


"IT'S NOT EASY BEING GREEN": THE AUDUBON HOUSE

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ABSTRACT

In the spirit of its concern and awareness for environmental issues, The National Audubon Society in the cooperation with the Croxton Collaborative, renovated a lower Manhattan eight-story building the building with an intent to create a working example of sustainable architecture. The case study took place within an undergraduate seminar course over the spring semester.

We focused our investigation on the application of the integrated daylight systems. Our hypothesis stated that the lighting system in the Audubon Building does not function as intended because it does not respond to the variable lighting conditions nor to occupant needs and satisfaction. To engage the proposed hypothesis we broke it down into specific questions of investigation: distribution of illumination on a typical office floor, lighting power density, penetration of the daylight into the space, pattern of electrical lighting use, pattern of use for the blinds, energy use and savings, and occupants perception of glare and general lighting conditions.

Overall, we found the integrated lighting system functioned partially as intended. Occupants are pleased with the daylight quality and availability, but the integrated system is not operating at it maximum efficiency because of broken, disconnected, or uncalibrated occupancy and daylight sensors. Also, the spatial layout and lowered partitions of the workstations, sacrificed occupant voice privacy and noise control. Finally, we hope that our investigation rather than being a conclusive final analysis of a built project, becomes the beginning for future inquires that will further develop some of our observations and interpretations of the issues raised by the example of the Audubon Building.

ANALYZE

OBSERVE

WORK AS A TEAM

MEASURE

"It's Not Easy Being Green": The Audubon House

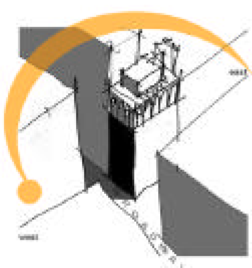


Fig. 1. National Audubon Headquarters Building, 700 Broadway St, NYC

The National Audubon Society, an organization dedicated to the preservation of the environment, maintains its lower Manhattan headquarters in the eight-story Schermerhorn building designed in 1891 by George W. Post. Audubon and the Croxton Collaborative renovated the building with the intent of creating an example of energy efficient and environmentally responsible architecture, while remaining an economically viable proposition for the National Audubon Society. Thus, the Audubon Society was able to preserve valuable resources and a historic landmark.

The renovations focused on four primary environmental goals: 1) energy conservation and efficiency 2) direct and indirect environmental impacts 3) indoor air quality and 4) resource conservation and recycling. (NAS *Factsheet*). The "hook" for our class was the opportunity to compare design intent of one of these goals, the integrated lighting scheme with on-site measurements and observations of the built product. Lighting performance is a topic that we considered to be "doable" within the time constraints of the semester, yet rich enough to yield interesting investigations that our class could easily "divide and conquer." For example, energy use by electric lighting could be fairly easily quantified by estimation of energy bills or measuring the current directly. A study of daylight contribution and its effects on the electric lights under different sky conditions (overcast vs. sunny) might require a study of conditions during several visits.

Our primary objectives in this investigation are: a) the opportunity to look at a nearby building that seems to have clear design intentions of energy efficiency, resource conservation, and occupant well-being, b) to measure the physical performance, energy use and survey occupant response, and c) to compare design intent to the built artifact.

Hypothesis

The lighting system in the Audubon Building does not function as intended because it does not respond to the variable lighting conditions nor to occupant needs and satisfaction. We then proposed specific questions to investigate in order to gather information for our hypothesis:

- What is the distribution of illumination on a typical office floor?
- What is the lighting power density in the space, and how does it compare to the standard for offices?
- How far does daylight penetrate into the space?
- What is the pattern of electrical lighting use at the perimeter zone vs. the interior zone? What is pattern of use for typical task lighting?
- What is the pattern of use for the blinds?
- Do the occupants perceive glare at their workspace?
- How much energy is saved by dimming the lights?
- How much energy does the lighting use?
- What are the occupants' perceptions of the workspace?

Methods and Equipment

As a class, we made the decision to focus on lighting after a preliminary visit to the Audubon building on February 4th and 5th when we gathered preliminary measurements and general impressions of the space. After generating a hypothesis we broke into sub-teams to tackle the different questions and returned on the 25th - 27th of February to take final measurements for the study. We selected the 6th floor as the location for most of our measurements because of accessibility and least disturbance to the Audubon work activities. Like other floors, we could compare lighting between 3 zones: perimeter daylit zone, middle, and the enclosed offices. The variable weather created an opportunity to witness the performance of the integrated lighting scheme during both overcast and sunny conditions.

General Illumination - *What is the distribution of illumination on a typical office floor?*

1. The team created a grid with a six-foot interval based on the existing eighteen-foot column grid, then measured at a "standard" height (top of partitions, approximately 5'-0") for light meter measurements. At that height, we felt that we could adequately measure daylight, yet the electric lighting would not excessively influence our measurements.
2. We gathered illuminance measurements in footcandles with a handheld OSRAM Sylvania light meter.
4. Illuminance measurements became the basis for an isolux contour of the space.

Fig. 2. OSRAM Sylvania light meter

Lighting Power Density - *What is the lighting power density in the space, and how does it compare to the standard for offices?*

1. We counted, classified, and recorded each luminaire and the wattage on the sixth floor in each zone classification: 1) perimeter window areas 2) interior "middle" offices, and 3) enclosed offices and utility spaces.
2. By adding up the total luminaire wattage used in all zones and dividing it by the square footage, the team was able to estimate the lighting power density used on a typical floor.

Daylight – *How far does daylight penetrate into the space?*

1. Using the previously determined grid and measurement height, we took daylight measurements at 10:30 AM on the unoccupied day (Saturday) when we could turn off all the lights on the floor.
2. Members of the class photographed lighting conditions with 35mm and digital cameras.

Task Lights - *What is the pattern of electrical lighting use at the perimeter zone vs. the interior zone? What is the pattern of use for typical task lighting?*

1. The team selected five task surfaces illuminated by daylight along the perimeter window areas.
2. Using a 12" grid overlaid onto the desk surfaces, we took illuminance readings using OSRAM Sylvania light meters with the following conditions: a) daylight + ambient lighting + task lighting; b) daylight + ambient lighting; c) daylight only.
3. We also installed Hobo On-Off Status dataloggers beneath the task lights of selected desk surfaces to record pattern of use.

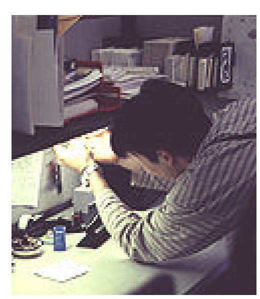


Fig. 3. Hobo placed under a task light

Blinds - *What is the pattern of use for the blinds?*

1. We photographed the interior of the south façade at 10:00am and again at 1:00pm to determine any changes in the position of the blinds. Keeping the camera settings constant, the team attempted to visually record sunlight penetration, illumination, glare conditions, and use of blinds in response to the changing position of the sun.
2. We also installed Hobo Light dataloggers to monitor sunlight along the edge of several windowsills at the south façade of the building.

Fig. 4. Hobo Light

Glare – *Are there conditions of glare in the workspace?*

1. We took photographs and composed a panoramic view of the interior. We then enhanced the panoramic view through Adobe PhotoShop (a technique that we could use in the computer lab) to show the contrast of lighting conditions along the perimeter window areas.
2. In addition, a member of the team created a free hand sketch of the space, replicating the panoramic view where luminance readings on each surface were taken with a Minolta LS-100 luminance meter, and recorded on the accompanying sketches.
3. From the measurements, we calculated the brightness ratio and compared them to the recommended guidelines from IES (Stein and Reynolds).

