux diagram for November 14
2:00pm to 3:30pm
Hall of Champions Great Hall Atrium
Altitude 31.63° to 31.61°
Azimuth 8.46° to -8.29°
Maximum Solar Altitude 32.04 @ 12:29pm
Partly Sunny Skies

IES Illuminance Catagories and Values for Generic Type Activities

Type of Activity	Illuminance Catagory	Ranges of Illuminance
Working spaces where visual tasks are only occasionally performed	C	10 - 15 - 20 (fc)
	Measured levels	40 - 1500 - 3000 (fc)

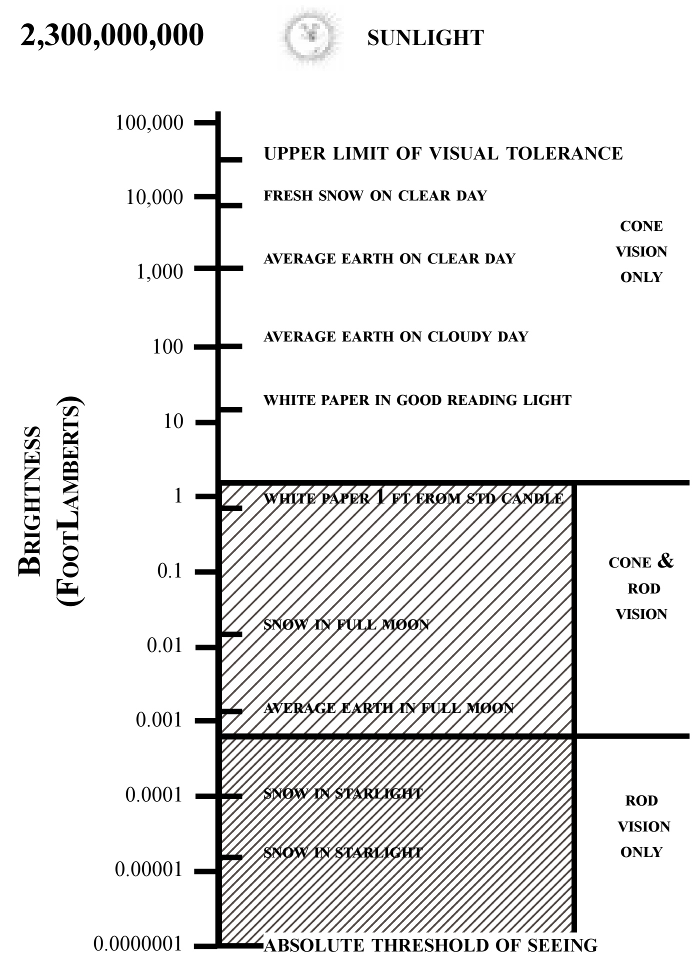


Luminance, the reflectance of light bouncing back off of material surfaces that we see, is considered the single most important factor in visual acuity, particularly in cases involving glare. More accurately, it is the brightness contrast caused by photometric luminance that plays a key factor in discerning detail and visual perception.

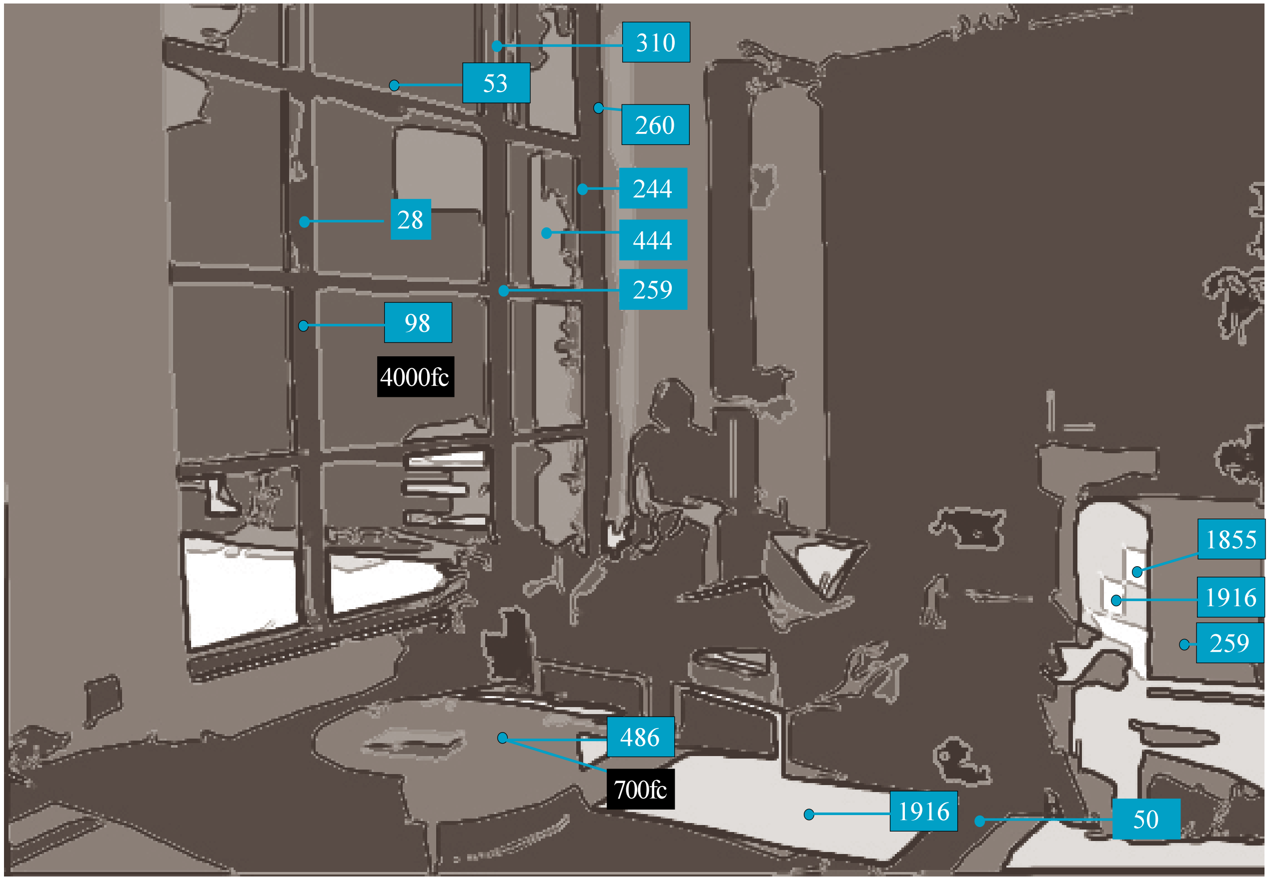
Contrast Ratio

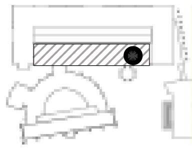
It is high contrast, such as the luminance of this paper and that of the ink on it (at 94% contrast), that we percieve visually, independent of illumination levels (above a certain level). Because of the high contrast, this page could be read in moonlight illumination levels of 1/100th of a footcandle. High background luminance makes an object look darker, assisting in the discrimination in outline detail. This is what allows us to make clear distinctions between the numbers 3 and 8 on the printed page.

Maximum visual acuity is possible when the object surface lumination is equal to or slightly higher than the background luminance level, within a range up to 3:1 ratio. However, the ability of the eye to adjust to different brightness levels of the overall scene affects visual perception of these ratios. At 1fL, a background to task ratio of 1:10 *appears to be* more like a 1:4 ratio. The apparent ratio is smaller than the actual ratio because the low adaptation level causes the eye to dimminish the difference between high brightnesses. This effect decreases as the brightness level increases to the adaptation level of daylight conditions at 1000 fL, where the actual and apparent ratios correspond and smaller ratios



can be discerned. In other words, visual acuity increases with increasing adaptation levels, from low levels where apparent brightness seems brighter, to higher levels where appearent brightness seems less bright.





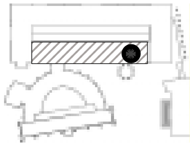
Luminance measurements
December 10th @ 10:30am
Office Wing Reception Area East
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1° @ 12:26pm
Partly Cloudy Skies

luminance in footLamberts

illumination in footcandles

Reflectance Factors
Walls 60%
Furniture 35%
Carpet 35%
Table 50%

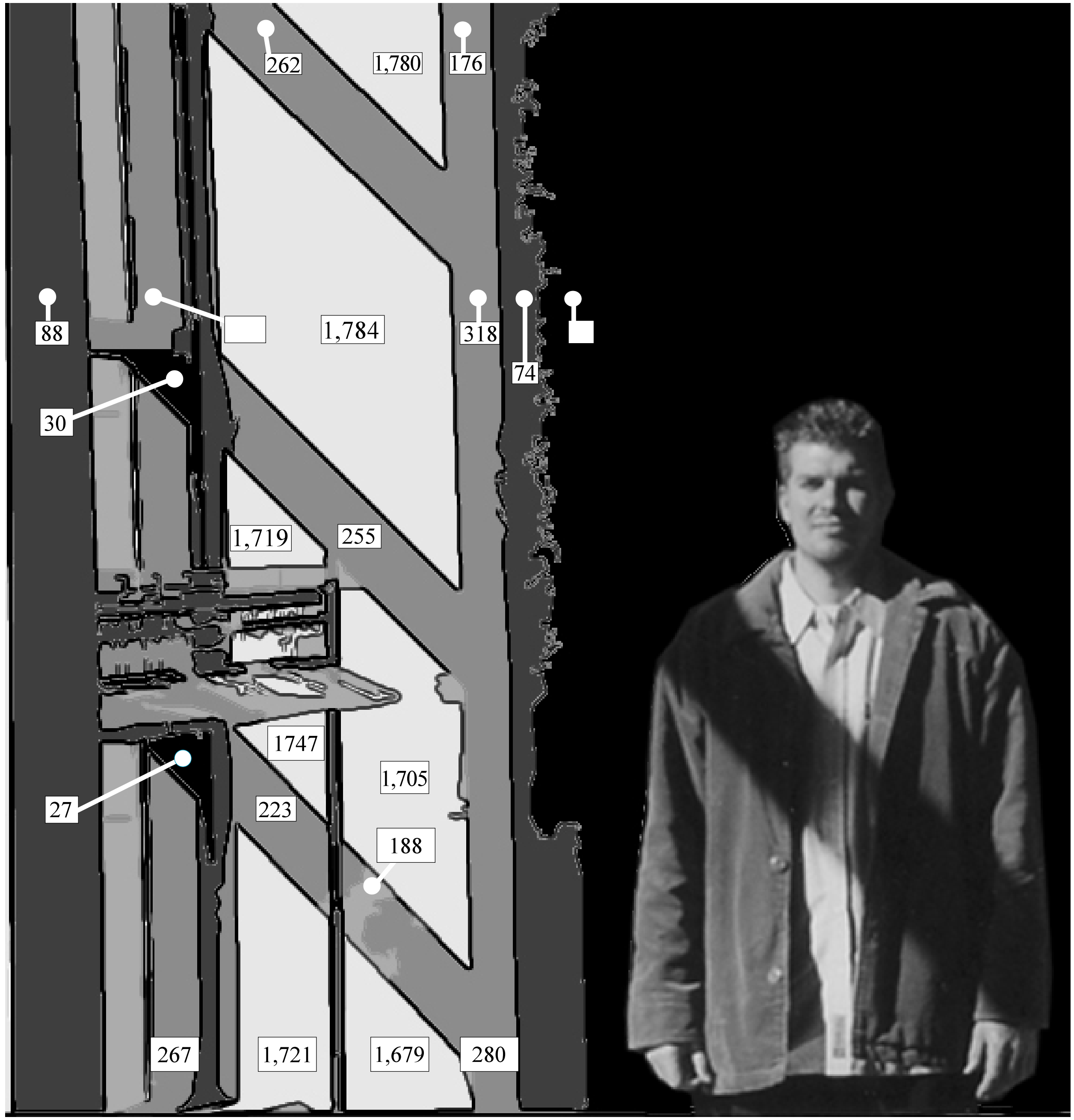
The photometric analysis shows adjacent brightness contrast ratios as high as 38:1 (carpet sun and shade), but most are along the order of 7:1 or less. These are the conditions that create discomforting glare, which is present in the space, yet the materials and the overall brightness tend to diminish the impact somewhat. The design utilizes contrast grading to minimize the impact of direct beam radiation.

