School Entrance


Exterior Photograph from the Northwest


Exterior Photograph from the Southeast

W.D. Richard's Elementary School

Vital Signs VIII

Richard's Elementary School
Columbus, Indiana
Daylighting and Illuminance Case Study
Fall 2003
Ryan Luthman, Sal Impellitteri


View of school from the noutheast

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Silhouette of the clerestory wondows from the northwest.

ABSTRACT

This report documents a semester long instrumented field study of daylighting and illumination of the corridor spaces of the original W.D. Richards Elementary School in Columbus, Indiana.

Following an indicative investigation of the space, we questioned why the corridors were not naturally lit like many of the other spaces within the school (i.e. the classrooms and gymnasium), since daylighting was an essential part of the overall design of the school. We also questioned whether daylighting could be used to light the corridors, and whether this natural light would meet the accepted Illuminance level as determined by the Illumination Engineering Society (IES) for spaces where visual tasks are occasionally performed. The indicative visit allowed us to form our hypothesis and determine methodologies for gathering data for the study.

Data were gathered in the artificially lit corridors and compared with data gathered in the small corridors, which are lit with electrically powered luminaries and daylight discs. We discovered that the illumination levels in the corridors from the daylight discs alone do not meet acceptable IES illumination levels, and therefore this particular "daylighting disk" technique would not provide enough light if used in the main corridors without modification to that technique and/or the assistance of electrical lighting.

BACKGROUND

The Vital Signs program at Ball State University began in 1996. This program has produced excellent results on the study of light, published on the BSU CERES website, www.bsu.edu/vitalsigns. Previous classes have studied the Alumni Center at Ball State University, the NCAA Headquarters in Indianapolis, and a number of signature buildings in Columbus, Indiana. The focus of this class is on the study of physical performance of buildings, and where necessary, the recommendation of design solutions.

Our project this semester was the study of illumination, day light control, and occupant response in W.D Richards Elementary, designed in 1965 by Edward Larrabee Barnes. The design for the school was unique at the time of its completion; it utilized the beneficial effects of natural light. In 1994, the elementary school added 20,000 square feet of space; this addition was designed by the firm Lee&Timchula. Included are nine new classrooms, a new library and computer laboratory. The design integrity of the building was maintained with this addition; the front part of the classroom addition mimics the original classroom plan and utilizes the same daylight monitors overhead.

For our case study, we were asked to choose an area within the elementary school to study the effects of daylighting. Our group decided to study the effects of daylighting versus artificial lighting in the corridors. The corridors have several different functions: from being a "locker room" for the schoolkids, to a location for one-on-one special needs, to a place for migration between classes.

There are several connecing corridors that have daylight discs, as well as windows that link the hallways to the daylighting from the main gymnasium as primary sources of natural light. We felt that the lighting needs in the corridor can be best accomplished using daylighting techniques. The primary source of artificial lighting are flourescent lights, spaced at 7 feet on-center the entire length of the corridor.

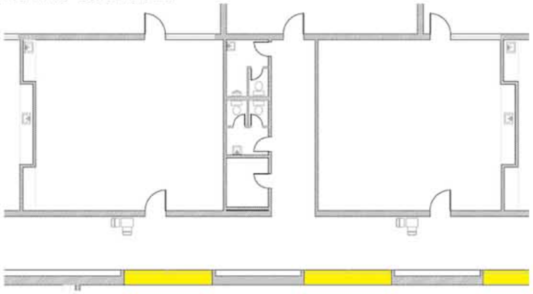

Fig. 6D: Enlarged plan showing gymnasium windows allowing natural light into adjacent corridor

Fig. 6A: Exterior view from the north-east

Fig. 6B:Exterior view from the south-east

Fig. 6C: View of cafeteria addition

Images courtesy of Lee & Timchula Architects

NARRATIVE

The main corridor spaces serve the school's office, gymnasium and classrooms. The main corridors have smaller branch corridors connected to them, which serve classrooms. The carpeted corridors are artificially lit with fluorescent bulbs, and have concrete block walls painted white. Glass windows, which allow a small amount of natural light into the corridor from the gymnasium, adjacent to the corridors, accent the corridors. While the corridors are primarily utilized for movement between classrooms by students and faculty, they also contain desks and chairs outside each classroom, which allow for students and teachers to engage in one-on-one learning sessions. The wall surfaces are utilized as pin-up space for displaying artwork and announcements. Coat hooks and shelves are located along the south wall, adjacent to the gymnasium, which allow students to hang up their coats, and backpacks outside their classrooms.

Following our first indicative visit to the school, we thought that the corridors could be retro fitted architecturally with a system that would allow day light to illuminate the space. Because of the time constriants of the semester and this class, we found out that doing this would not be possible. However, we then decided to measure a daylighting element which was already present in other parts of the building. We presumed that the analysis of these day lighting disks would give us the information we would need to then apply its use in the main corridor.

