EVALUATING THE DAYLIGHT PERFORMANCE OF THREE MUSEUM GALLERIES

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ABSTRACT

This paper presents the results of the evaluation of the daylight performance of three museum galleries at the Texas A&M University campus in College Station, TX.

The museum galleries were analyzed through inspections and assessments of the actual spaces, physical scale models, and computer simulation programs. Scale models were used to analyze the annual sunlight penetration into the galleries and to compare daylight factor measurements with those of the actual space. The computer programs, Desktop RADIANCE and ECOTECT, were used to simulate the patterns of sunlight penetration and to calculate illuminance and luminance levels at different times of the year.

The results of this study indicated several lighting problems in the galleries, mainly due to direct sun penetration over the display areas. We found high illuminance levels, glare, high contrast areas, lack of visual adaptation, and overheating problems. Several recommendations are suggested to control sunlight penetration and to improve the lighting conditions.

3. INTRODUCTION

Lighting plays an important role in the design of museum galleries. Museum lighting differs from other types of lighting design. Museums have the most difficult lighting criteria of all building types. Museum lighting must balance the exhibition and conservation needs. Light in museums is necessary to enhance and view museum objects; but at the same time, light can be harmful and destructive, and reduce the life of the museum objects. Exposure to excessively high lighting levels (Fig. 1) gradually causes permanent damage to many museum objects. Light is radiant energy, and when radiant energy strikes the surface of a material, can cause degradation of museum objects. Many times architects underestimate the effects of daylighting in museum buildings and not much care is paid to the design of windows. From early designs until present, designers have been both successful and unsuccessful in illuminating museums. This paper presents three galleries where daylight is creating serious problems to their valuable exhibits.

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Fig. 1: Cushing Library’s first floor exhibits showing direct sunlight striking an oil painting, April 15, 2003 at 6:00 PM.

4. THE GALLERIES

The galleries analyzed are located in the Cushing Library, the Forsyth Gallery of the Memorial Student Center (MSC), and the George Bush Presidential Museum.
The Cushing Library is a three-story building with classic proportions, designed by Architect S. Vosper and F. Giesecke in the 1920’s. The collection consists of historic manuscripts, rare books, historic artifacts, photographs, oil paintings and sculptures. The area of the gallery is 625 ft² (second and third level). The second floor has vertical and horizontal displays, which are essentially temporary in nature, while the third floor has vertical displays of the valuable permanent art collection (Fig.2).

Fig. 2: Interior view of the third floor gallery at the Cushing Library.

The MSC Forsyth Center Galleries are located in the southwest corner of the Memorial Student Center Building. This building was designed and built by Architect Carleton W. Adams in 1950, and was renovated in 1973. The exhibits include a wide range of glass objects and 66 valuable oil paintings (Reference 1). The gallery is a two-story high space with floor-to-floor windows facing southwest. The area of the gallery is 2,700 ft². The exhibitions are arranged in individual glass displays located close to the windows. Paintings are hung on partition walls on the second floor as well as on the enclosing walls (Fig.3).

Fig. 3: Interior view of the Forsyth Galleries showing the blinds and foam-core boards on the SW-facing windows.

The George Bush Presidential Museum is a one-story building designed by the firm of Hellmuth, Obata + Kassabaum (HOK) in 1995. The display objects consist mainly of official and personal paper documents, videotapes, photographs, and paintings. The museum has 17,000 ft² of permanent exhibit space and 3,000 ft² of temporary exhibits. The gallery studied is the temporary exhibit area, “Fidelity Corridor Gallery,” located on the north side of the George Bush Presidential Museum (Fig. 4). The gallery is a long corridor that serves as a transition between the permanent exhibit space and the exit of the museum. Exhibits in this gallery are photographs and manuscripts, displayed on both horizontal and vertical display surfaces (Reference 2).

3. METHODOLOGY

3.1 Site Visits

Inspections of the museum spaces involved building drawings verification, interviews with curators and facility managers, photometric measurements (with and without electric lighting), occurrences of sunlight penetration, documentation of electric light fixtures, interior photographs, visual adaptation, and material properties.

The variables measured in the three museums were: daylight factors, horizontal and vertical illuminance, horizontal and vertical luminance from viewer’s locations, and sunlight penetration. Reflectances of all the interior surfaces were measured. Photographs of the galleries were taken considering that the viewpoints will be matched in the physical model and the Radiance model.

The galleries at the Cushing Library are illuminated by clerestory windows located above the third floor. On the second floor walls are painted white with a three-feet waistcoat, while the third floor is all white. The floor has a dark-colored carpet and all the doors in the space are wooden. The third floor display space is a gallery with a wooden railing that overlooks the second floor display space.