Fig. 5. Minolta LS-100 luminance meter

Savings by Dimming/Occupancy Sensors - *How much energy is saved by dimming of the lights?*

1. We placed Hobo Light dataloggers under the lights along the perimeter zone, since these are presumably calibrated to dim with the daylight. In a pretest of the equipment, we discovered that if the Hobos were placed too close to the light source, “noisy” data appeared that made it impossible to distinguish lighting variations. After testing various distances between the light and the datalogger, we determined that 5 inches was most appropriate distance.
2. Hobo Lights were launched for a period of 18 days, hung in masking tape “slings,” and suspended five inches below the fixtures (Fig. 6).
3. The data, exported to Excel, became the basis for a graphic analysis.

Fig. 6. Hobo “sling”

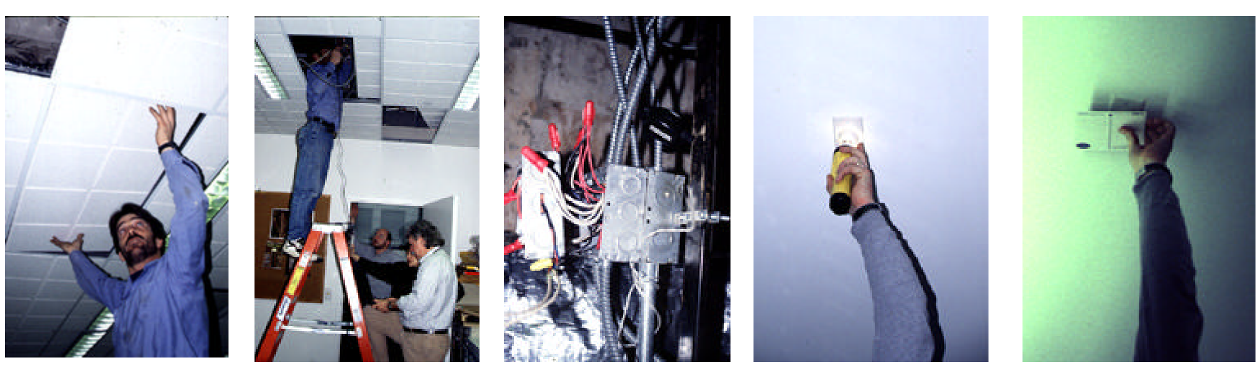


Fig. 7. Placement of clamp-on amprobe on a lighting circuit and testing of the daylight sensor

Energy Use - *How much energy does the lighting use?*

1. With the assistance of building service supervisors, Jim Feaster and Tom Schoch, the group installed ACR amprobe dataloggers on the 4th floor perimeter light circuit to monitor the actual connected loads.
2. By connecting the datalogger to a laptop computer, it was possible to see the actual amperage use in real time. To confirm that the correct circuit was being measured, we pointed a flashlight at the daylight sensor to force the lights to dim and covered the sensor to ramp the lights up to their full connected load.
3. An ACR datalogger was left for a two-week period in order to see a week and weekend pattern of use. We later retrieved the datalogger, downloaded the data and exported the file into Excel.

Fig. 8. ACR clamp-on amprobe

Occupant Response - *What are the occupant perceptions of the workspace?*

1. Each of the sub-teams of the class generated a set of questions for the survey.
2. These survey questions were combined and adapted from two other previously developed surveys. The first, *Environmental Quality in Offices*, provided a general model for sections on air quality, noise, privacy, and spatial comfort. The second, Classroom Thermal Comfort Survey (Kwok), provided a model for layout and the "Personal Comfort" section of the survey.
3. The in-house mail system distributed the Audubon House Environmental Quality Survey to all Audubon House employees on the 4th through 8th floors, and were returned the same way and placed in an envelope which we picked up later.

Data & Analysis

General Illumination

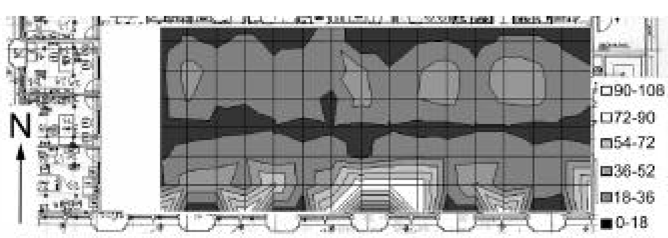


Fig.9. General illumination (overcast day)

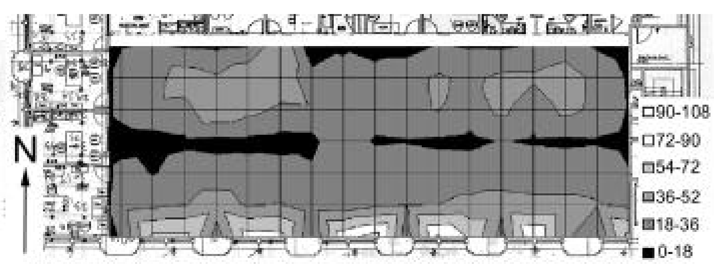


Fig.10. General illumination (clear day)

Through analysis of our isolux drawings (Figs. 9 and 10) we found unevenly distributed illumination on the 6th floor and light levels varied widely. The perimeter window zone was brighter than the interior offices as expected, because of daylight through the tall windows, with light level readings measured in the range of 20 to 150 footcandles (adjacent to window). Illumination in the interior zones varied 10 to 50 footcandles, which was largely dependent on the placement of the overhead of the fluorescent fixtures.

The isolux drawings show the differences in light levels between the perimeter window and interior office zones, one lit primarily by daylight and the other through electric lighting. The dark band, which runs between the two spaces, shows where daylight ceased to illuminate the workspace (circulation path between office stations) and electric lighting became necessary. In a later section that discusses daylight measurements, we found that daylight did not penetrate into the interior office area as much as we had expected.

Lighting Power Density

According to *Audubon House*, the objective was to achieve 0.97 watts per square foot, less than half of what a code compliant New York City building typically uses (NAS, *Factsheet*). Our calculations for the 6th floor:

5,049 watts divided by 6,200 square feet = 0.82 watts per square foot

The figure was the result of the total illumination from the ambient lighting and supplemental task lighting. The calculation was based on office area and did not include service and bathroom spaces.

Daylight

"The Audubon Team took full advantage of the natural light by devising an open floor plan that matches the south and west orientation of the building exterior, thus 'daylighting' the building -- allowing the maximum penetration of daylight throughout the space. This was to be in essence an “office without walls.” (NAS, *Audubon House* p. 73). By integrating the use of daylight with other lighting energy reduction strategies, the Audubon House projected a 75% decrease in lighting electricity. (NAS, p. 71).