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HYPOTHESIS

We believe that bringing natural light into the original corridors of W.D. Richards Elementary school would meet the IES standard of 15 footcandles of illuminance, and that this level of illuminance would be greater than the illuminance levels in the original corridors.

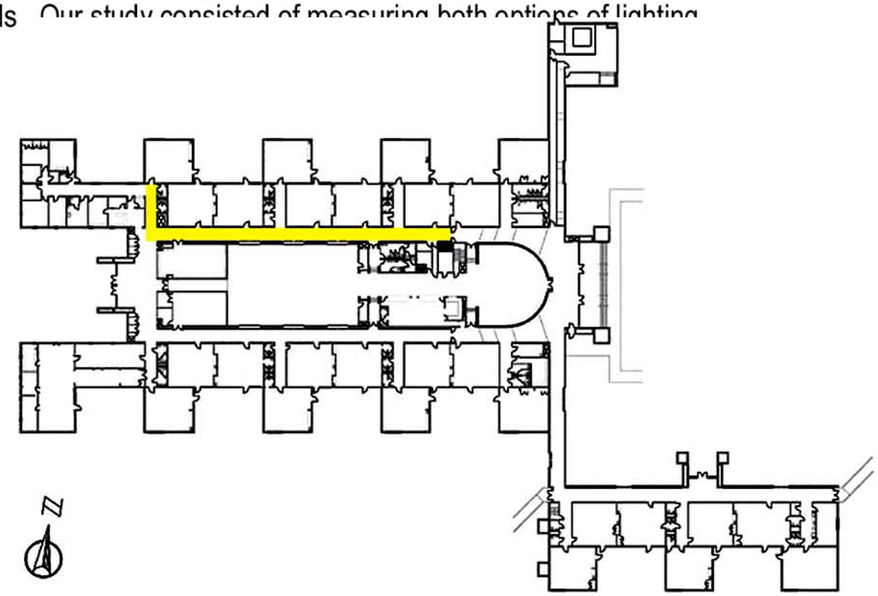
On days where the natural lighting does not reach 15 footcandles, we suggest that artificial lighting be used to supplement the natural light. The use of artificial lighting in the corridors can be justified for several reasons. There are areas in the corridors that have a high contrast ratio; that is, there are areas in the corridors that are considerably darker or lighter than their immediate surroundings. The problem occurs when the gymnasium becomes overlit from natural light, which then passes through the windows and onto the corridor walls. Artificial lighting can solve these dark spot problems.

Also, there have been complaints by teachers that the corridors would be much better places if there was an increase in the amount of daylight in those spaces. They believe that the natural daylight, which is available in all the classrooms, helps the kids stay more focused and work more efficently. There are specific places in the corridors where teachers tutor students who have special needs. Our study consisted of measuring both options of lighting

Fig. 7A: A view of the classroom windows

Fig. 7B: An example of how natural light reaches the classrooms

Fig. 7C: This extends to the rest of the school...



Key Plan of W.D. Richards Elementary with spaces studied highlighted.