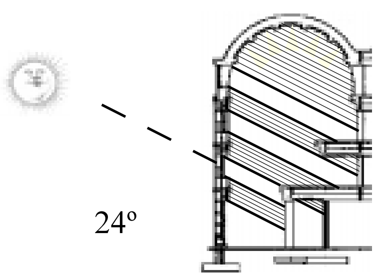


Luminance measurements
December 10th @ 11:00am
Administration Building Reception Area East
Sunrise 7:10am **Sunset** 5:40pm
Maximum Solar Altitude 36.1º @ 12:26pm
Clear Sunny Skies

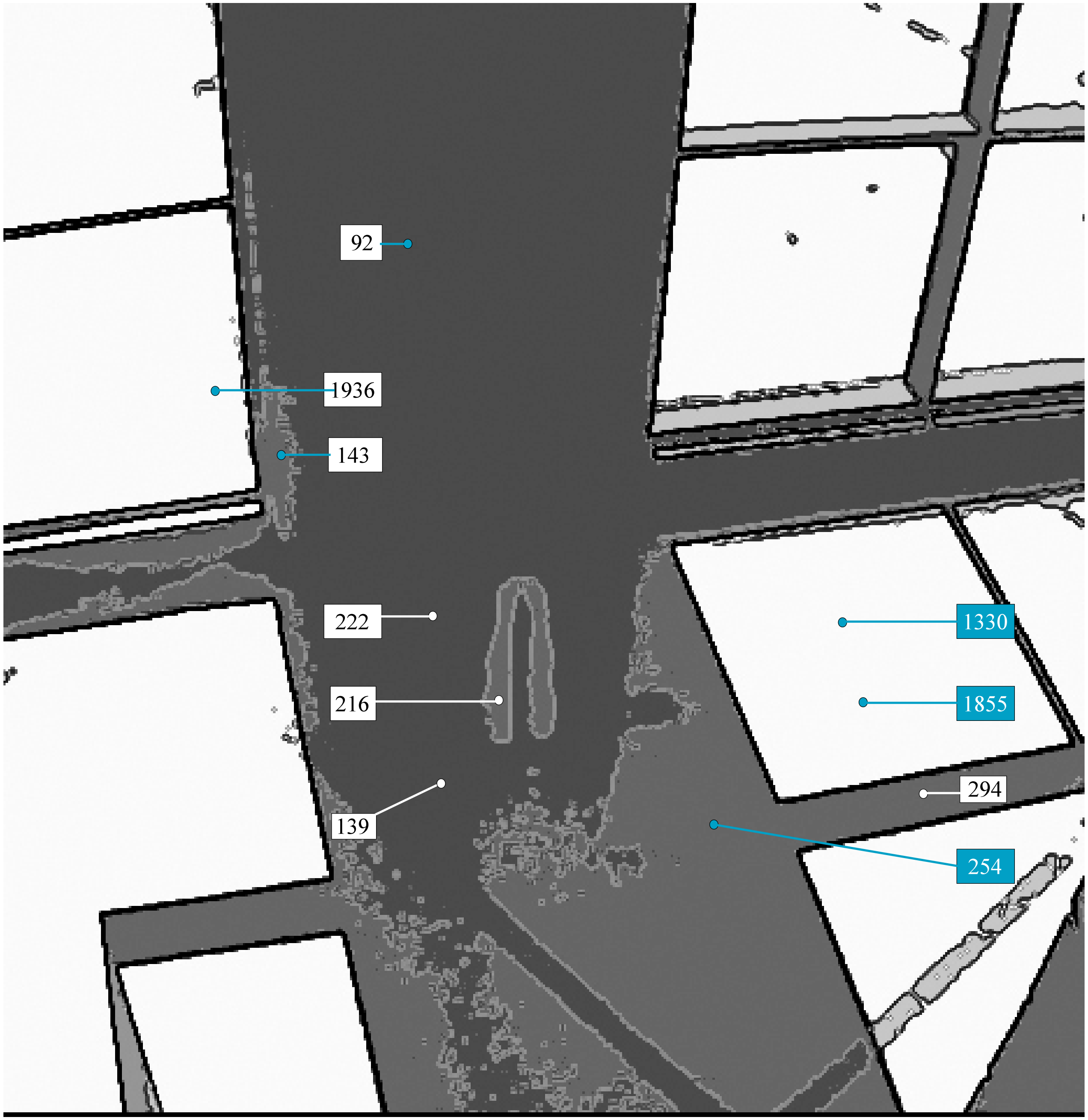
Reflectance Factors

Walls 60%
Carpet 35%





Altitude 24º **Azimuth** 25º @ 11:00am
Maximum Solar Altitude 36.1º @ 12:26pm
Clear Sunny Skies

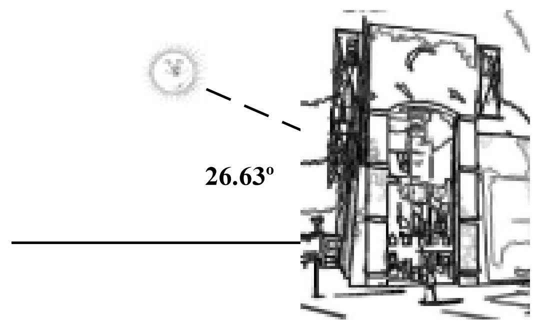


Luminance Measurements
December 10, 11:00 AM

Great Hall

Hall of Champions

While contrast grading is present, the brightness contrast ratios range from 6:1 to 13:1, showing that conditions exist for veiling and reflected glare



Altitude 27° **Azimuth** 0°
Maximum Solar Altitude 27.1° @ 12:38pm
Clear Sunny Skies

CONCLUSIONS

Based upon the collection and analysis of the data that we have gathered, we have concluded that visual discomfort does exist in the atria of the Office Wing and the Hall of Champions. In our hypothesis, we stated that the visual discomfort experienced in these spaces were due to multiple factors which included the following:

- direct beam radiation.
- high illumination levels
- material reflectance
- brightness contrast in the field of view

Glare is caused by direct beam radiation.

Our computer modeling revealed that direct beam radiation is always present in the Hall of Champions throughout the year, due to facade design and solar orientation. The southern facade of the building is made up of 75% glass fenestration with a 6:1 length to height ratio and an orientation of true (solar noon) south. This design wraps around the east and west facade of the atrium insuring the penetration of direct beam radiation all throughout the day, over the course of the entire year.

The Office Wing also receives penetration by direct beam radiation due to its facade design and solar orientation. The southern facade of the Office Wing is split between the tall 10 ft. windows of the first floor lobby, followed by three levels of 5 ft. windows below the barrel vaulting. The treatment of the materials inside the deep four foot window wells of the facade casts a luminous glow into the atrium.

The Office Wing structure is orientated 14° west of true (solar noon) south, perpendicular to the pre-existant historical Superintendent Building that connects to it with an enclosed walkway. On the east end, the morning sun is blocked out until mid-morning by the Superintendent Building, and the afternoon sun is blocked by the entranceway Rotunda. On the west end, the Rotunda and the Superintendent Building block out the sun in the early morning, and the Hall of Champions blocks out the afternoon and evening sun. Due to its slightly west orientation of true south, it also receives direct beam radiation all year round.

Glare is caused by high illumination levels.

Our measurements indicated extremely high illumination levels in the atria spaces of both buildings, many times above the Illumination Engineering Society (IES) recommendations for atria spaces. Yet an internal survey of the employees (see appendix C) of the NCAA Office Wing and the Hall of Champions revealed that 82% of the 128 querants responded that they did not belief the atrium created visual discomfort, 6% agreed that discomfort existed, with 12% replying nuetral to the question.

When asked if the daylight entering the atrium space created a pleasant and comfortable light, 86% agreed, and of those, 24% strongly agreed, with 5% disagreeing and 9% remaining nuetral on the question.

Even with the high illumination readings, most of the people taking the survey did not consider this to be a glare problem. I believe this is because of the next catagory.

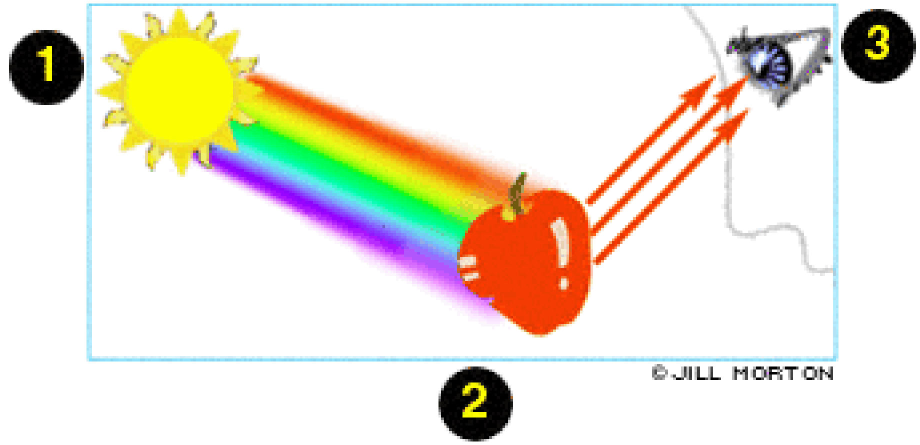
Glare is not caused by material reflectance.

The design of the atrium spaces utilizes contrast grading to minimize what would normally be very high contrast ratios.

Luminance, what we actually *see*, is simply illumination (fc), which we can't see, times a reflectance factor (RF)

$$fL = fc \times RF$$

As stated previousely, we cannot see illumination. What we call vision is the ability to discern contrast in luminance values. We discern contrast by luminance, or the reflection of light off of surfaces.