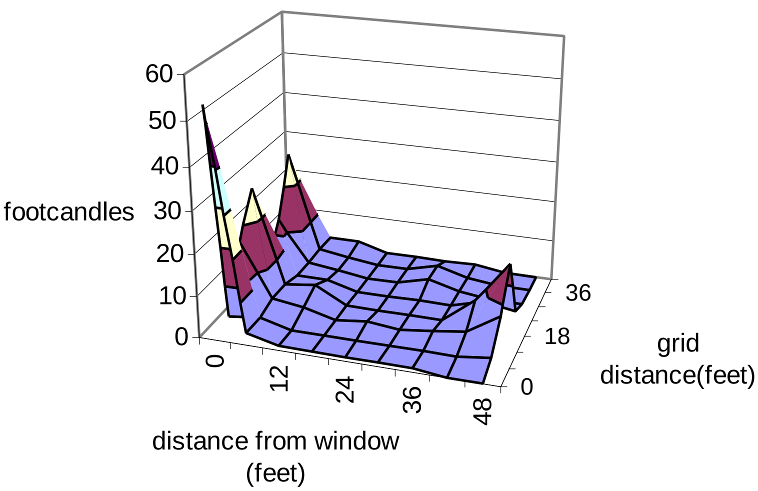


Fig. 11. Daylight contours from perimeter zone

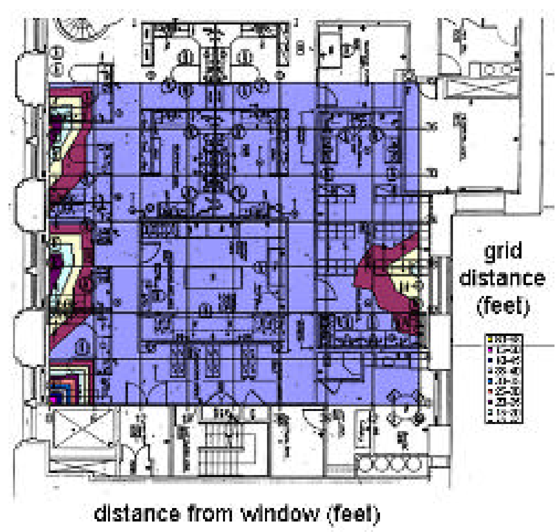


Fig. 12. Isolux plan drawing

Our measurements during an unoccupied day where we could turn off all of the electric lighting revealed that daylight penetration was minimal. For example, light levels dropped from 54 foot-candles at the window to three foot-candles just six feet from the window. We could see from the isolux drawing (Fig. 12), that the geometry of the office furnishings appeared to hinder the penetration of daylight from the window, but only by approximately two feet.

During this time of year (winter) when we took these measurements, we expected the lower winter sun angles to maximize the penetration of daylight. However, the combination of window geometry on the 6th floor and the surrounding buildings, prevented maximum daylight penetration. On the other hand, the occupants overwhelmingly agreed that daylight enhanced their workplace (discussed in later) demonstrating that while the light readings were low in the interior zone, daylight and the visual connection to the daylight through the windows over the office partitions has a positive psychological impact.

Glare

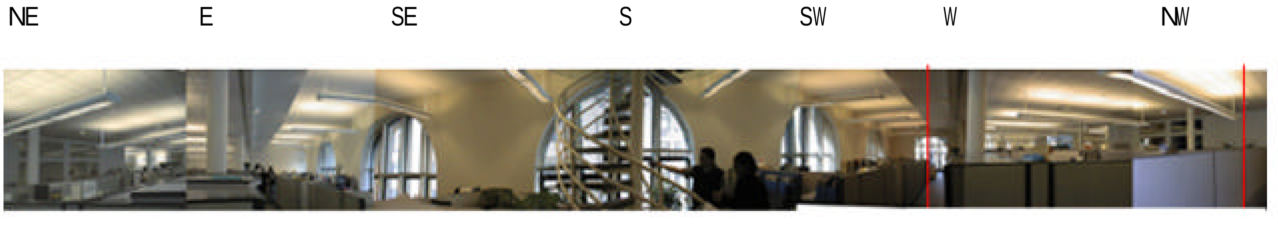


Fig. 13. Panoramic photograph of the 6th floor taken on a sunny day

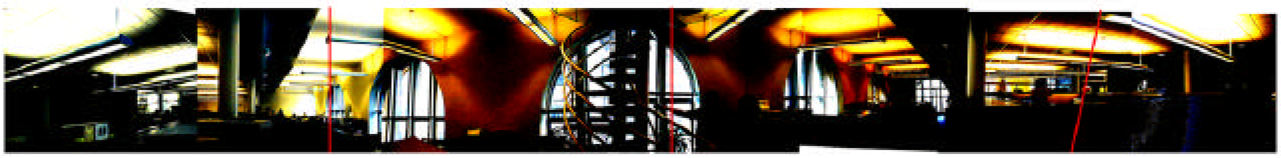


Fig. 14. Same image applied in PhotoShop in order to enhance contrast

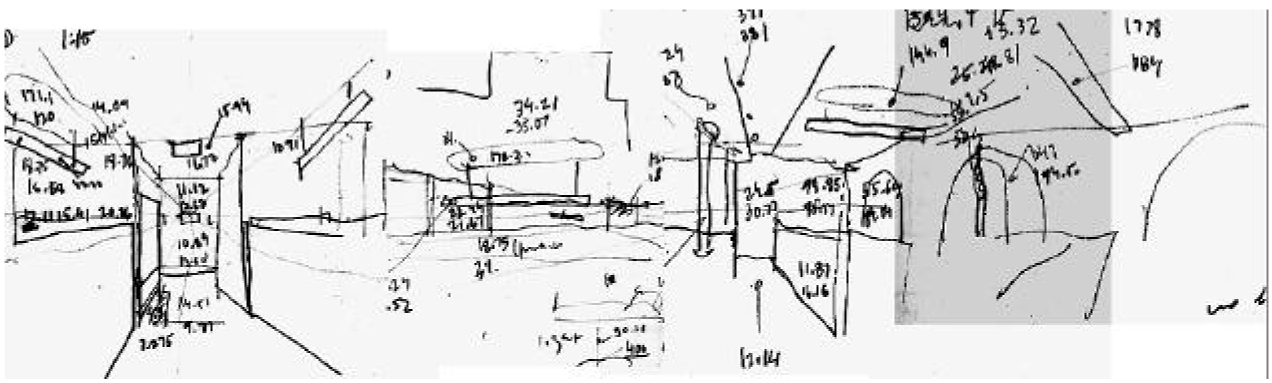


Fig. 15. Panoramic sketch of the same space with overlay of luminance readings

Both quantitative and qualitative observations suggested potential glare conditions. The composed panoramic views (Figs. 13 and 14) indicate where these conditions appeared to occurr. We took several adjacent areas of high contrast shown in the photographs and used the luminance measurements to calculate brightness ratios, then comparing the data to the IES recommended **maximum luminance ratios** (Stein and Reynolds, p.958). At the perimeter zone, the difference between the visual field at the computer (18 cd/m^2) and the adjacent window field (347 cd/m^2) was a ratio of approximately 1:20. But the recommended maximum luminance ratio to achieve a comfortable balance between task and adjacent surroundings is 1:1/3, greatly exceeding the acceptable brightness ratio. We also noticed dark banding on the ceiling between the fixtures. Our readings showed a ratio of approximately 9:1, whereas the recommendation suggests 20:1. Despite the recommended values, we felt it the banding was distracting.

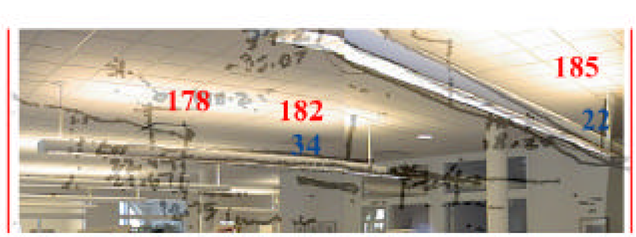
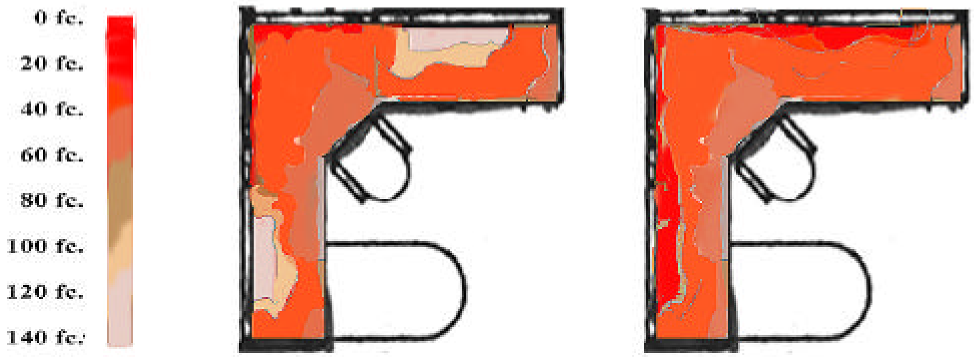


Fig. 16. Ceiling reflection of the ambient luminaires

Fig. 17. Perimeter window zone

Task Lighting Conditions and Patterns of Use



Task light: ON Task light: OFF

Fig. 18. Pattern of illumination from task lights

Lighting Conditions Provided by Task Lights

The development of the isolux drawing led to two key observations. The suggested illumination for a task surface is 50 fc (Stein and Reynolds p. 958). The isolux readings illustrate an inadequate illumination on the working surface when the task lights are off. However, when task lights are on, their extreme intensity on the task surface creates luminance ratios exceeding the recommended **maximum luminance ratios** (Stein and Reynolds p. 958), causing undesirable contrast.