EXISTING CONDITIONS

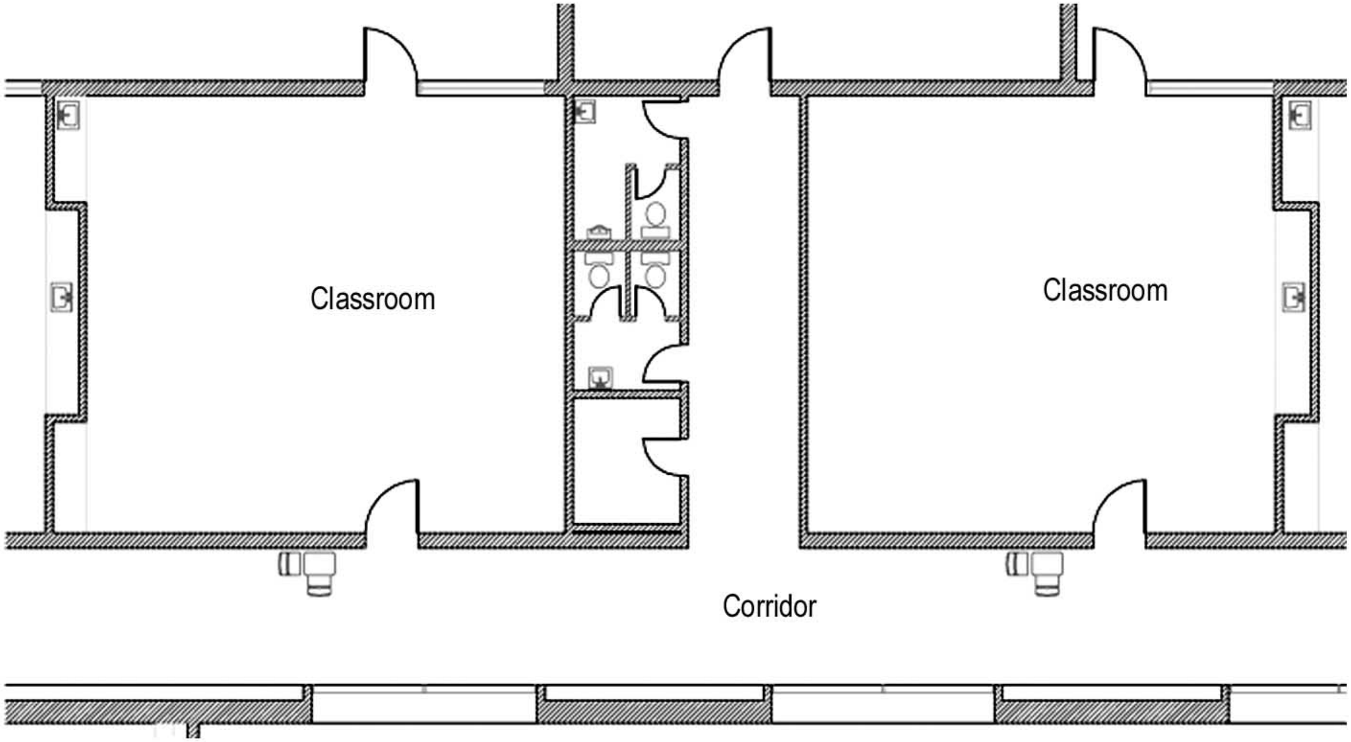


Figure 8A: Photograph at left showing a student and teacher engaged in a one-on-one session.

Figure 8B: Enlarged floor plan above showing small desks outside each classroom for student and teacher one-on-one sessions.

The main use of the original corridors in W.D. Richards Elementary School are as a means for movement from one classroom to another for all users. They also serve as a secondary classroom for students who have special needs. Here, single desks are located along the north side of the corridor, where a single student and single teacher engage in activities relevant to the needs of the student. These activities include reading, writing, and tutoring for upcoming tests.

Therefore, we believe that the IES standard of illumination in the corridors should reach 30 footcandles, which is the recommended level of illumination for a classroom.

EXISTING CONDITIONS

The corridors are flanked by large windows looking into the gymnasium, coat racks to the south, and doorways and student work displays to the north. Materials include carpet, concrete blocks, and acoustic ceiling tiles. The carpeting absorbs much of the sound, preventing echoes throughout the corridors.

Not much natural light reaches the corridors, unless it is a bright clear day, at which time excessive glare comes into the visual field from the gym. Artifical lighting presently provides the primary illumination of the corridors.

Fig. 9A: A view looking down the corridor showing the dependence on artificial lighting.

Fig. 9B: Photograph of the corridor, showing the large windows of the gymnasium and exterior window.

Fig. 9C: An example of the floor material, as well as the placement of a set of Stow-Away's.

Fig. 9D: Photograph of a secondary corridor, including a single daylighting disc.

RESEARCH METHODOLOGY

Many documentation tasks were performed during the initial visit to W. D. Richards Elementary School prior to framing and testing our hypothesis. Instantaneous measurements were taken with the GE meter outside the school, where nothing could influence the readings (i.e: shadows). These measurements were taken every hour on the hour for the duration of the visit. These readings were coordinated with those taken in the corridor.

Four Stow-Away meters were placed at specific points in the corridor, in two groups of two. One group was placed directly underneath an artificial light, and the second group was placed in between two artifical lights. The two meters comprising each group were placed across from each other along the baseboard, so students would not interfere with them. The Stow-Away's took measurements for one week, gathering data at six-minute intervals. They measured the amounts of artificial lighting during the weekdays, and the natural lighting during the weekend days. This was achieved by asking the custodial staff to keep all lights off in the corridor during that weekend.

Instantaneous measurements were then taken in the corridor at the exact locations of the Stow-Away's with the GE meter. The meter was placed at ground level to determine the amount of artificial light reaching the floor plane. These measurements were taken twice during the day. All measurements were taken with all artificial lights turned on.

Photos of the corridor were taken with a digital camera. These pictures were taken at a 6 foot height from the floor, and were processed in Adobe Photoshop to create visual field maps, a technique used to document the measured brightness of surfaces within the field of view.

The Stow-Away's were picked up one week later. The same instantaneous measurements were taken during the previous week to check the accuracy of those measurements.

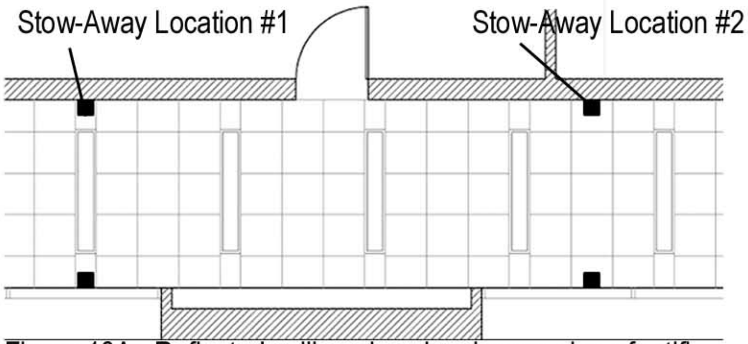


Figure 10A: Reflected ceiling plan showing spacing of artificial lighting, windows separating corridor and gymnasium, and placement of Stow-Away's.