In the above illustration, what the observer is viewing is the luminance of the red color wavelength reflected off of the apple. The apparent brightness of the apple depends on the illumination of the sunlight falling on its surface, and the reflectance factor of the apple.

	Required fc	
Catagory of Visual Task	10% RF	50% RF
Casual	50	10
Ordinary	200	40
Moderate	450	90
Difficult	900	160
Severe	1200+	240

The above graph illustrates that, for similar spaces of differing reflectances, the reflectance factor determines what the adequate illumination requirements should be.

In the office wing, the windows are single glazed, allowing 85% transmittance. The window wells and walls are cantelope colored, with a reddish brown maroon mullion trim. The cantelope color has a reflectance factor of 40%, and the maroon trim has a 20-25% reflectance factor.

The cantelope coloring has a cooling effect on the bright illumination, causing the interior of the atrium to be seemingly cast in shadow.

These pictures are used to show what the space would possibly look like if the material reflectance were higher. Recommended reflectance of interior space calls for 70% reflectance from ceilings, 50% reflectance from walls and 30% reflectance from floors, as this is what we find in natural environments. Taking into account that this is a digitally produced image, and realizing the limitations inherant in a digitally produced image, one can still see that the result would be a wash over the entire space, creating a bland, much less dynamic, almost sterile environment.

The ceiling and walls have a 40% reflectance factor, light enough to create a gradual contrasting grade between the incoming source luminance (the sun) and the background luminance (window well), reducing the source to background ratio and minimizing glare. It also serves to tone down the overall illumination within the space.

Subjectively, it feels like the cooler side of a warm color, creatively establishing a warm-lighted, open area within a cool, shaded environment. It takes advantage of one of the assets of daylighting by masterfully modeling the shadows, bringing out a dynamic patterning in the coffers and caisson window wells. This effect is architecturally enhanced by the slight tonal mixtures of different shades of cantelope between the adjecent surfaces of the coffers and the window wells. The results are a subtle yet dynamic sense of movement as the light travels across the space in the course of the day.

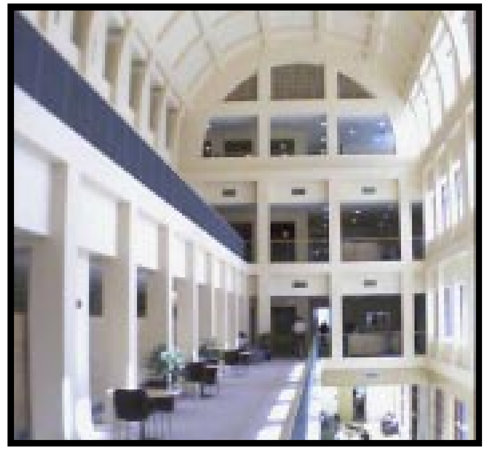


Fig. 46-a Using digital recreation, the Office Wing atrium is reproduced showing a "lit" space with a higher material reflectance, closer to the 70-50-30% rule that corresponds to the natural environment.

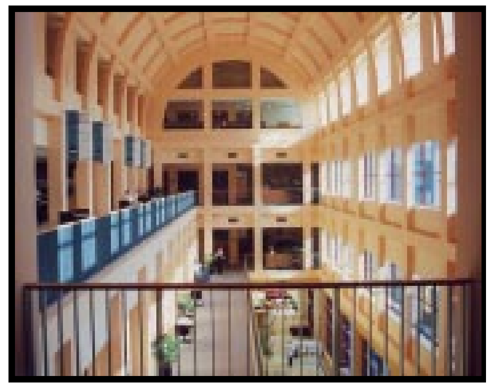


Fig. 46-b The Office Wing atrium as it is, showing a much cooler space with a lower material reflectance that can reduce the harsh effects of bright direct beam radiation.

The first impression of the coloration is striking, as cantelope is not usually an interior designers first choice of color for comtemporary office decorum. Many of the people working in the office have made comments on how different it is from other offices they have worked in, the usual somber greys and blues, and how warm and open it feels to them. And given its performance in this space, maybe it should be a designers first choice in atrium and light well spaces.

In the Hall of Champions, the first impression you get when you come inside the Great Hall is one of high illumination levels from direct beam radiation. It's obvious when you walk in the front or side doors from outside. The architects intent here was to have the Great Hall act as a transition space between the outside and the inside gallery spaces

The interior walls are red brick with a 30% reflectance factor and blue glazed brick, which, in spite of the glazing, has only a 15-20% reflectance factor. The red brick succeeds in creating the contrast grading necessary to minimize glare by reducing the brightness ratio between source luminance and background luminance. The blue brick works even better in toning down the harsh effects of direct beam radiation.

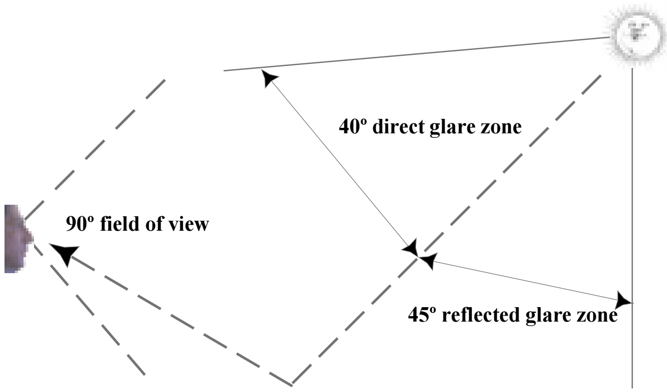
The mullions in the large, single glazed facade are a deep azure blue, with a 40-50% reflectance factor. The floors are a yellow-gold terrazzo with a reflectance factor of 60%. This aids the design intent of the architect to create a lantern effect in the White River State Park at night, but it also contributes to the problem of glare inside the space during the day.

Visual Discomfort

In order to prove our hypothesis, we needed to gain a better understanding of the chararcteristics of visual discomfort caused by glare in general and direct glare in particular.

Glare

Glare, defined as a harsh, uncomfortably bright light, results in visual discomfort to the observer.

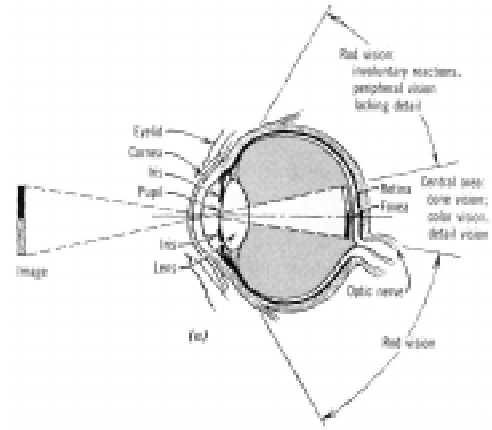


Discomfort or **direct glare** is caused by the light source being in the field of vision.

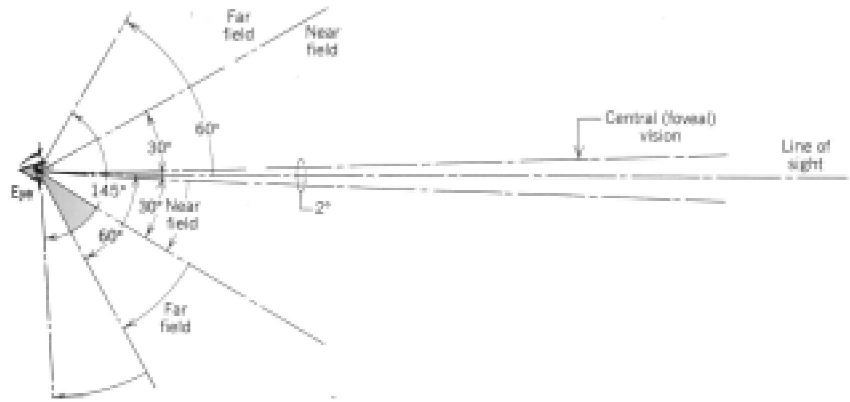
Reflected or **veiling glare** is caused by a reflection of the light source in a viewed surface.

The Eye

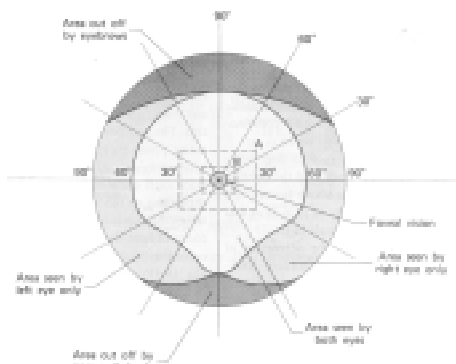
The iris controls the amount of light entering the eye by opening and closing according to the intensity. The light then passes through the lens to focus on the retina. An extremely narrow 2º cone of this area is the fovea, centrally located on the retina and densley populated with cone shaped cells, capable of acute perception of detail and color.



Around this fovea is a 60º cone of binocular vision called the surround (near field), where the lesser, coarser info is processed.



Surrounding this are areas of an 120º cone of horizontal monocular vision called the far field and an 180º cone of peripheral vision.



Characteristics of Direct Glare

The visual discomfort from direct glare is caused by two simultaneous reactions

- the eyes quickly adapting to the average brightness of the overall scene.

- the eyes being drawn to the highest luminance in the scene.

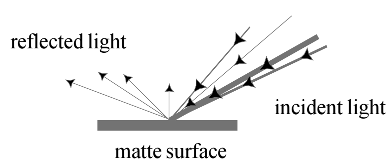
These reactions are involuntary and automatic. When a bright source of light exists in the field of view, it sets in motion a sequence of reactions. The eyes very rapidly adjust to the higher luminance level, causing the task or object viewed to lose brightness, relatively speaking. At the same time, the eyes are drawn towards the task and then the highest luminance and back to the task again. This repeated shifting of focus causes the adaptation level to constantly shift, causing fatigue.

The size of the light source is significant as well. A small luminary of high luminance may not cause significant discomfort, whereas a lower luminance of a larger source could cause discomfort.

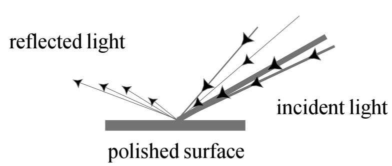
Characteristics of Veiling and Reflected Glare

The common vernacular refers to reflected glare when speaking of specular (polished or mirrored) surfaces, and veiling glare when referring to dull or semimatte surfaces. However, the terms are interchangeable.

If the task or surface being viewed mirrors the source of illumination, glare exists.



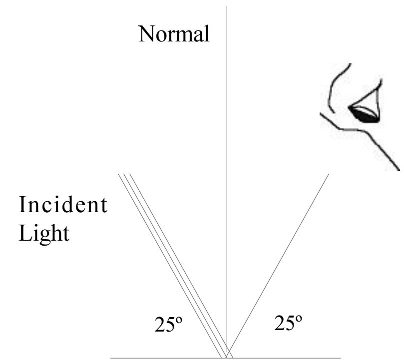
diffuse glare



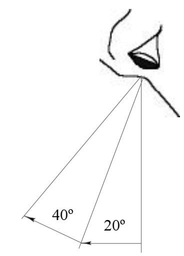
specular glare

Vision is the ability to see reflections of light in the object that is being viewed, or the objects **luminance**. The illumination from the source is invisible to the eye. What we see is the reflection of the incoming illuminance, or the **task** or **surface luminance**. Object definition and detail of the task or surface comes from the task's surface diffuseness. Veiling glare is due to task surface specularity, such as a sheet of glossy paper, or a VDT screen, and is proportional to source luminance, not illumination levels.