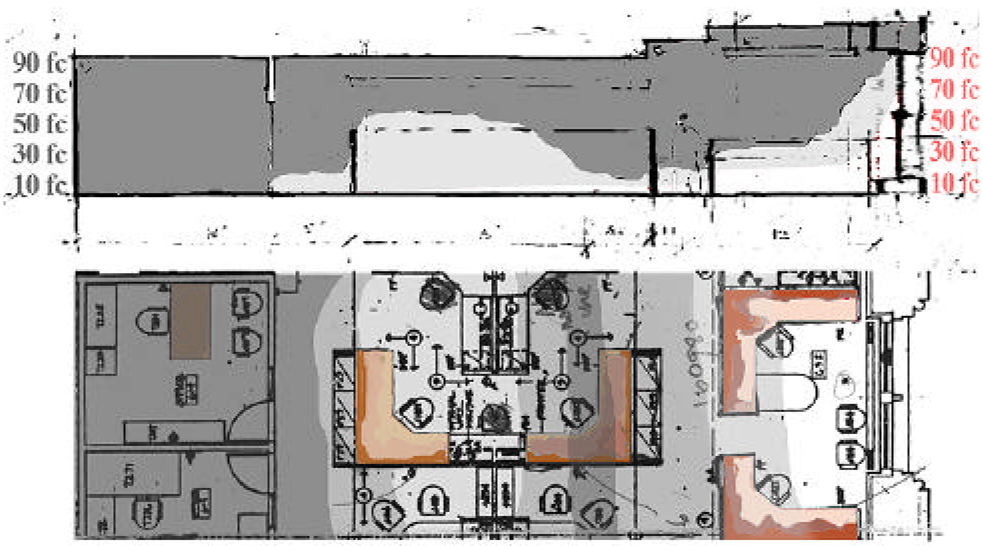
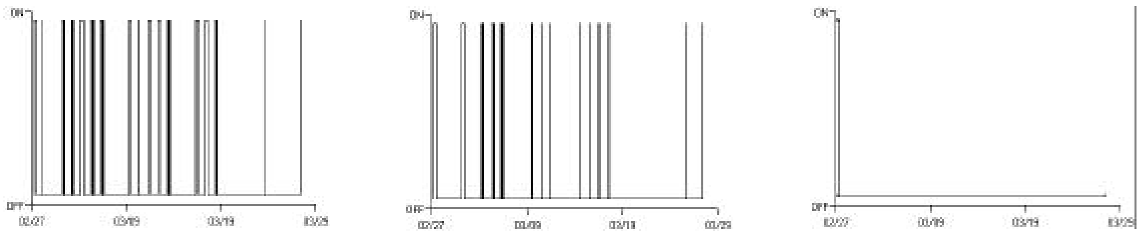


Fig. 19. Illumination of task surface in perimeter, interior and enclosed office zones (with overlay of office ambient lighting)

Daylight penetration diminished markedly between the perimeter office spaces and the interior office core. The readings of daylight dispersion and Hobo on-off graphs of task light usage illustrate the correlation between daylight illumination and the pattern of use of tasklights (Fig.19). The perimeter zone received adequate daylight and consequently task lights were not used. The frequent use of task lights in the middle and enclosed zones demonstrated the inadequate amount of daylight in their workspaces. (Fig. 20). It's interesting to note that use pattern shows that the occupants turned them off when not in use.



enclosed office space　　middle office space　　perimeter-daylit space

Fig. 20. Pattern of use for task lights showing on-off conditions

Daylight Controls:
Occupancy and Daylight Sensors

In our quest to find the savings by dimming, we found many surprises. From the "hobo slings" placed at the perimeter window zone (where we knew dimming should occur), we found lighting circuits that worked with the occupancy sensors and also circuits that remained on constantly during non-office hours. Most significantly, we found that none of the lighting circuits in the perimeter zone of the 6th floor actually dimmed, leading us to wonder if the only-installed daylight sensor was calibrated.

The perimeter zone graph (Fig. 21) shows two sets of readings, one circuit which appears to be connected to an occupancy sensor, where patterns of weekly and weekend use are evident and the other circuit constantly "ON" through the weekends.

Although not accurate as a light meter, the Hobo Light is useful to show on-off patterns and any gradual decay in the light readings would indicate a dimming function. The graphs show a constant lighting level with no variation. However, to be sure we examined the connected load from the ACR data and found the amperage used did not vary at all (Fig. 22).

When we used a flashlight against the daylight sensor, the Hobo measurements showed gradual decay of light levels, characteristic of a working daylight sensor. This led us to believe that daylight sensors are not properly tuned or adjusted.

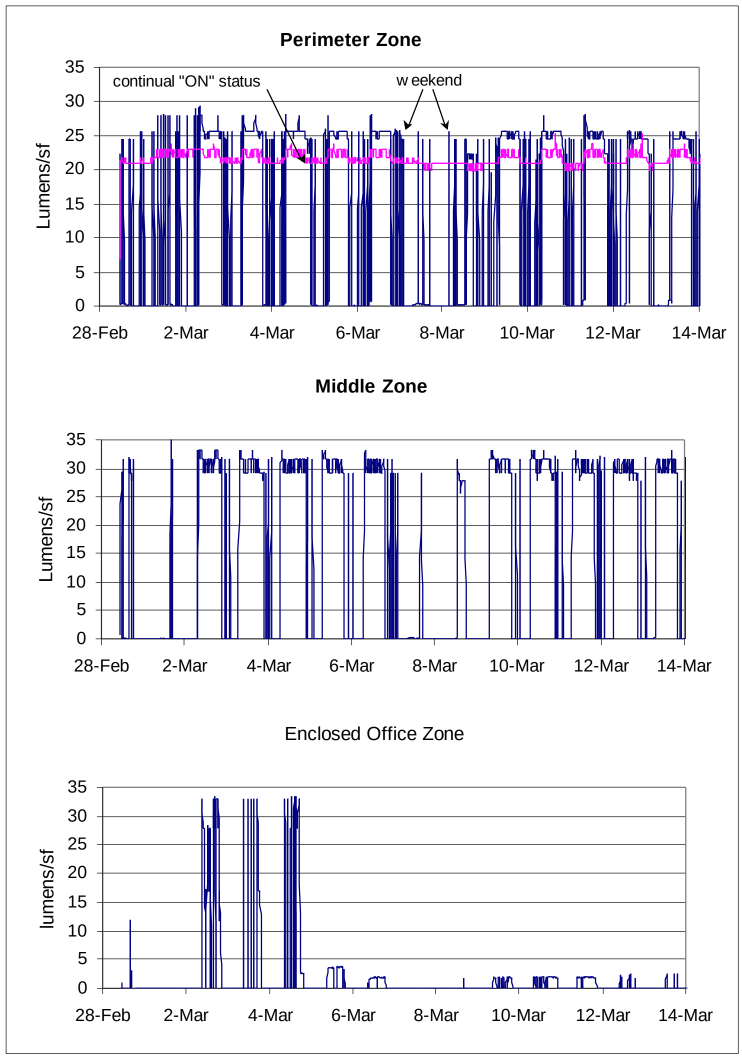


Figure 21. Lighting use pattern for perimeter, interior and enclosed office spaces. Note the weekly use pattern of lights. More significantly, note that that there is no "decay" of ambient light which would indicate dimming occurred.