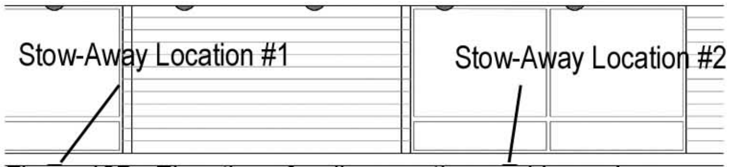


Figure 10B: Elevation of wall separating corridor and gymnasium showing spacing of artificial lighting, windows, and placement of Stow-Away's.

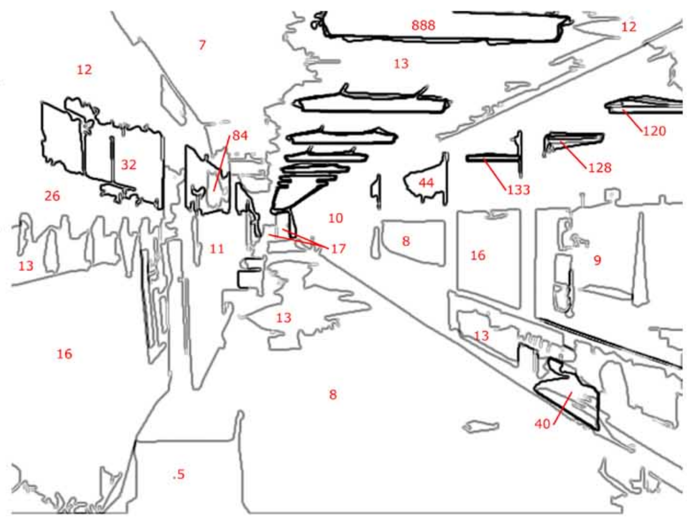
Figure 10C: Photograph showing placement of one group of Stow-Away's.

RESEARCH METHODOLOGY

Fig. 14A: Image of corridor, before filters were applied.

Fig. 14B: This image shows the first step in the technique of visual field mapping. A series of filters were applied to the image using Adobe Photoshop to create the patterns of different areas of color which are indicitave of different levels of light in the corridor.

Fig. 14C: The "edges" were then extracted, and the luminance gun was used to measure the number of footlamberts in each of the areas. Numbers which are significantly higher than surrounding numbers indicate the presence of glare.



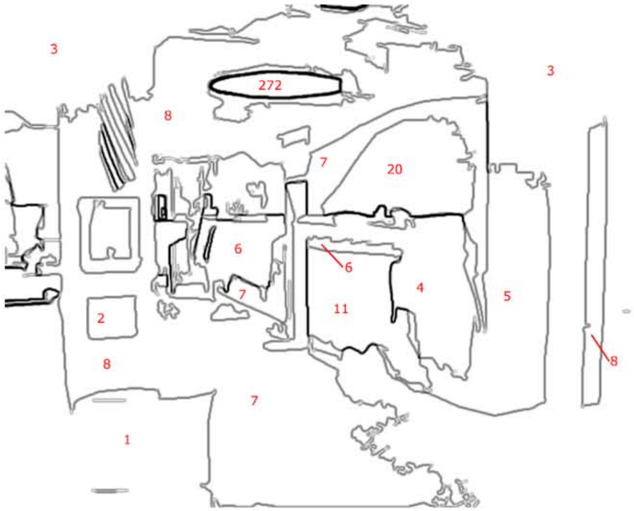
RESEARCH METHODOLOGY

Using the data gathered by the Stow-Aways, we found that our hypothesis was incorrect. An instantaneous measurement was taken with the GE meter placed at floor level underneath a daylight disc in the connecting corridor adjacent to the office. Measurements were taken with the artificial lights off and on. The GE meter measured 21 footcandles of illuminance with the artificial lights on, and 14 footcandles of illuminance with the artificial lights off. This means that natural lighting provided twice as much lighting as artificial. This analysis concludes that natural lighting plus the assistance of artificial lighting meets the IES standard.

While the ratio of artificial light versus natural light is 1:2, natural light alone does not provide the standard IES recommended illuminance level of 15 footcandles, which proves our hypothesis.

Fig. 12A: This is a view using the field mapping technique. In this case, we chose to study the effects of the daylighting disk located in the secondary corridors, in hopes of proposing these for use in the main corridors. This was done with the artificial lights on.