Glare sources must be within the geometry of reflected vision



Veiling Glare



Viewing Angles

and is therefore dependent upon the relationship of the angles of the viewer, incident light and angle of the task to the vertical plane. As specular reflection, the cause of veiling glare, approaches the viewing angle, it reduces contrast between the object and its background, reducing visibility.

Visual Comfort

The factors involved with visual comfort are

- adequate illumination
- limitation of glare
- low brightness contrast ratios

The aim of lighting design is to create a luminous environment that provides good task visibility without causing eye strain.

Adequate Illumination

The standards that establish adequate illumination levels for varying degrees of tasks are 70 years old. They focus on quantitative measurements of footcandles falling on horizontal surfaces as determined by the visibility of the smallest or most difficult detail that must be recognized. This visibility , however, depends on other factors, such as the tasks apparent size, its contrast with the immediate surroundings, the available time it takes to adapt, as well as the eyesight of the viewer.

Distractions from ceiling reflections, veiling reflections and glare also factor in and affect task performance.

On Skylab, crews found light levels inadequate for the performance of some tasks and offered recommendations that levels be increased up to sixfold. While modifications, at least those affecting work areas, may be required, it should be remembered that many adult Americans today grew up before energy conservation was a widespread concern and are accustomed to higher levels of illumination than are required for good vision. For extended spaceflight, it will be necessary to maintain levels of illumination adequate to the tasks required, while readapting to lower levels of illumination generally.

Preferred wall luminance -25 - 150 cd/m2
Preferred ceiling luminance - 50 - 250 cd/m2
Preferred task luminance - 100 - 500 cd/m2
Permissible luminaire luminance - 1000 - 7000 cd/m2
Depending on position in field of view
Sun luminance - 2,300,000,000 cd/m2
For maximum visual acuity, the luminance of a surface type task should be the same or slightly higher than that of the background, with ratios of 3:1 acceptable in most circumstances

The eye adapts to the overall brightness levels. Visual acuity is the ability to distinguish between different levels of illuminance, with visual acuity increasing with increasing adaptation levels.

At low adaptation levels, 1fL, a measured luminance ratio of 1:10 appears to be approx 1:4, smallerthan actual.

I. The Task
primary factors
(a) Size
(b) Luminance (brightness)
(c) Contrast, including color contrast
(d) Exposure time
also

(e) Type of object
(f) Degree of accuracy reqiued
(g) Task: moving or stationary
(h) Peripheral patterns

II. Lighting conditions
(a) illumination level
(b) disability glare
(c) discomfort glare
and
(d) luminance ratio
(e) brightness patterns
(f) chromaticity

Daylighting in Design

Daylighting as a Design Factor

The days of cheap, bountiful supplies of energy are over, if they ever really truly existed, and we can no longer afford to turn our back to the sun as an option in meeting the lighting requirements of building design. The utilization of daylighting in lighting design present the architect or lighting designer with overlapping considerations:

- Interesting balanced luminous environments
- Adequate ambient light levels
- Minimal HVAC loads
- Integration with electrical lighting schemes

Artificial lighting in large buildings is the largest use of primary energy in the U.S.[4], making up 40% to 50% of total energy consumption in many commercial and industrial buildings. Effective use of daylighting, in conjunction with energy efficient lamps, can lower the lighting power density from 2.2 W/ft^2 to 0.88 W/ft^2 without reducing measured lighting levels.[5]

Any successful daylighting design will address three critical issues:

- Light Quality: How pleasant and comfortable is the space?
- Light Quantity: Is there enough light to meet needs?
- Energy Savings: How energy efficient is the system?

Daylighting is a combination of direct beam radiation, diffuse daylight, and reflected light from the surrounding exterior landscape as well as the internal reflectance of materials and surfaces within the space.

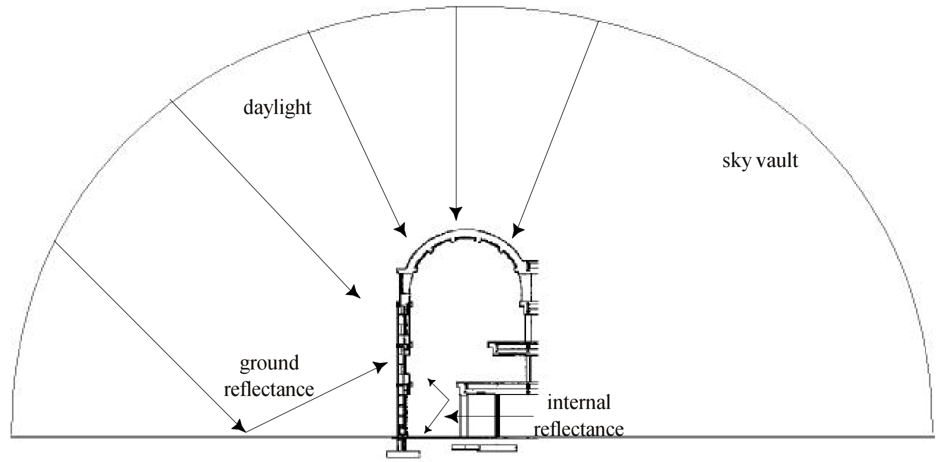


Fig. 39-a Daylight components

Direct beam radiation is light that takes a direct path from the sun. It has the most intensity and can add considerable heat-gain to spaces. It will also fade materials and finishes of surfaces and furniture.

Diffuse daylight is sunlight that has been reflected or refracted by clouds, particulate matter or pollution in the atmosphere, and makes up most of the light that buildings receive on a cloudy day. Diffuse light is less intense than direct beam radiation and covers a broader area.

The DF - Daylight Factor, the amount of natural light in the building, is defined as a ratio between the interior illuminance on a horizontal surface to the exterior illuminance on a horizontal surface, excluding direct beam radiation (overcast sky conditions)

$$DF = \frac{E_i}{E_e} \times 100$$

expressed as a percentage, where E_i = Interior Illuminance and E_e = Exterior Illuminance

The illuminance added by daylight at any point within a given space is a result of three factors.

- sky component (SC)
- externally reflected component (ERC)
- internal reflected component (IRC)

Sky Component (SC)

The sky component is the received portion of illuminance striking a given point inside the space which is coming directly from the sky visable from the window. Because it is the *received* light as measured from within the space, it must take into account obstructions (mullions) and transmission losses.

SC = incident light - window losses

External Reflectance Component (ERC)

The external reflectance component is the relative illuminance striking a point within the space received from adjacent buildings or structures. This **does not** include ground-reflected light. It is estimated by the amount of sky component obstructed by the building reduced by the reflectance factor of the obstruction. For a building that obstructs 25% with a RF of 20%

ERC = SC x 0.25 x 0.20

and that gives us

ERC = 5% of SC, to be added to the remaining 75% SC

Internal Reflectance Component (IRC)

The IRC is the light received directly or indirectly from daylight at a given point within the space, that is reflected from interior and exterior surfaces, and is entirely dependent on surface reflectances and the amount of window glazing, becoming a large part of the DF deep within the space.

Direct Beam Radiation

Daylighting

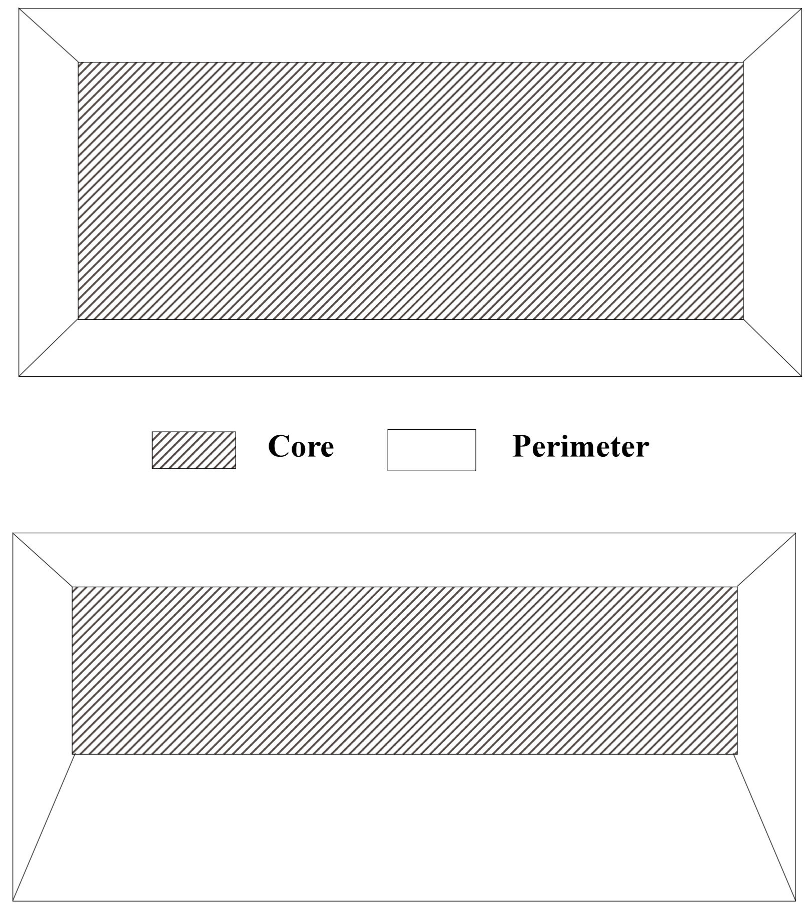
Today's approach to daylighting is designed to overcome earlier shortcomings related to glare, spatial and temporal variability, difficulty of control and over-illumination[1]. In the process, they reduce the effectiveness of direct sunlight, responsible for 85% of the light available on a sunny day, by shading or diffusing it.

Direct and Filtered Direct Daylight

Lighting accounts for 33%, in most cases, and up to 60% in some cases, of the total energy dollar spent in today's offices[2]. The efficacy of **direct sunlight** is comparable to 100 lm/W, and interestingly, **filtered sunlight** is comparable to 200 lm/W, far exceeding existing electric lamps (15-90 lm/W). The benefits derived from utilization of daylighting are improved aesthetics, possible health benefits and reduced energy consumption.
Therefore, any consideration given to improving the available lighting needs of an architectural space should attempt to make use of filtered sunlight more effectively first, and then direct sunlighting, thereby reducing or even negating relamping options that may require the use of energy dollars at a much higher environmental and financial cost.

Daylight Atria Systems

Atria, light courts and reentrants are ways of manipulating the perimeter of a building to optomize the amount of space that can be illuminated by natural light. The perimeter is defined as the part of buildings that is in contact with the surrounding environment.