Wasted Energy: Back-of-the-Envelope Calculation

We did a quick calculation to determine the cost of having the lights running constantly at the 6th floor perimeter zone because of occupancy sensors that were not connected, broken, or not calibrated:

> 6 fixtures in the bank with 2 lamps each @ 32w each = 384w
>
> "ON" hours assumption: 14 hours each day, 5 days/week, plus 48 hours (weekends), 50 weeks/year plus 336 hours of vacation times. This totals 6236 hours that the lights are unnecessarily on, 2400 wasted kw hours/year.
>
> 2400kw hours * $0.117/kw hour = **$280/year** wasted

Since we also found other areas on the 6th floor where the occupancy sensors were not functioning properly, we can assume that the total wasted energy is even greater. (Note: these calculations were based on reading lamp labels and do not include a ballast factor).

Energy Savings by Occupancy Sensors

We found enclosed offices with working occupancy sensors and those that didn't work. Following are the comparative calculations for the energy consumption of lights for both scenarios:

Non-Working Occupancy Sensor Energy Consumption:
3 fixtures with 3 lamps each = 9 lamps @ 32w = 288w
24 hrs/day x 365 days/year = 8760 hrs/yr
8760 hrs * 288w = 2512 kwhrs/year * $0.117/kwhr = ~$300/year
If 20 enclosed offices have non-functioning occupancy sensors = **$6000/year**

Working Occupancy Sensor Energy Consumption:
3 fixtures with 3 lamps each = 9 lamps @ 32w = 288w
Lights are on approx. 4 hrs/day, 5 days/week, 50 weeks/yr = 1000hrs/yr
1000hrs/yr * 288w = 288 kwhrs/yr * $0.117/kwhr = $35/year
Multiplied by the same 20 offices, that is **$700/year**, ***saving*** **$5300!**

Energy Savings by Dimming

Data from the ACR clamp-on amprobe gave us a more accurate idea of how much energy was used by the perimeter lights and also confirmed our previous findings (6th floor). The lights did not dim at the perimeter with the variable daylight conditions and they stayed on during the evenings and weekends (Fig. 22). We calculated that the lights were running at *72% of their maximum (something was going on here)*, by measuring the minimum and maximum connected load using the flashlight and covering the daylight sensor while reading the real time loads on the laptop. However, the daylight conditions were particularly sunny and we hypothesized that the lighting could run at 30% of their maximum (when we did this the Audubon staff exclaimed "do that again, we like it!"). Our calculations show this would save $126/year for this zone of lights on the 4th floor. (calculations in Appendix C).

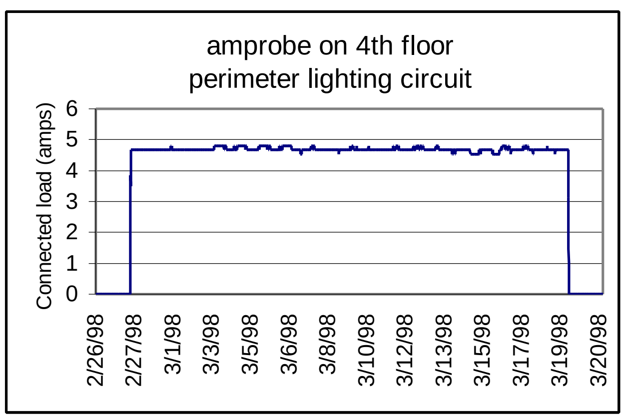


Fig. 22. ACR clamp-on ambrope connected to a perimeter window zone lighting circuit.

Blinds
During our first building visit, we learned from the building manager that people along the perimeter window zone closed the blinds in order to use the electric lights. How often did people change the blind position? How did the various positions of the blinds change the daylight in the space? We took photographs at 10:00 AM and 1:00 PM, but they revealed no difference in the blind configuration or operation despite the obvious visual differences in light quality and variability. We suspect operation of blinds might occur on other floors more frequently because of specific tasks.

We recorded the status of the blinds (Fig. 23) people did not adjust the blinds at all during our test period. We found a number of inoperable blinds and others were difficult to open or were missing adjustment rods. Qualitatively, the amount of light coming through the perforated blinds appeared to reduce contrast between the window and adjacent wall and provide the visual connection to the outside through the large windows.