Fig. 12B: The result of the field mapping technique, showing the luminance values in several areas of the corridor. The day lighting disk has a luminance level that is far above any of those around it.



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RESEARCH METHODOLOGY

Fig. 13A: Here the same study was done as on the previous page, but the artificial lights are now turned off, to see how much of a difference there is in the amount of light in the corridor.

The daylighting disk did not emit more light than an artificial light, as we hoped it would. The artificial lights in the main corridor are spaced 7 feet apart, thus there is not enough space to install the necessary number of daylight disks needed to light the corridor with natural light only.

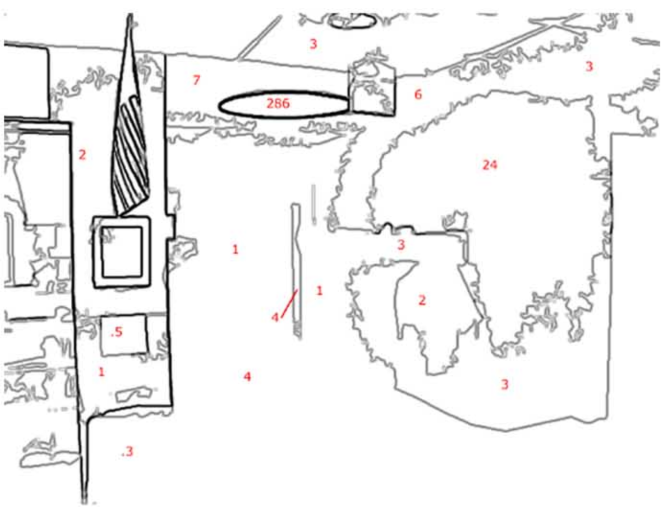


Fig. 13B: The daylighting disk shows a large amount of glare compared to the areas around it. Unfortunately, the disk in its original size is not large enough to efficiently light the corridor. The diameter of the disk would have to be significantly larger in order to match the amount of light emitted by the artificial lights.

FINDINGS / INTERPRETATIONS

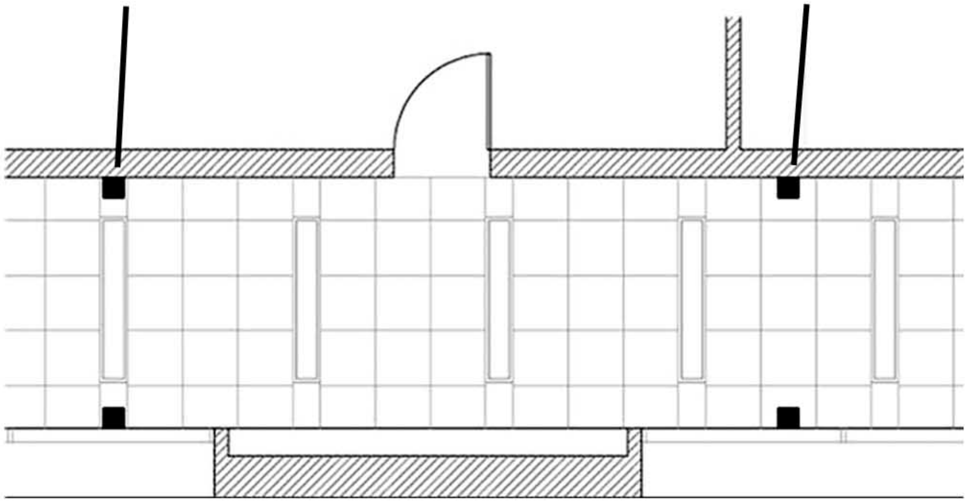


Fig. 11A. Diagram of Stow-Away placement.

The diagram to the left is a reflected ceiling plan, showing the location of each group of Stow-Away's. The values measured by each Stow-Away at its location on either side of the corridor were taken at an interval of six minutes. The measurements taken at the center of the corridor are averaged from instantaneous measurements taken with the GE meter. These can be found on page 16,