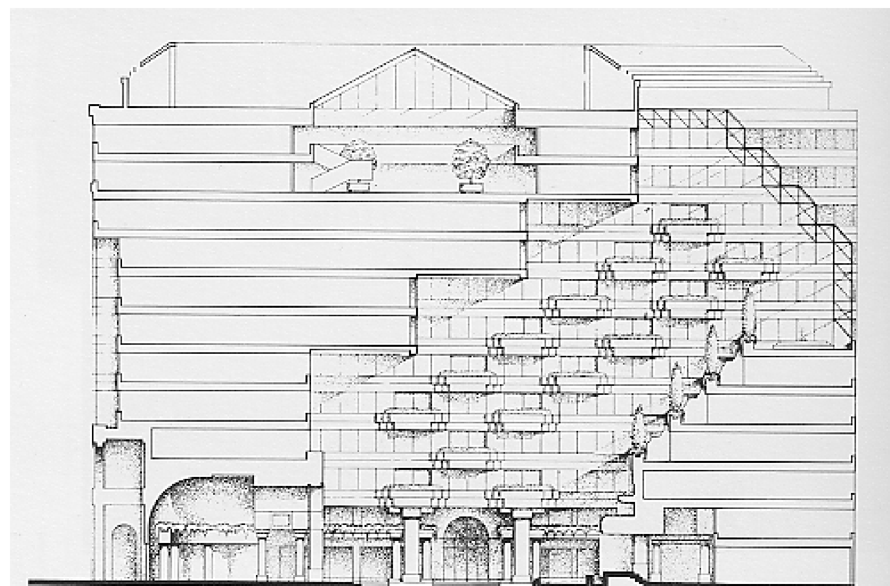
Daylighting Perimeter and Core

The perimeter connects with and responds to the daily (light, temperature) and random (rain, wind) weather phenomena. It has access to daylighting that the core doesn't have. The atrium allows for manipulation of daylighting by bringing natural light deeper into the building, in effect reducing the size of the core by increasing the size of the perimeter area.

The use of daylighting as a free energy source can offset the cost of electric energy in load dominant commercial and institutional buildings where high light levels are required during the daytime. Each unit of energy used for artificial lighting requires an additional one-half unit for air conditioning to offset the heat generated by the lights.[8] The payback period can be short when designed in a coordination with artificial lighting.

The optimal design utilizes some form of overhead system as the source, for both the quantity of light admitted, the sky-dome being brightest at its zenith, and the control opportunities available. The primary reason for atria sidelighting is the ability to capture long distance views, or, as in the case of the NCAA campus, to engage the atrium to the exterior space.

The sectional scheme employed by the NCAA Office Wing, with each floor projecting further than the floor above it, contributes greatly to daylight distribution. Although this design scheme can be effective, it does reduce the atrium floor area while at the same time making each floor progressively deeper and more difficult to light. The office building at 1300 New York Avenue, designed by Skidmorem Owings & Merril, utilizes a central atrium and a reversed step-sectioning quite effectively without reducing rentable floor space or creating deeper pockets of the building where it may be hard to illuminate.



Transverse building section.

Economic Analysis

	January	February	March	April	May	June	July	August	September	October	November	December
8 AM	288.638	808.731	1078.308	1233.519	1222.627	1214.458	1244.411	1345.162	1296.148	974.834	383.943	138.873
9 AM	1524.88	2023.189	1998.682	1944.222	1767.227	1701.875	1767.227	2020.466	2224.691	2148.447	1486.758	1440.467
10 AM	2799.244	2875.488	2875.488	2597.742	2262.813	2140.278	2241.029	2641.31	3101.497	3294.83	2608.634	2799.244
11 AM	3842.153	4196.143	3564.407	3104.22	2638.587	2472.484	2600.465	3117.835	3784.97	4209.758	3520.839	3918.397
12 PM	4427.598	4732.574	3942.904	3379.243	2842.812	2652.202	2793.798	3373.797	4158.021	4716.236	4035.486	4552.856
1 PM	4427.598	4732.574	3942.904	3379.243	2842.812	2652.202	2793.798	3373.797	4158.021	4716.236	4035.486	4552.856
2 PM	3842.153	4196.143	3564.407	3104.22	2638.587	2472.484	2600.465	3117.835	3784.97	4209.758	3520.839	3918.397
3 PM	2799.244	3229.478	2875.488	2597.742	2262.813	2140.278	2241.029	2641.31	3101.497	3294.83	2608.634	2799.244
4 PM	1524.88	2023.189	1998.682	1944.222	1767.227	1701.875	1767.227	2020.466	2224.691	2148.447	1486.758	1440.467
5 PM	288.638	2023.189	1078.308	1233.519	1222.627	1214.458	1244.411	1345.162	1296.148	974.834	383.943	138.873
6 PM	0	0	255.962	569.107	691.642	735.21	732.487	686.196	443.849	0	0	0

For daylighting to be an effective alternative to electric lighting, it must reduce lighting and cooling energy costs more than it increases energy costs from heating, solar gains on the glazing and from envelope loads.

1. Annual hours of operation:

52 weeks x 5 days/week x 9 hrs/day = 2340 hours/year

The table above gives each months average available daily daylight illumination levels, in footcandles/ft^2, for the daytime hours of operation in Indianapolis, Indiana. This can be useful in estimating available daylighting contributions to a buildings overall illumination, allowing designers to integrate lamping in coordination with direct beam radiation levels.

The best way to do this is with conventional ballasts with partial dimming in core areas (because reduction in lighting will not exceed 40%), electronic ballasts with full dimming capabilities and either SCR dimming plus switching or a multilevel switching system in perimeter areas because daylighting will provide all the lighting needs when it is available.

The Office Wing atrium uses 70Watt PAR30 lamps at a cost of 67.2KwHrs/10hr day. The Hall of Champions Great Hall uses 500W PAR 56 lamps at a cost of 120KwHrs/10hr day. These lights are not necessary and do not need to be operated during the daytime. The savings would be around $2900/yr in electric lighting costs alone, not including cooling costs for the heat generated by these lamps.

Next we need to compare the thermal balance affected by the fenestration to determine the energy gains and losses for the atria spaces.

Thermal conduction is the process of heat transfer through solid building materials. There are four factors affecting the rate at which energy conducts through a substance.

- the temperature differential (T_{Hot} - T_{Cold})
- the thermal conductivity of the substance
- the heat-transfer area
- the thickness of the substance

We want to look at the wall and determine how much heat transfer is going through the glass fenestration. **Thermal transmission** is the rate of heat transfer, an expression of thermal power or flow rate in units of **Btu/hr** or **Btuh**.

$$q_{con} = A \times k/t \times (T_{in} - T_{out})$$

where

q_{con} = conduction
A = area (sg.ft.)
k = thermal conductivity
t = thickness
T_{in} = Temperature inside
T_{out} = Temperature outside

Windows are rated by their U values, which is the same as k/t, (the inverse of R-values), and (T_{in} - T_{out}) is the same as Δ**T**, so we can rewrite the equation

$$q_{con} = A \times U \times \Delta T$$

Heating Degree Days

In order to arrive at an annual average, we need to include the Degree Days factor. Heating degree days (HDD) refer to average temperatures below a base temperature. HDD65 refers to a base temperature design 50 years ago, when buildings were poorly insulated. Residences kept at 70ºF did not require supplemental heating until the temperature dropped below 65ºF.

If the average of one days high and low temperature was 40ºF, its HDD would be

$$65^\circ - 40^\circ = 25\text{HDD}$$

Using HDD65 as our Δ**T**, our equation is now

$$\mathbf{Q = UA \times DD \times 24hr/day}$$

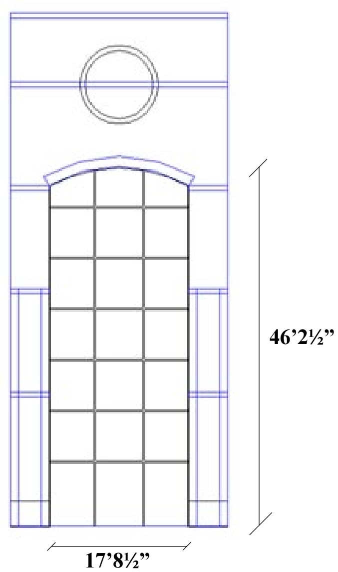
where

Q = total heat loss
U = conductivity of window
A = area in ft^2
to keep the units straight between Heating Degree in days and thermal transmission in units of Btu/hr•ft^2•ºF, we multiply by 24hr/day

The U-value for single pane glass fenestration is

$$\text{glass U} = \frac{k}{t} = \frac{5.5\ \text{Btu/hr•ft}^2\text{•ºF}}{\tfrac{1}{2}\text{“}}$$

glass U = 11



Each section of glazing contains
46ft 7½in x 17ft 8½ = 818.273 ft^2

The total amount of south facing glass is
818.273 ft^2 ea. x 7 = 5727.91ft^2 tot.

HDD65 yearly for Indianapolis, Indiana 5620 Btu/hr•ft^2•°F

$$Q = UA \times DD \times 24hr/day$$

$$Q = 1.1(5727.91ft^2) \times 5620\ Btu/hr•ft^2•°F \times 24hr/day$$

$$Q = 849{,}838{,}550.8\ Btu/•ft^2•°F$$

If electric heat were used to replace this lost heat (100% efficiency) it would cost

$$\frac{849.84MBtu}{yearly} \times \frac{KwH}{3414\ Btu} \times \frac{\$.06}{KwH} = \frac{\$14{,}935.65}{yearly}$$

Solar Gain

The *greenhouse effect* describes the temperature increase of an enclosed space with a glazed aperature exposed to the sun. At the same time that we are losing heat through the glass fenestration due to thermal transmission, we are also gaining heat energy from the sun by the greenhous effect. Glass is 80% to 90% transparent to shortwave (solar) radiation coming in. It is rather opaque to longwave (infrared) radiation.

This is normally assumed (erroneously) to be the primary cause of the net heat gain in glazed enclosures. The relative insignificance of the longwave opacity of glass has been known since 1909. Experiments done by the British physicist R. W. Wood, using identical enclosures, one with glass (opaque to lonwave radiation, the other with rock salt (transparent to longwave radiation) showed an insignificant difference of less than 1° Celcius between the temperatures of the two enclosures.

In his analysis of the mousetrap theory of the greenhouse effect, R. Lee (1973, 1974) states:

> Greenhouse glass does not trap radiant energy, but it does trap air... The secret of the greenhouse is that it permits a relatively normal radiant energy exchange while trapping a small amount of air near the surface.

It is this trapped air near the surface that prevents heat loss. Being relatively motionless, compared to the normal atmosphere, it becomes less efficient in removing energy from the surface. The temperature surface needs to be greater in order to dissipate the same radiant energy.