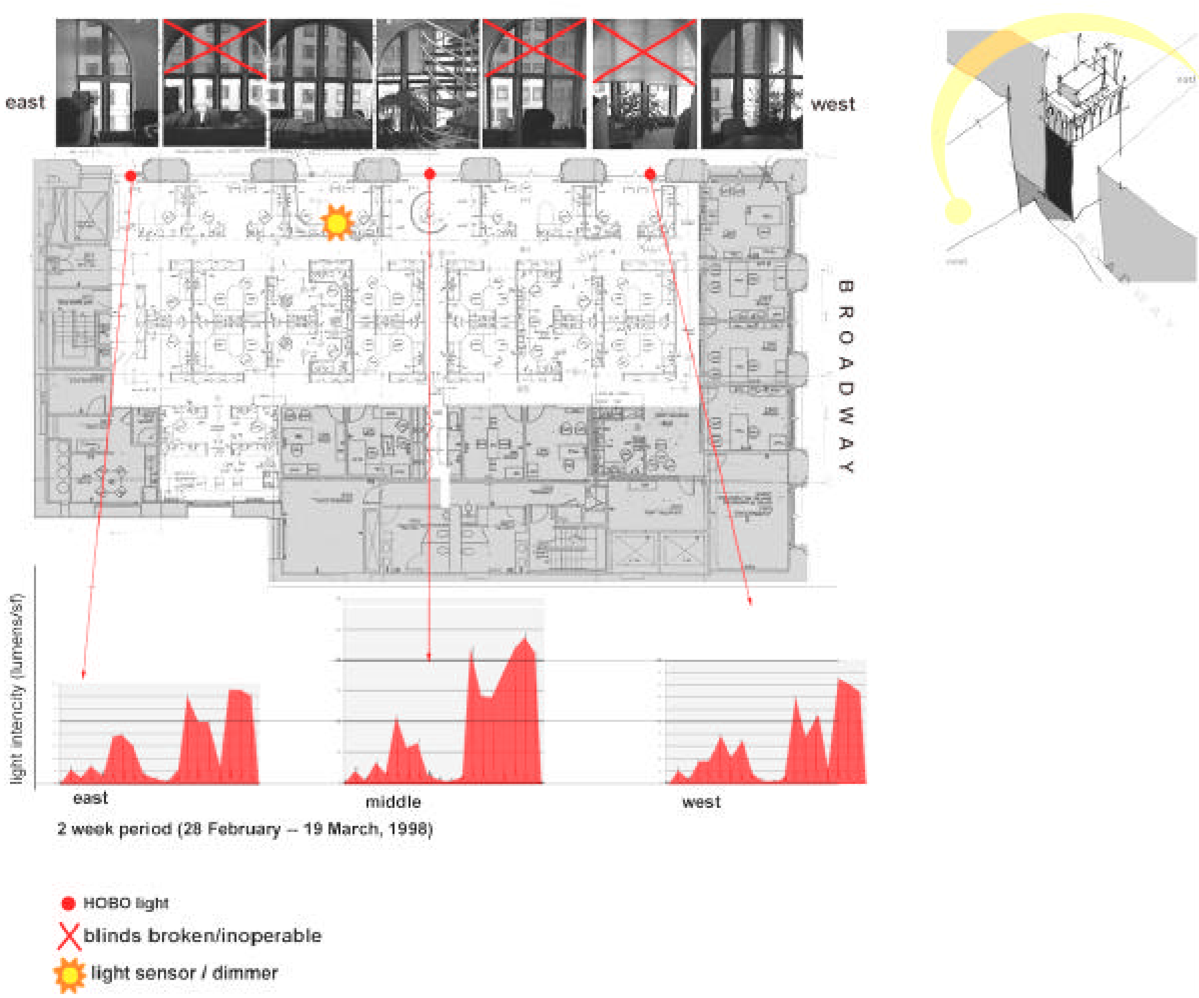


Fig. 23. Distribution of sunlight over the perimeter space, conditions of blinds, and penetration of daylight into the office space.

The data revealed uneven distribution of sunlight on the south façade throughout the daytime due to the proximity of adjacent tall buildings at the intersection of West 4th Street and Broadway. (Fig. 23) This data was also confirmed through the analysis of the general illumination of the 6th floor. (see Figs. 9 and 10)

Occupant Survey

Of 150 workers, 66 (44%) returned completed surveys. On a scale of 1 to 5 (5 = outstanding), the Audubon workers rated the *overall lighting* in the office at an average of 4, regardless of whether they were seated near the window or toward the interior of the space (Fig. 24). However, Audubon workers sitting along the perimeter window zone rated the *quality of daylight* at their workspaces more favorably than those seated in the middle or enclosed zones (Fig. 25). On other qualities of light such as *color* and *enhancement of daylight to the workspace*, office workers responded with better than average ratings, regardless of seating location. (see Appendix D for additional analysis).

It's also interesting to note that despite glare conditions found along the perimeter zone, that people rated both the overall lighting and the quality of light in the workspace favorably.

Almost all workers responded that they have not brought in additional light fixtures to enhance lighting conditions at their workstations, and generally do not adjust the blinds in their work area. In addition, most people regardless of location believed that there were not dimming controls in their work (or were not aware of any), but did report the presence of occupancy sensors. Occupants in the enclosed offices reported, on average, not to perceive as much contrasting conditions (glare), while people in the enclosed offices and perimeter zone reported slightly higher incidents of glare conditions (Fig. 26). This corroborated our luminance measurements discussed in a previous section.

The primary concern of Audubon workers was privacy and control of noise in the office area. The results from these sections of the questionnaire were overwhelmingly negative. Low partitions were usually cited in the survey as the cause of discomfort in these areas. Office partitions, especially along the perimeter zone of the office, were kept low in order to maximize the depth of daylight entering the office space. Thus, the lighting seems to be generally acceptable, but privacy has become a major concern. Even those workers in enclosed office spaces expressed moderate dissatisfaction with privacy, presumably because their offices are made of transparent glass, again designed to allow maximum light into the office core. The survey suggests that lighting is actually acceptable at the expense of privacy.

TABLE 1: Demographics	n	%
Sample size*	66	100
Gender		
males	44	67
females	22	33
Office location		
perimeter	35	53
Interior, middle	18	27
enclosed	13	20
Years of employment	2.3	---

*population = 150

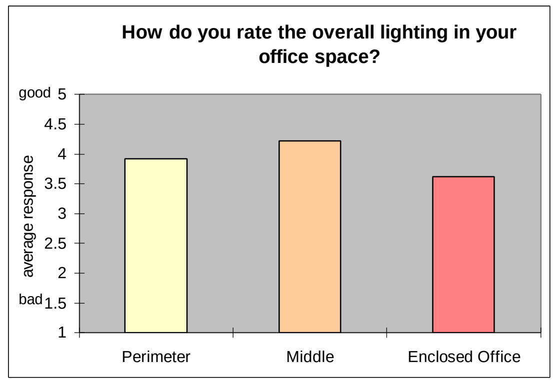


Fig. 24. Response to overall lighting

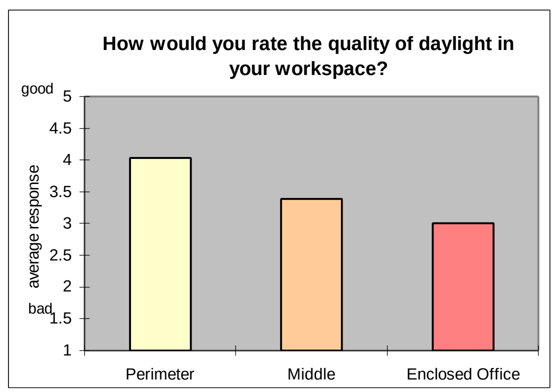


Fig. 25. Response to quality of daylight

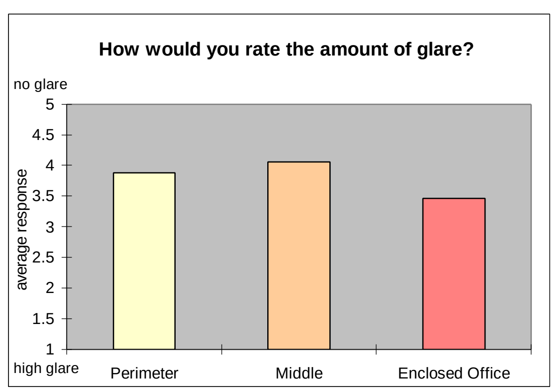


Fig. 26. Response to glare

Conclusions - Overall, we found the integrated lighting system functions partially as intended. Occupants are pleased with the daylight quality and availability, but the system is not operating at its maximum efficiency because of broken, disconnected, or un-calibrated occupancy and daylight sensors. Our conclusions from the inquiry questions were:

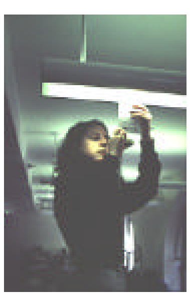
1. The illumination distribution on the 6th floor was fairly even within the middle zone, but varied widely in the perimeter zone, with the greatest variability and distribution of light nearest the window.
2. The lighting power density of 0.82 watts/sq. ft. met the design goal of 0.97 watts/sq. ft. and did better than the *ASHRAE 90.1* recommends.
3. The workstations adjacent to the windows revealed two completely different lighting situations within five feet of each other. The workstation design and placement does not allow the sunlight distribution or the light to further penetrate the space. However, the value lies in its positive psychological connection to the outside. Although the open office layout does not meet the expectations of the architect's design, it increases the visual quality of the office according to the occupant survey results.
4. One daylight sensor located in the perimeter zone does not adequately control the variable lighting conditions as the sun moves from the eastern to the western portions of the floor plan. It seems that installation of at least two more daylight sensors in this zone would allow the electric lighting respond to the lighting conditions of the entire floor.
5. The individuals at their workstations turned off task lights when not in use, thereby saving a certain amount of lighting energy.
6. Brightness ratios were generally within the recommended values, except in some areas of the perimeter window zone, resulting from areas of high contrast between the visible field adjacent and the task.
7. Non-functional occupancy and daylight sensors, significantly reduced performance of the integrated lighting system in terms of energy savings (potentially $5000/year).
8. Although the occupants are generally unaware of the effort to increase daylighting in the Audubon building by lowering office partitions, their visual and voice privacy were sacrificed by this design.