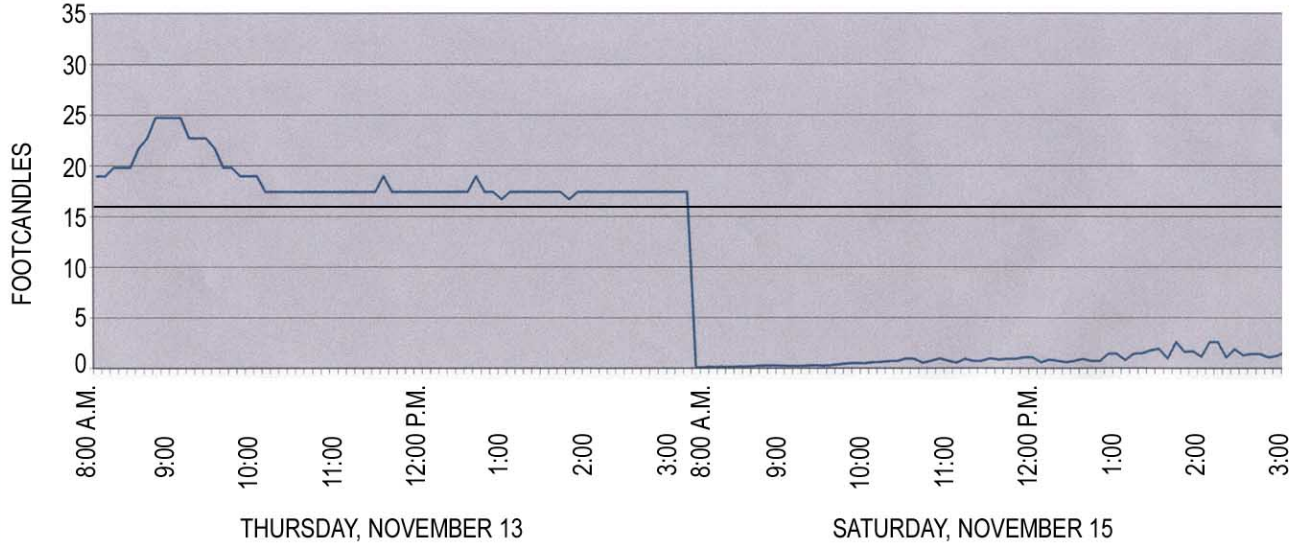
Findings:

The distribution of artificial light across the corridor at both locations exceeds the IES recommended level, which dis-proved our original hypoth-esis (natural lighting would provide better illumination of the corridors than electric lighting).

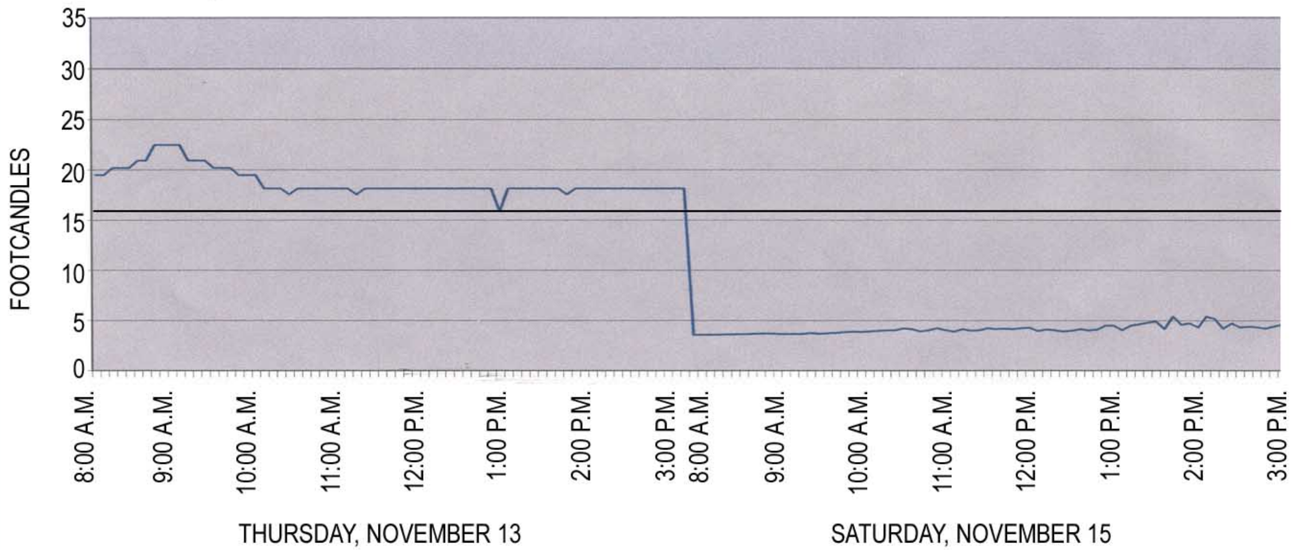
There is not a significant amount of natural light reaching the corridor, as indicated by the averages of the measurements during periods when the artificial lights were turned off.

FINDINGS / INTERPRETATIONS

Stow Away Location 1A



Stow Away Location 1B



* dark line on the graphs represents the IES recommended minimum illumination level for a hallway

These graphs show sample illumination levels taken from a normal school day; Thursday, November 13, 2003 from 8:00 A. M. to 3 P.M. as well as a typical weekend day, Saturday, November 15, 2003, from 8:00 A.M. to 3: 00 P.M. The difference between the days was substantial: The average footcandles for Stow Away 1A during a typical school-day was 18.5 fc, compared to the weekend day, 1.1 fc. For Stow Away 1B, the averages were 18. 8 fc for the weekday, and 4.1 fc for the week-end day.