We used clear day solar heat gain tables[9] to calculate our space heat gain for one ft^2 of glazing in January

$$HG_{sol} = ½D_t \times 2 \times .94$$

where

HG_s = heat gain from direct beam radiation
$½D_t$ = Half day totals given in table (2x for full day) multiplied by .94 (6% absorbtion loss in glazing)

$$753 \times 2 \times .94 = \frac{1{,}415\ Btu}{ft^2•day}$$

Knowing the amount of daily solar radiation for one ft^2 per day, we can than calculate the total solar gain through the southern walls fenestration

$$HG_{sol} = A_{gl} \times I_t$$

where

HG_s = heat gain from direct beam radiation
A_{gl} = surface area of the unshaded portion of glazing
I_t = solar heat gain through one square foot of glazing

$$HG_{sol} = 5727.91ft^2 \times \frac{1{,}415\ Btu}{ft^2•day} = \frac{8{,}104{,}993\ Btu}{day}$$

This is the amount of solar gain for one day in January

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BRIGHTNESS, LUMINANCE AND CONFUSION

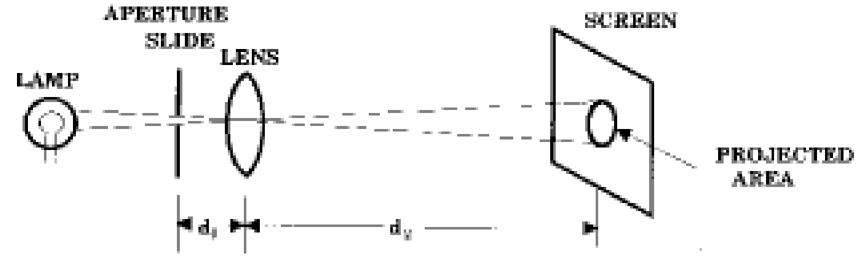
LIGHT - radiant energy capable of exciting the retina and producing a visual sensation. For the purposes of this report, we are excluding UV and IR wavelengths. The visible wavelengths of the electromagnetic spectrum extend from about 380 to 770 nm. The unit of light energy is the lumen second.

2. **LUMINOUS FLUX** - visible power, or light energy per unit of time and measured in lumens. Since “light” is visible energy, the lumen refers only to visible power. One watt of radiant power at 555 nm - the wavelength at which the typical human eye is most sensitive - is equivalent to a luminous flux of 680 lumens. One can measure the visible energy of radiation, but measuring the visible power is more common.

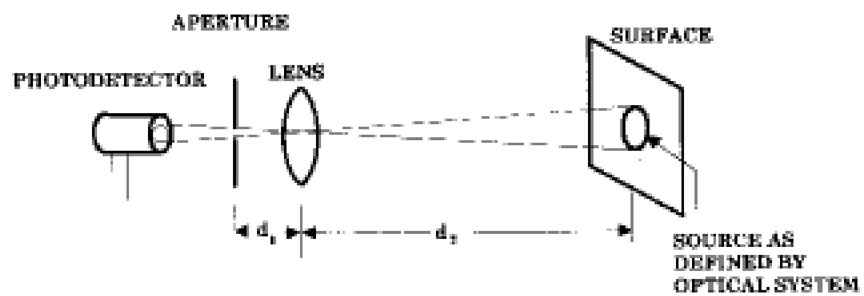
3. **LUMINOUS INTENSITY** is the luminous flux per solid angle emitted or reflected from a point. The unit of measure is the lumen per steradian, or candela (cd). (The steradian is the unit of measurement of a solid angle.) The Intensity control on an oscilloscope adjusts the magnitude of the luminous intensity and, consequently, the luminance and the brightness of the light output. Luminance and brightness are defined below.

4. **LUMINANCE** is the luminous intensity per unit area projected in a given direction. The SI unit is the candela per square meter, which is still sometimes called a nit. The footlambert (fL) is also in common use (1 fL = 3.426 cd/m^2). The concept of luminance is challenging and deserves detailed discussion. First, let’s look at what is meant by “projected area.” Think of a slide projector containing a slide that is opaque except for a small clear spot at the center.

When d1, and d2 are correctly related to the focal length of the lens, light passing from the lamp through the clear spot in the slide is focused by the lens onto the receiving surface (SEE **Fig. 1**).

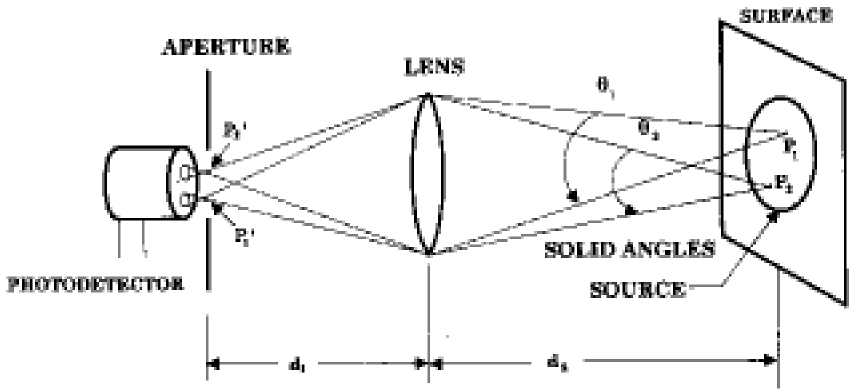


This in-focus image of the spot is the projected area. The size of the projected area can be adjusted by changing the focal length of the lens, d1 and d2, and/or the size of the spot - the aperture - on the slide. Replacing the projection lamp with a photodetector and the projected area with a source of light - either self-luminous or reflected provides the basic elements of a luminance photometer (SEE **Fig. 2**).



Most luminance photometers’ have special optics that allow the user to view the source and bring the projected area into focus. Any luminous flux that leaves the source - as defined by the projected area - and passes through the lens will also pass through the Aperture. That luminous flux will enter the photodetector and permit a luminance measurement. What is being measured is power - the rate at which energy is being transferred from source to detector - but there can be no power without energy.

To see how luminous intensity contributes to luminance, review the definition of luminous intensity and refer to (SEE **Fig. 3**).



Each of the points - such as P1, and P2, - on the projected area emits luminous flux over a solid angle of 2 PI steradians. However, only that portion of the flux that falls within the cone defined by the effective area of the lens and the distance d, from the lens to the point on the source succeeds in arriving at the detector.

There is a little cone for every point on the projected area. Two cones of angles 1 and 2 are shown. For each point on the projected area, there will be a corresponding solid angle. The greater the projected area, the greater will be the luminous flux collected by the lens. The larger the lens diameter, the greater will be the luminous flux from each point collected by the lens and directed through the Aperture to the photodetector. P1 and P2 are two of the many points on the object source plane. The optics form the images Pl’ and P2' of these points at the aperture plane. A point on the source is focused by the lens onto the aperture plane. There is no need to focus on the photodetector because all of the light that passes through the aperture must fall on the photodetector. If the projected area were to be reduced to one-half, the number of little cones would be reduced to one-half and the luminous flux collected by the lens and arriving at the photodetector would be reduced by one-half. This assumes that the projected area is uniformly luminous. If the projected area is not uniformly luminous, the photodetector will average the luminous flux over the projected area.

The luminous flux collected by the photometer lens (and directed to the photodetector) is proportional to the projected area. This is important in, for example, measuring the luminance of a display. The placement of the projected area on the luminous source of a display - such as a symbol stroke - is important when making a luminance measurement.

5. **BRIGHTNESS** is a subjective attribute of light to which humans assign a label between very dim and very bright (brilliant). Brightness is perceived, not measured. Brightness is what is perceived when lumens fall on the rods and cones of the eye’s retina. The response is non-linear and complex. The sensitivity of the eye decreases as the magnitude of the light increases, and the rods and cones are sensitive to the luminous energy per unit of time (power) impinging on them.Luminance is the measurable quantity which most closely corresponds to brightness. The luminance photometer and the human eye both have a lens and both receive light from specific directions. The photometer has a single photodetector - maybe three for color - while the eye has a very large number of sensors (rods and cones). One may think (loosely) of each cone in the fovea - the area near the center of the retina - as being part of a human light meter using a common lens.

6. **ILLUMINANCE** is the luminous flux incident on a surface e per unit area. The SI unit is the lux, or lumen per square meter. The foot-candle (fc), or lumen per square foot. is also used (1 fc = 10.764 lux). An illuminance photometer measures the luminous flux/unit area at the surface being illuminated without regard to the direction from which the light approaches the sensor. Using cosine correction to correct for changes in the illuminated area of a surface as a function of angle of incidence guarantees that the measured value of illuminance is independent of the direction from which the light approaches the sensor. Let’s try to say that again in a more intuitive way. If you aim a flashlight perpendicular to a nearby surface, it produces a circle of light on the surface. Tilt the flashlight and the illuminated spot increases in area and becomes elliptical in shape. The same luminous flux is now spread over a larger area as the angle between the axis of the flashlight and the normal to the surface increases. For a given luminous flux, the illuminance decreases as the illuminated area increases.

If you have an illuminance photometer handy, make an illuminance measurement with the light directly over the sensor. Now make a measurement with the light off axis by a given number of degrees from the normal. The off-axis reading should be equal to the on-axis reading times the cosine of the angle. If it is, the meter is cosine corrected. This experiment requires the meter sensor to be small compared with the projected area.

INTERVIEW WITH RON FISHER

Interview with Ron Fisher @ Schmidt Engineering, Architect of Record for the NCAA Headquarters.

I'll cover some general concepts with lighting, starting with, in its broadest sense, some of the concepts that Michael Graves had.

There are really three building there. The one building your not really looking at is the one that the NCAA doesn't house, the High School Federation does. That is the old Superintendents building. These make up a sort of campus of the three buildings. Conceptually what was envisioned there was that it would really be a small type of campus of buildings that would reflect the specific functions that were going on. In the interview that Michael spoke to that the NCAA liked. There was to be a collegiate feel to these collections of buildings within the park there, in relationship to the client that the NCAA actually serves.

The Hall of Champions is a envisioned as a more public facility. The Great Hall, which is the main space that you walk into, which is nicknamed the Free Hall because you can go into that space without having to pay. It will hopefully prompt you to go into and pay a few dollars to go into the main exhibit area. With the large expanse of glass there, the desire was that there would be clearly during the day the flooding of natural light, but a sense of an inside/outside feel to the space. It would draw people in from the park to that space. There would also be a sense of activity that you would see.

At night, and this is very important, there's a sense of light, that the space itself would actually light, or to use a term that we use is a lantern, that the building, the Great Hall, would become a lantern. There really is no exterior light per se, that is on the building.

As kind of an after fact, something that wasn't part of the design team, the NCAA actually added some floods to flood the face of that building from the ground. That wasn't really the intent. The intent was for the building to glow from the light from within. Actually, from as far back as Washington Street, you could look across the park and see the building glowing as a lantern.

There are large tri-fold type murals that are on that wall, and you can actually see them better at night when the building is lit, and kind of glowing. They have different collegiate sports on these murals that are constantly moving, and you get a sense of activity. Again, this is to draw people into the building, and at night, to give it a sense of presence.

The Grand Hall is envisioned as its own kind of space, from the way it was treated not only architecturally but also with the lighting, and that it would have more of a presence at night, and then again during the day that it would be s naturally lit space with a strong sense of inside/outside.