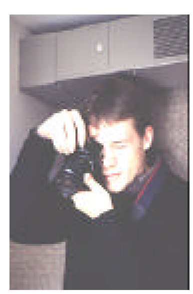
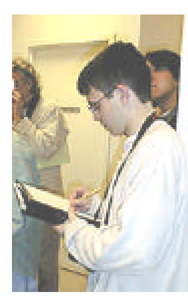
Design Lessons Learned

- When a building is completed it is critical to periodically evaluate how all systems work to insure maximum performance. An initial *post-installation check* (commissioning) and *regularly testing* of equipment could significantly improve lighting system performance
- Building green and living green present different challenges. When considering lighting design in an office environment, the lighting system must have *flexibility* to satisfy individual preferences and control, yet produce energy efficient and good lighting quality for a variety of tasks, though occupants may not see this as a cause and effect relationship.

Future Studies:

Given more time for this study, we might look at the reduction of thermal loads by the integrated system, tune and calibrate the daylight sensors and compare savings, try to match indoor illuminance to exterior illuminance over time (seasonal), use a different technique to record blind positions to examine if people change the blinds seasonally rather than for light quality, and/or modify the spatial arrangement of the office furniture.

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Appendix B

Date:_______________

Time:_______________

AUDUBON HOUSE ENVIRONMENTAL QUALITY SURVEY

This survey in intended to allow us to gain an understanding of your overall experience working in the Audubon building with regard to specific environmental conditions.

PART 1. PERSONAL COMFORT

1. Please mark with an (X) on the scale below how you feel at this moment.

♦---------------●---------------♦---------------●---------------♦---------------●---------------♦

-3	-2	- 1	0	1	2	3
cold	cool	slightly cool	neutral	slightly warm	warm	hot

2. Are the thermal conditions in this building acceptable to you right now?

   1☐ acceptable
   2☐ not acceptable

3. Right now I would prefer to be:
   1☐ cooler
   2☐ no change
   3☐ warmer

PART 2. LIGHTING

4. Please rate the quality of daylight in your work space.

1	2	3	4	5
bad				good

5. How would you rate the overall lighting in your office space?

1	2	3	4	5
bad				good

6. How would you rate the color of the light?

1	2	3	4	5
unpleasant				pleasant

7. How would you rate the amount of glare?

1	2	3	4	5
high glare				no glare

8. In your opinion, does daylight enhance your work space?
   1☐ YES
   2☐ NO

9. Have you brought in additional light fixtures?
   1☐ YES
   2☐ NO

10. Do you adjust the blinds :

1	2	3	4	5
frequently				never

11. If you do adjust the blinds, why?
   1☐ reduce glare
   2☐ reduce overall light level
   3☐ other (please explain)

12. Are you seated near an occupancy sensor?
   1☐ YES
   2☐ NO

13. If YES, do they work?
   1☐ YES
   2☐ NO
   3☐ UNCERTAIN

14. Are there dimmers for the light in your area?
   1☐ YES
   2☐ NO

15. If yes, please rate the effectiveness of the dimmers.

1	2	3	4	5
bad				excellent

16. Have you ever opened a window in your workspace?
   1☐ YES
   2☐ NO

PART 3. AIR QUALITY

17. How do you rate the general air freshness?

1	2	3	4	5
stale				fresh

18. Ventilation

1	2	3	4	5
bad				good

PART 4. NOISE

Please rate noise:

19. From the lights.

1	2	3	4	5
disturbing				comfortable

20. From the air system:

1	2	3	4	5
disturbing				comfortable

21. From outside the building:

1	2	3	4	5
disturbing				comfortable

22. From the office area:

1	2	3	4	5
disturbing				comfortable

23. From office occupants:

1	2	3	4	5
disturbing				comfortable

PART 5. PRIVACY

Please rate your :

24. Voice privacy:

1	2	3	4	5
bad				excellent

25. telephone privacy

1	2	3	4	5
bad				excellent

26. visual privacy

1	2	3	4	5
bad				excellent

27. Is privacy a concern for you?

1☐ YES
2☐ NO

If yes, please explain.

PART 6. SPATIAL COMFORT

28. How would you evaluate the amount of space in your work area?

1	2	3	4	5
bad				good

29. Furniture arrangement

1	2	3	4	5
bad				good

30. Furniture comfort

1	2	3	4	5
bad				good

31. Do the partitions affect lighting levels at your workstation?
    1☐ YES
    2☐ NO

If yes, please explain.

32. Do you find the height appropriate?
    1☐ YES
    2☐ NO

If yes, please explain.

PART 7. DEMOGRAPHICS

33. Gender:
    1☐ female
    2☐ male

34. How long have you worked in this office building?
    _________ years _________months

35. Do you sit :
    1☐ on the perimeter
    2☐ in the middle
    3☐ in an enclosed office

36. On what floor are you located? _____________

37. Approximately how far do you sit from the nearest window? _____________ ft.

PART 8. OVERALL PERSONAL SATISFACTION

38. What would make you more comfortable in this building?

____

____

____

39. Is there anything else that you would like to say about the environmental conditions in this office building that has not been covered in this survey?

____

____

____

Thank you for your time.

(OPTIONAL)

Name:______________________________ email:_________________________

Appendix C

Energy Savings by Calibrating the Daylight Sensors for Proper Dimming

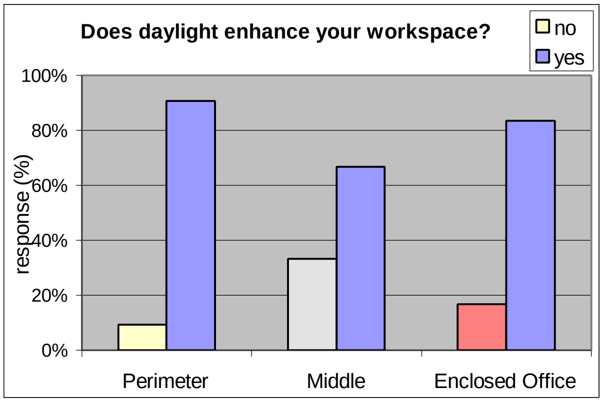
We found the connected load extremes (1.1 amps and 4.81 amps) by shining a flashlight onto the daylight sensor and also covering it. We approximated and calculated the energy savings of the daylight sensors for one year. If the daylight sensors were calibrated more precisely, the Audubon Building would save more energy. Currently, the daylight sensors are contributing little to the energy savings. We also noted that the use of one sensor to control the lights for the entire floor might be inadequate. From preliminary numbers generated during the first building visit we made the following calculations.

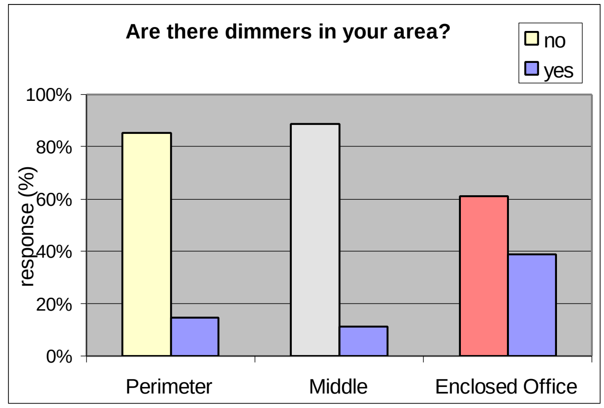
12 fixtures in this zone on this circuit with 2 lamps each @ 32 watts = 768 w undimmed (connected load)
768w x 1.05 (approx. for ballasts) = 806.4w/120v (with no dimming on maximum) = 6.72 amps
4.81amps/6.72amps = .71577 ~72%
On this day, the lamps in this zone were running at 72% of their maximum, due to the dimmers.