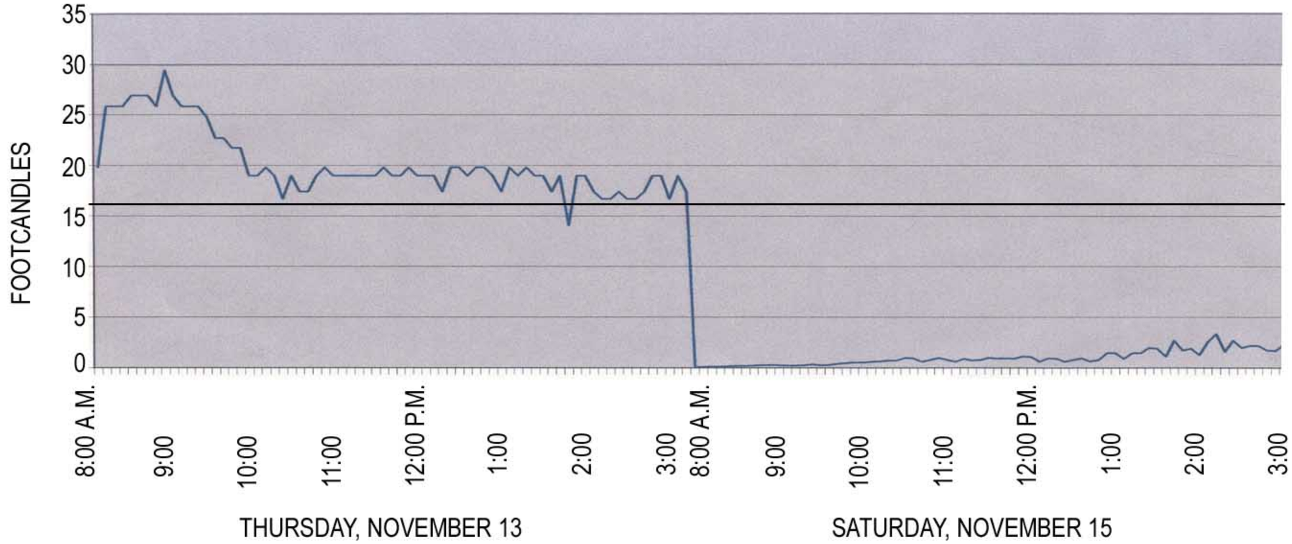
The difference in numbers is the result of the presence of the gym windows, which allow some day-light into the corridor. Our results found that the Stow Away closest to the gym window received more total light than the Stow Away closest to the classrooms. Therefore, any architectural integration, such as daylighting disks, should be placed in the ceiling grid closer to the classrooms rather than the gymnasium.

FINDINGS / INTERPRETATIONS

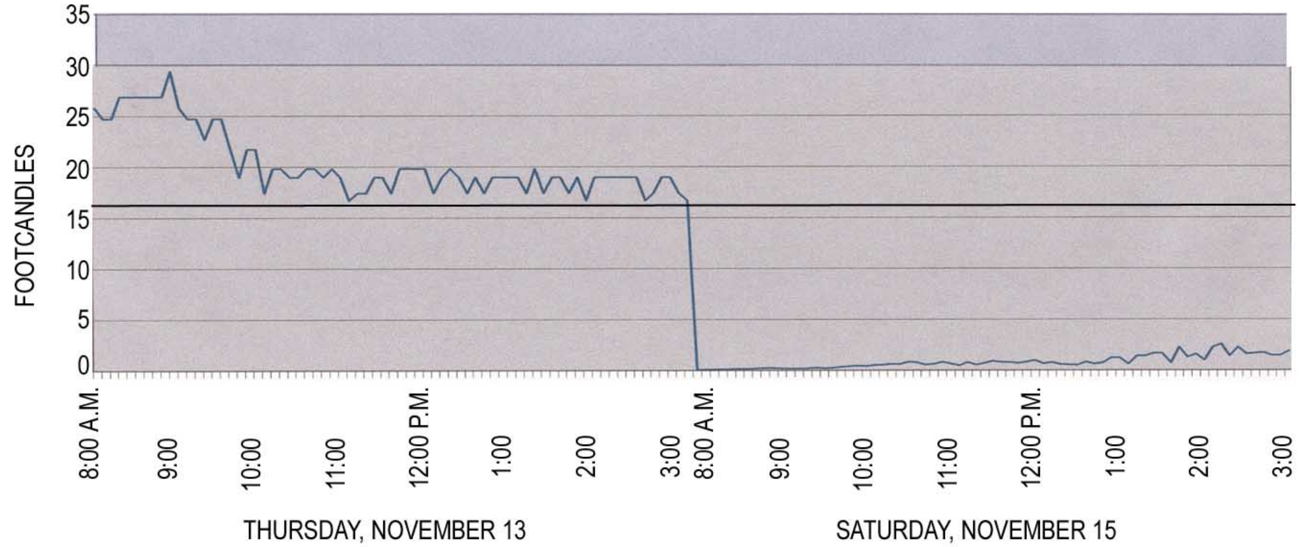
These graphs show sample illumination levels taken from a normal school day; Thursday, November 13, 2003 from 8:00 A. M. to 3 P.M. as well as a typical weekend day, Saturday, November 15, 2003, from 8:00 A.M. to 3:00 P.M. The difference between the days was substantial: The average footcandles for Stow Away 2A during a typical schoolday was 20.2 fc, compared to the weekend day, 1.0 fc. For Stow Away 2B, the averages were 20.3 fc for the weekday, and 0.8 fc for the week-end day.