As you would go into the actual exhibit area of the Hall of Champions, a lot of that lighting became specific to the exhibit and the experiences that were happening there.
There were a couple of consultants that were involved in the design process as well. The concept of the exhibits, the interactive videos, the music score that was developed as unique for that facility and that exhibit, that was all conceptually developed and executed by Seventeen Seventeen out of Richmond, Virginia. They do a lot of exhibit work for the Smithsonian. They did a Cowboy Hall of Fame in Oklahoma City. They were an integral part of working with the architectural and engineering design team in really understanding how the building would work as a concept, and then how the exhibits needed to work.

There was also a lighting consultant that was involved in the project, Fisher, Morantz, Renthrow and Stone, FMRS, out of New York. They worked hand in hand with Seventeen Seventeen, Michael Graves and our office in developing the different designs of some of the different areas.

Interview with Ron Fisher @ Schmidt Engineering, Architect of Record for the NCAA Headquarters.

The exhibit area, the lighting is to reinforce the actual designs of the exhibits and the experience you would have with them. The first space you enter into is the Hall of Honor, with the onyx panels that are back lit, and then up to the second floor gallery into areas that are a little more reminiscent of sports areas, a high tech or industrial kind of feel, as if you were in the underside of a stadium or something like that.

The office building itself, the concepts in the lighting there, really comes back to the notion that the building itself was to be very horizontal. When the NCAA was in Kansas City, they were located in a building that would be very similar to the North Keystone area of Indianapolis, north of 465, where there are just a lot of spec type of office building space or office park. They had their own building that was very closed, almost like law offices, where everyone had their own closed offices. If you needed to go from floor to floor, you took the elevator. They had card access to go from floor to floor, almost in the sense of a lock-down environment, very closed.

What they wanted to do in the new facility was to have a very open environment. I'll say even horizontal. They were trying to change their management structure, the way they interacted to be more interacted and more horizontal. The idea that the building would be very open was the concept that the atrium and the floors would step back and open into the atrium became very important in that concept. While it is a multistory building, people could literally stand at different points of the atrium or the monumental stair and look across and maybe some someone on a different floor, up or down, and meet there in the balcony area of one of the floors and have a quick conference or lot of incidental interaction, that sort of thing.

There are actually two cores to that building, the two monumental stairs at either end. The monumental stair encourages people to move either up or down without jumping into an elevator. Encouraging people to flow up or down through that building easily was very important.

For code reasons they have a core fire stairs as well. It was very important that we didn't have a combined stair core that would serve as a fire stair and a communicating stair. We had an open monumental stair so that, again, people would move up and down that building very freely.

With that as the core concept of the atrium space and what that was about, the idea of bringing natural light into that atrium was important to the NCAA. Again, they came from an environment that was much more closed. It was also an environment where everybody had an office with a window. They knew culturally they would have to move away from that where it would be a much more communal space. So a naturally lit atrium became important, so that everybody, in a sense, had their own window, even though, in the open office environment people wouldn't have their own private offices and private window.

The lighting in the Administration building… The atrium is one kind of space, how it is lit, the use of natural light, the conference center and the auditorium clearly have different kind of functions. The way the lighting needs to work there and the controls, the operation of the lighting and all of that.

I might add that as you are looking at the different controls, pre-sets and all of that in that lecture auditorium, you may also want to look at the flat floor conference multi-purpose space because it also has a series of different kinds of lighting arrays in it. Its kind of a custom designed, coiffured light feeling element there, so that they could get some general lighting in the space. But also, then again there are a lot of presets on options on how they can set up the lighting in there for the various functions.

The office spaces themselves have different lighting, with the barrel vaulting and the uniqueness of that. The design notion of lighting, even on that building, was to let the building itself, especially at night, kind of express itself in that lighting.

There are not a lot of exterior light fixtures or things like that mounted on the building, and that was intentional, pretty consistent with Graves and they way they would look at design buildings. As you see the building is lit internally, that's how you see it through the windows, the punched openings, the fenestration, that's how it reads, and that was very intentional.

We do have some lighting out in the plaza area. It was important there, with White River State Park, that the site lighting be consistent with the site lighting that had been developed across the park. Susaki was the master planner for the White River State Park, and so they were consultants on the team also, from the site lighting standpoint, just to make sure the fixture types and just the way the lighting was handled be consistent across the park. That was fine with the team. This was also why Graves approached the building with their own elements within this kind of campus and plaza, and the park itself with the lighting as a part of their standards across the park itself work itself across that area.

In terms of some of the technical questions about the light and stuff like that, I really would recommend getting in touch with Charles Stone (Stowe) was the lead person with Fisher, Morants, Renfroe and Stone out of the New York office. Their number is 212-691-3020.

The people with Seventeen Seventeen, and again, they are the ones who worked with the exhibits.

Question 2.

Schmidt Associate, the Architect of Record, which means not only were we certifying the design, we were also the prime contract holder with the state of Indiana. Actually our contract was with White River State Park. They are technically the owner of that facility. The NCAA is technically the tenant of that building. Michael Graves was a consultant to Schmidt Associates. Their responsibility as design architects, our responsibility as Architect of Record, how those duties or responsibilities played out, the conceptual design of that building, and Michael himself was involved with that kind of conceptual design, although he has a group of associates that were really assigned to the project. They know the "book", so to speak, the kit of parts, so to speak, of the vernacular that Michael works with.

So conceptually Michael developed that. But there was an associate that was in charge of the project that really developed those concepts. Their project architect that they had involved with the project, that we interfaced with a lot on a day to day basis…The way that the team worked, and it worked very well, both firms were involved all the way through the project.

There was no black and white as far as them handling the design and then when it came time to developing the construction documents, just handing that over to us, and we took over and that sort of thing… I was involved with them in programming meetings out in Kansas City with the NCAA. We were involved in all design presentations, although the lead at that point was coming out of Michael's office. We were engaged and involved in supporting and developing that.

As that moved into the more technical end of it, we would take more of the day-to-day lead. But they were, again, involved daily with us. They had a group of individuals working very extensively, with the Internet, on drawings moving back and forth. We were very pleased with the level of technical detail that their project architect was involved with and engaged in, working with our architects and our team.

That was a very good relationship, it worked well. Even through construction, and again, we were in the lead of that, their individuals were involved on a day to day basis, technically through the development of the documents, were also on site every other week. We really functioned as an integrated team. Again, there were a lot of consultants involved in this project as well, and I have mentioned several of the key ones. Schmidt Associates handled the engineering, with the mechanical, electrical and plumbing engineering on the project. We had a series of specialty consultants that assisted the team.

Bob Koester: The design associate that was in the firm at Graves, you say he was different than the project architect?

Yes, Tom Rowes, an associate with Michael Graves, at the time associate, I believe now he is a partner. The individual that we worked with on a day to day basis, their project architect was Steve Panzarino.

Michael's involvement with the project, any key presentation to White River State Park and the NCAA, Michael was involved with. But once he kind of set the concept in motion, then Tom Rowe really took and developed the design. Working with Steve in our office really kind of brought that to fruition. I think most of you are familiar with Michaels work, there is clearly a style or vernacular that they work with, you could just see that rolling out. We worked hand in hand in terms of developing the structural grid, the basic patterns, back and forth, and how that would develop, and some of the technical issues through that. They were very involved in terms of the color, both the exterior and interior colors. There is a palate there very much that Michael does influence, and they work with. They are very particular about that.

Chuckles heard throughout the room!

Question 3

Actually, in terms of the preset controls, I think that was done kind of jointly with FMRS, and then our electrical engineer that worked on the project. Our particular electrical engineer, he is actually on his own now. His name is David Schuck. He is pretty experienced in theatrical lighting systems. He did a lot of that.

Another player in the project was Browning Construction. Browning Construction was the owners rep. The funding on this project was a combination of private and public dollars. The state provided some of the money. Corporate donations were also provided. That was all spearheaded through the Indiana Sports Corporation. While they weren't technically an owner, they were a player for sure, because they were the group that brokered getting NCAA to come to Indianapolis, and they were able to put up, basically, half of the money through their corporate donations. And they were really charged with running the project of moving NCAA here, that coordination.

As I said, Browning Construction was the owners rep. Their task was watching the dollars and cents. There are parts of that building that are approached as, I'll say a typical spec type office, the way it was budgeted. Some of those things that came to the table went away because they were working in a budget and a scope level of more of a spec office building.

Another person who could really give you some pretty good background on this is a fellow by the name of Greg Shaheen. Greg now works for the NCAA in the basketball championship area.
Greg is also, actually his Mother, is part owner of Long Electric; and Greg himself has a pretty good knowledge of lighting and electrical, and he was the person at the time that actually was working for Indiana Sports Court in coordinating the move of NCAA to Indianapolis. He could provide maybe some background in resources of why decisions were made. He can be reached there at the NCAA.

Question 4

The fact that they needed to bring in a hydraulic lift

Those things were discussed, yes, like how we were going to clean windows.… I think, in fact I was talking to one of the fellows from REI, and they're looking at maybe getting some longer life bulbs maybe in that atrium space. Those things were discussed. There was,at one point, a building wide dimming and control system for the lighting that was at one point, a building wide dimming and control system for the lighting that was envisioned and discussed. We ended up with a modified version of that, so that they would be able to control lighting. One of the things that was discussed was a central lighting control system that was that would be tied also to the internecine managing system, that they would be able to get longer life on their lighting and make sure they were turning on and off lights at appropriate times and that sort of thing. But that went the wayside of budgets on the initial construction costs.

Question 6

Bob Koester: We know, going in, that the colors were quite carefully defined. The question that came up last week in the class discussion was whether, knowing that the colors were going to be what they are, how did that play a role in the lamp selection and fixture selection?

FMRS advised on the lamps for the coloration, and it was a consideration, particularly in the office area. Although, I am trying to think…, Greg Shaheen can tell this story. I believe the original lamps that went in the office area were way to pink, and they actually relamped to a different lamp. There is a story there. Greg Shaheen would know that story. Something happened there, and I don't recall which way it went, if they didn't do the original recommended lamping, and went with something else and had to change it or what happened.

Bob Koester: This is an aside, but, how early in the process did you know the inside was going to be canteloupe?

Fairly early. We had some computer rendered drawings that came from Graves office, that were completed before the completion of the documents. In fact, its kind of canny, to sit there in the atrium and look at them, and its what you see right there. That color palette was well understood, clearly by Michael, what was going to happen there. I don't think NCAA fully understood the colors. I know Ced Dempsy didn't fully understand all the colors he was going to get. But that was part of the whole palette that they were going to work with.

One of the things on this project that was a real challenge, this was put on an extremely fast timetable. We were hired by White River State Park in November… The first thing we had to do on that site, there was a steam power plant sitting on that site that had to be torn down. We had to reroute some major high-pressure steam lines. I think they were 36" high pressure steam lines that fed IUPUI and that side of the city, and get that site ready. That was a first effort while we were, one group was doing that while we were programming in Kansas City, and beginning the design, so that we could get a foundation package out to bid that spring. Another thing that was a challenge on this, because portions of the money were public monies, we had to competitively bid the project with public documents. But we were fast-tracking the project. So you didn't know what contractors or who was going to be doing all of the work. But we had to work fast-track, because it was the only way we were going to get this done.