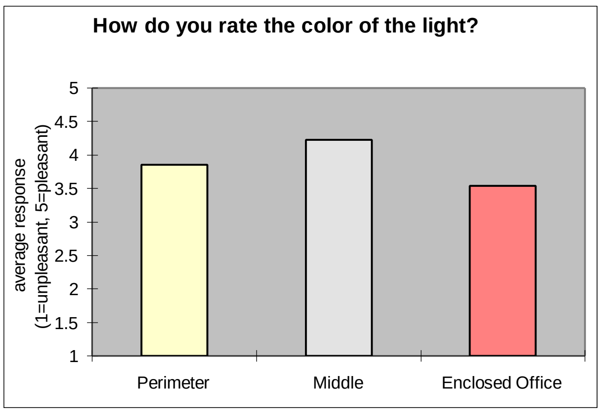
If dimmers were calibrated to dim down more, not all the way to 1.1amps, but safely to 2amps, then we complete the same calculations:
2amps/6.72amps = .2976 ~30%
If the lamps run 8 hrs/day, 5 days/week, 50 weeks/year, at their wattage, that is 1536 kwhr/year.
At $0.117/kwhr, this is a cost of $180/year to run this bank of lights. With the daylight sensors dimming the electrical lights at their current 72%, this saves $50/year. With the daylight sensors reducing electric lighting by 30%, this saves $126/year. (note: this is only for this one zone of lights on this one floor)

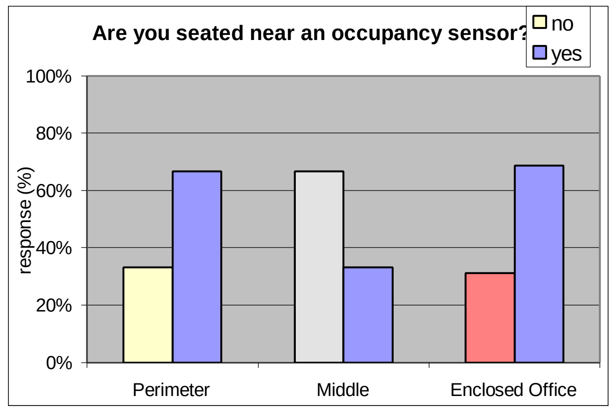
Appendix D

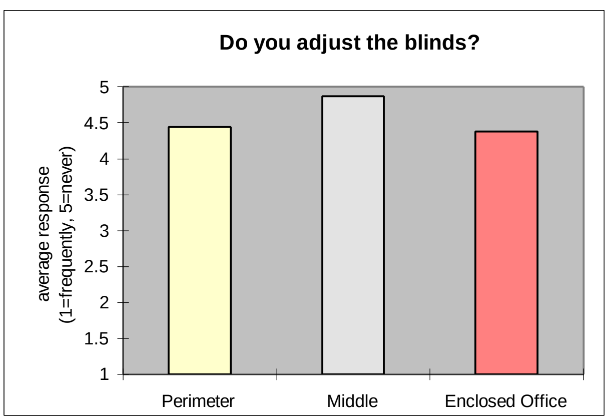
SURVEY RESULTS

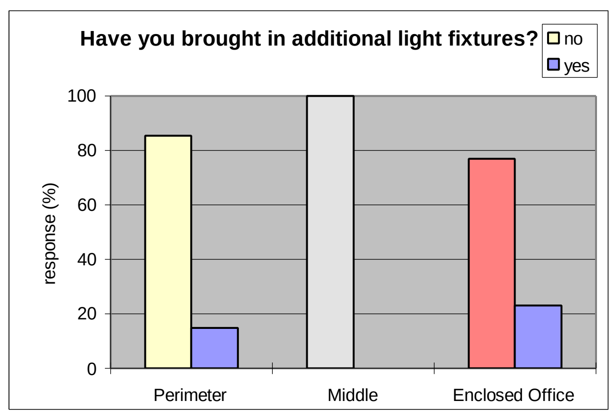




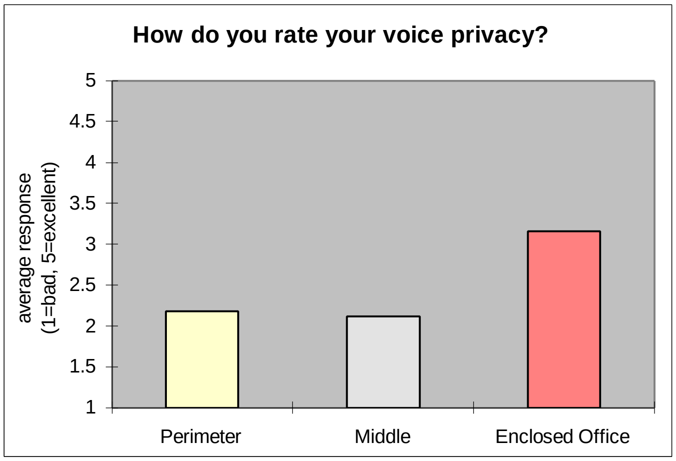


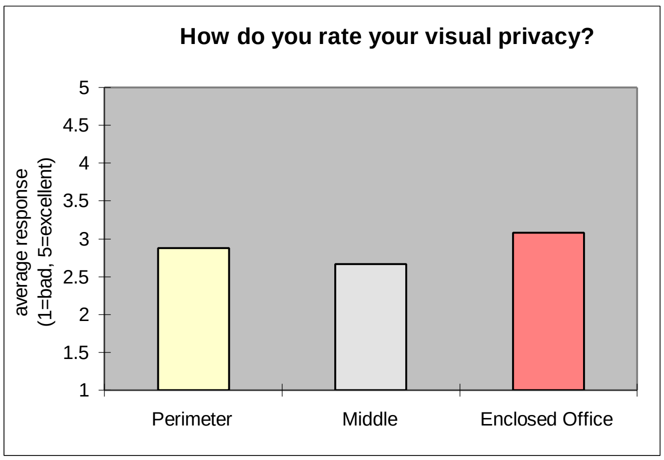


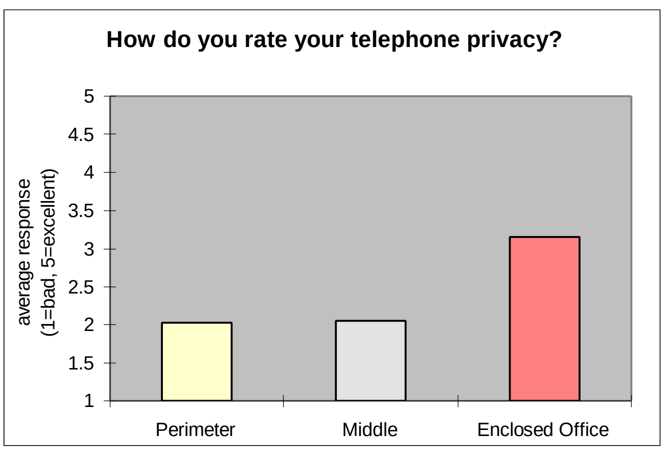




Appendix D


How do you rate your voice privacy?
average response
(1=bad, 5=excellent)
5
4.5
4
3.5
3
2.5
2
1.5
1
Perimeter
Middle
Enclosed Office


How do you rate your visual privacy?
average response
(1=bad, 5=excellent)
5
4.5
4
3.5
3
2.5
2
1.5
1
Perimeter
Middle
Enclosed Office


How do you rate your telephone privacy?
average response
(1=bad, 5=excellent)
5
4.5
4
3.5
3
2.5
2
1.5
1
Perimeter
Middle
Enclosed Office