The weekday averages for both Stow Aways in location #2 were higher than their counterparts in location #1 because of their placement closer to the artifical lighting. Location #2 was between two lights, resulting in the addition of both artificial lighting output. The weekend averages in both locations were very similar. Again, any architectural integration, such as daylighting disks, should be placed in the ceiling grid closer to the classrooms rather than the gymnasium.

Stow Away Location 2A



Stow Away Location 2B



* dark line on the graphs represents the IES recommended illumination level for a hallway

CONCLUSIONS

In conclusion of this daylighting study for W.D. Richards Elementary School, we recommend task lighting at the locations in the corridor where students are being taught. This recommendation is based on the fact that the existing artificial lighting in the corridors does not reach the IES standard of illumination for classrooms which is 30 footcandles. If this is done, in the interest of saving electricity costs for the school, we recommend using compact flourescent bulbs instead of incandescent bulbs in the lighting fixtures. This is because compact flourescent bulbs require a lower wattage than a comparable incandescent bulb. Compact flourescent bulbs also last longer, and would not give off as much waste heat as incandescent bulbs would.

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Table 18.7, pg. 1082.

ACKNOWLEDGEMENTS

1) Robert J. Koester, Professor of Architecture, Ball State University. For his help in the classroom at Ball State, at W.D. Richards Elementary, and for advice regarding this project.

2) Jeffery D. Culp, Operations Manager Ball State University. For his assistance in the classroom and advice and suggestions leading to the completion of this report.

3) Robert A. Fisher, Resident fellow and Professor of Architecture, Ball State University. For his presentation concerning the writing of research papers.

4) Mrs. O. Ercell Cody, Principal, W.D. Richards Elementary. For her assistance in helping our group conduct our study, and for her gracious attitude towards making our experience at the school a positive one.

5) The teacher and faculty staff of W.D Richards Elementary. For their cooperation with our study, and accomodation of our research protocol, which included measurements.

6) The student body of W.D. Richards Elementary and their cooperation with our study.

APPENDIX

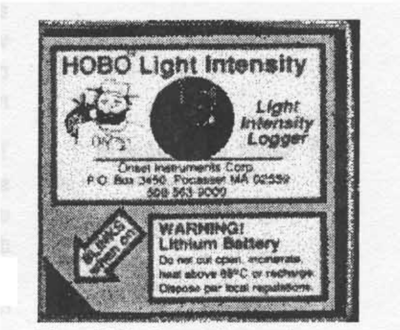

Fig. 19A: Stow-Away instrument

Stow-Away:

Stow-Away dataloggers are minitaure remote recorders, with BoxCar as its companion software, providing the Stow-Away with a graphical interface useful for launching, reading, and plotting data. The instrument runs on a single lithium battery, capable of powering the logger for 2 years. The Stow-Aways have a delayed-start feature, can mulitple sample, sample average, minimum, or maximum values. Data is read out by connecting the Stow-Away back to the computer and running the BoxCar software.

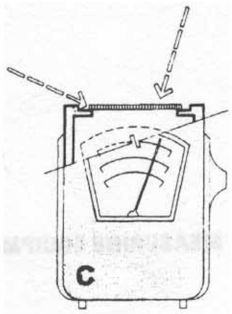

Fig. 19B: GE Light Meter

GE Light Meter:

The simplest illuminance photometer consists of a photovoltaic sensor with a photopic correction filter, connected to an amplifier with a display. The sensors detect light over a large range, thus effectively covering a 180 degree angle, or the entire hemisphere which faces the sensor. These small handheld units are easy to use, but not as reliable or accurate as stationary units.

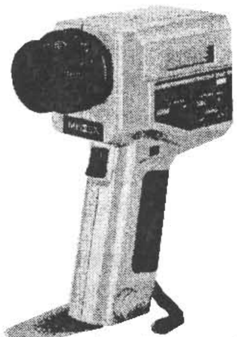
Fig. 19C: Luminance Gun

Minolta Luminance Meter:

This meter (also called Luminance Gun) is perfect for spot metering of light sorurces or surface brightness. It combines a glare-free optical design with a highly sensitive silicon photocell for accurate readings. The viewing is usually through the lens and the center spot indicates exactly what is being measured. There is an LCD panel on the side of the meter and with one inside the viewfinder to allow readings to be taken while viewing the object.