So we had a demolition package work going on immediately while we were programming. We had a foundation package out and the foundation work going in. We didn't, at that point, know the color. But as the design kind of finished itself that spring and through that summer, we had a steel package that went out, that was another package competitively bid so that when the foundations were done, the steel started going up that summer-fall. Because we had to have NCAA moved in that building the summer of 2000. So we had, from the time we started, and literally, by the time we were really underway, we had two years to design, construct and have the client moved in, a little over two years.

There was then a main shell package that was put out for the building shell itself. And then there was a finish-out, like an interior finish-out package. By that point, what we were able to do with that was, we were working with the private monies, so we were able to kind of negotiate more packages and more work at that point, which is what we needed to do to get a lot of that work done.
The point of all that being, is, some of the things you would normally like to do in a design and assessment and evaluation process, wasn't really an option here, because of the timetable and the complexity we were working with.

Now, parallel with all of this, we were working with Seventeen Seventeen developing concepts of the Hall of Champions, the experience of the exhibits, and then they are paralleling that exhibit designs, and how we needed to integrate those things with the building. There were a lot of things going on at the same time. But unfortunately, what suffers in some of that, are some of the longer term issues of life-cycle value and those sorts of things. Clearly there were life-cycle decisions that were passed because of initial budget issues.

Question 7

There is an E-glass in the atrium space itself, the south-facing window area. We looked at that and analyzed that, and felt that again, with the depth that we had there from the balcony back, and where the office spaces themselves would be, and the nature of that space, that sun control would not be a significant issue for us there. In terms of the windows on the north side of the building, because they were all from the office areas, because they were on the north side, that wasn't considered really as much of an issue there. In fact, it kind of gave them a heads up on this. But again, it was one of these, "Well, lets see when we get in there", the east and west end is where sun control is really needed. And there was sun control then added on those ends of the building. the packages. So it is part of a systems furniture. But I think by the time NCAA was done with things, it probably became pretty customized.

They ended up going in with a lot higher partition panels because it was very difficult for them to…while at the executive level, they were really working to try and change that culture and have the open office. They, quite frankly, made a mistake to, then, let their managers and supervisors have a little too much say in all that because they started getting a lot of inconsistencies and that, and some of that started to break down. So they ended up with a lot higher partitions in that area. It was never envisioned to be that high.

Now, as I understand it, they are going back and they are actually lowering it, they are modifying it by lowering those partitions. It was envisioned to be a lower system, more flexible, and as it rolled out, it became a lot more customized in that process, and I think they are kind of living with that right now.

They really use REI as their facility manager to facilitate all of those things for them. As such, they don't really request much of our services, or to my knowledge, any of the other consultants.

Now, on the exhibits, the plan there was always that there would be, with the videos and the interactive aspect of that, that has a pretty short shelf life. They need to keep that current, or they are not going to have somebody that has visited that and experienced that… they are not going to come back unless there are things that are changing and evolving. NCAA has their own staff that runs the Hall of Champions. That they use Seventeen Seventeen or that sort of thing is really driven at their discretion. My impression is that so far, they haven't been doing much of that. I think White River State Park is wanting to see a little more change in some of those things.

In one sense, I guess that fact that we have not had a lot of call backs is a good thing in that the building has not had too many problems with it. On the other side of it, though, we normally, at least in our office, we are use to having probably a little closer on going relationship with clients. We do a lot of K-12 school work and university institutional work. We tend to have longer ongoing relationships. This is more of a one of a kind sort of project. That linkage isn't as strong as what we normally have in our office.

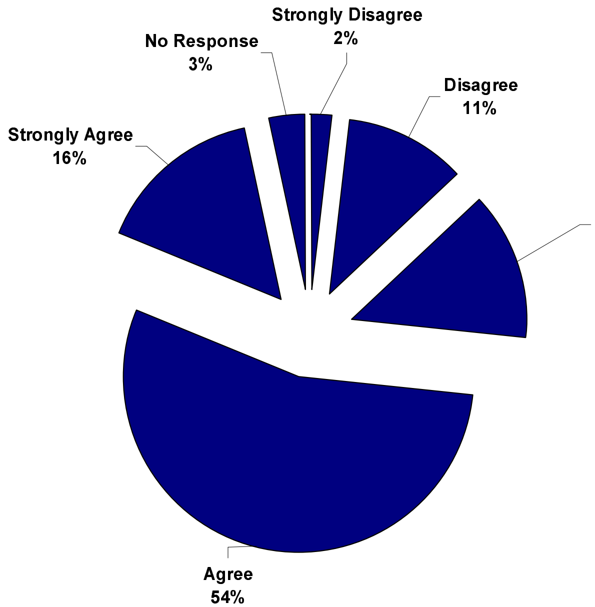
Question 10

I would probably start with Steve Panzirino. I think he is going to be the most accessible.

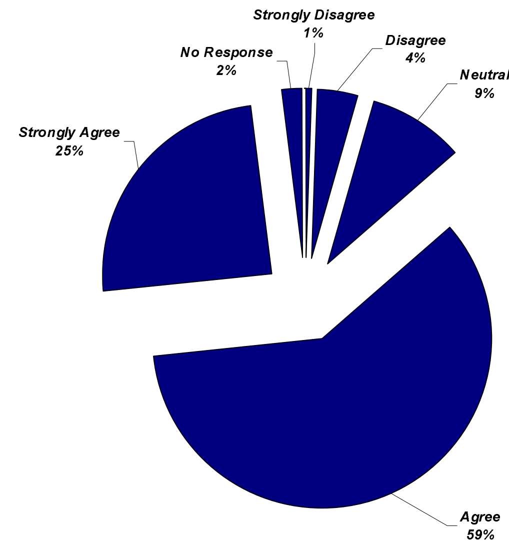
The number and name for Seventeen Seventeen is John Crank, the principle with Seventeen Seventeen. Their phone number is 804-644-1717 and they are out of Richmond, VA.

SURVEY RESULTS

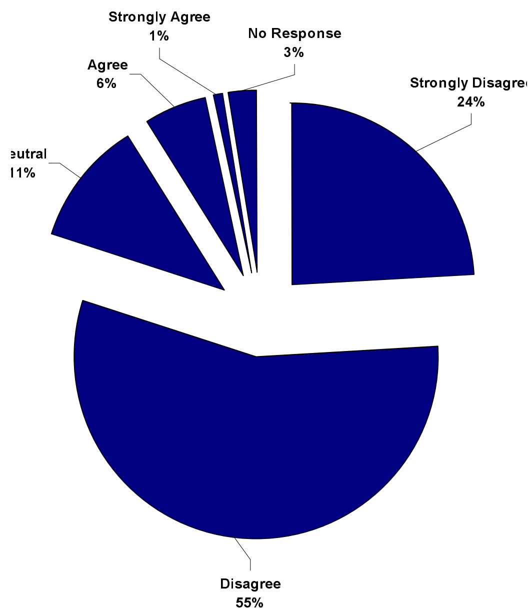
Question 1. There is adequate daylight entering the atrium, with no need for electrical lighting.



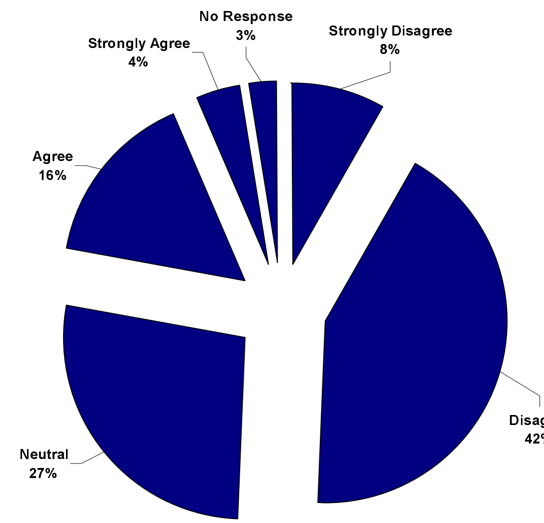
Question 2. The daylight entering the atrium creates a pleasant and comfortable light.



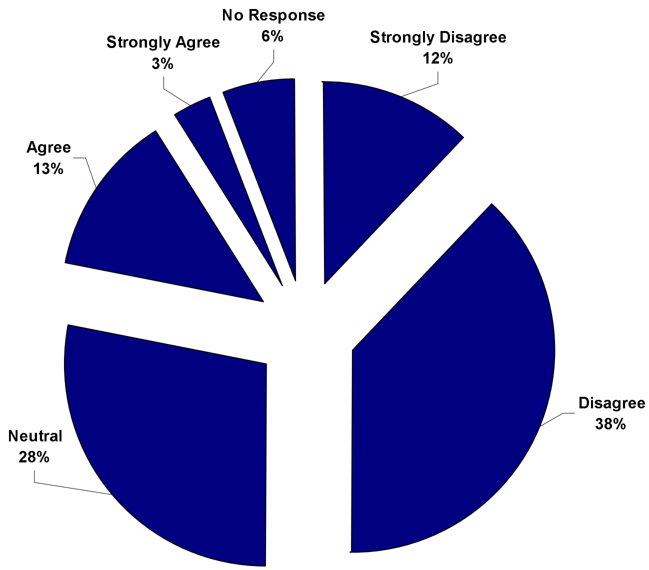
Question 3. The daylight entering the atrium creates discomfort



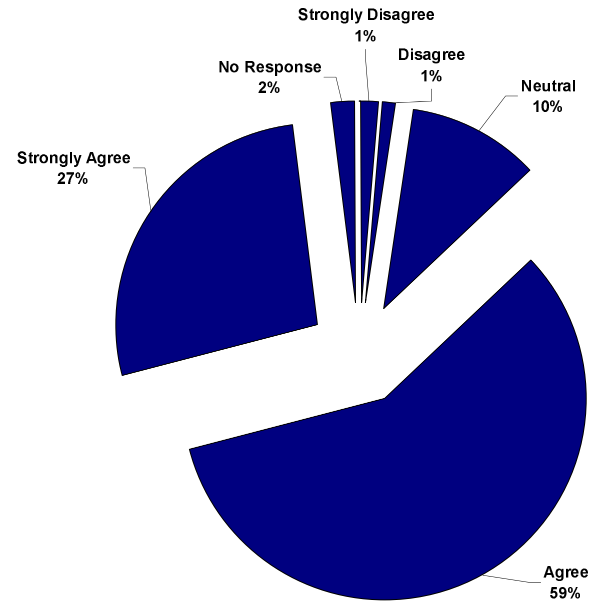
Question 4. The daylight entering the atrium creates a problem with glare.



Question 5. The daylight entering the atrium creates a problem with overheating.



Question 6. The large view from the atrium enhances and compliments the interior space.



Question 7. Direct daylighting is better than electrical lighting for the atrium space.