At the Forsyth Galleries, the SW-facing windows created several problems to the gallery due to the excessive exposure to sunlight. The windows have venetian blinds closed at all times. In addition to the blinds, foam core boards were added, between the glass and the blinds, in some windows of the second floor to protect the exhibits (Fig. 3). According to the curator, the foam core panels were placed in 1995 to reduce the light levels and the solar heat gains, because the blinds were not providing enough protection. These foam core panels have holes in their extremes to avoid deformation of the material. It was also found that a window on the second floor cracked in two occasions. This may have happened due to excessive heat.
At the Bush Museum, the permanent exhibit gallery is windowless and is illuminated with electric lighting, while the “Fidelity Corridor Gallery” has large spans of North- and East-facing windows. Gray partitions in front of the North windows along the typical bay of the gallery were added to the original design of HOK, to prevent the overexposure of sunlight to exhibits. These partitions do not cover completely the windows due to security concerns. The gallery has white ceiling, white walls, except for the gray partitions, and highly specular black & white terrazzo floor.

3.2 The Physical Model

Physical models of the three galleries were built: Cushing Library at 1”=1/2” scale, Forsyth Galleries at 1”=1/4” scale, and the Bush Museum at 1”=3/8” scale (Fig.5). No glass was placed on the windows of the physical models; a correction factor equivalent to the glass transmittance was applied to the variables measured. Crescent boards with similar reflectance to the real space were used to simulate the interior surfaces of the galleries.

The same variables measured in the actual spaces were studied in the models. The respective values were compared with the actual space values for model calibration and measurement verifications. The physical models and a sundial for latitude 30.6°N were used to check sunlight penetration throughout the year. Tests were done for extreme sun angles (solstices and equinoxes, morning, noon and afternoon hours).

3.3 ECOTECT Model

The program ECOTECT, from Square One, was used to study sunlight penetration within the galleries, and to determine the critical points where direct sunlight strikes the display areas. This analysis was done to identify the approximate number of hours that the museum artifacts [i.e. oil paintings] would be exceeding the recommended annual illuminance-hours, thus leading to possible damage by light. A stereographic sun path diagram (fish-eye view from critical points) provided the amount of hours that a reference point is getting direct sun.

3.4 Desktop RADIANCE Model

The Desktop RADIANCE lighting program was used to simulate the overall quality and quantity of light in the galleries. Illuminance levels were calculated at critical reference points on vertical displays for daytime hours throughout the year. Then, the percentage of hours when these points are over the recommended light levels is calculated. Several photo-realistic images of the galleries were generated for March 21, June 21 and December 21 at different times of the day (Fig. 6).

3. EVALUATION AND ANALYSIS

4.1 Daylight Factors

Daylight factors (DF) were measured in the galleries under overcast sky conditions and were compared with the DF in
the physical models. The measured DF at Cushing Library galleries were low, with a minimum values of 0.15-0.2% and a maximum value of 0.7-0.75%. The DF at Forsyth Galleries varied from 0.5% to 4.8-6.8%. The DF at the Bush Museum varied from 2% along the gallery to 7-9% in areas near the windows. The Bush Museum gallery has the highest DF, due to its extensive window area.

![Fig. 7: DF at the three galleries, Cushing Library (top), Forsyth Galleries (center), and Bush Museum (bottom).](image)

The DF measured in the scale models showed a similar daylight distribution, but with slight higher values due to the lack of glazing in the models. The DF of each model was adjusted based on the different transmittance values of each gallery's glazing.

### 1.2 Sunlight Penetration: Observed and Simulated

Sunlight penetration was observed and analyzed during the several visits to the three galleries. At the Cushing Library, the maximum sunlight penetration was observed in the early mornings and late afternoons (until 4:45 PM). Observations in the evenings could not be documented due to the library closing time (5:00 PM). At the Forsyth Galleries, the blinds had to be opened to observe the sun penetration mostly during the afternoon hours. At the Bush Museum, sunlight penetration could not be documented, because it occurs early in the morning (6:00-7:00 AM) when the museum is closed.

From the ECOTECT simulations, the following conclusions about the entrance of direct sun in the three galleries were derived:

At the Cushing Library, the maximum sunlight penetration occurred in the third floor: in the mornings between 7:00 to 9:30 AM on the West wall, and in the afternoons between 3:00 to 6:30 PM on the NE wall. The NE wall was selected as the most critical location at this gallery due to the extended hours of direct sun throughout the year. Fig. 8 (top) shows sunlight penetration at the third level gallery.

At the Forsyth Galleries, sunlight penetration occurred over the SE wall between 3:30 PM to sunset during the equinoxes and from 5:30 PM to sunset in winter solstice and from 5:30 PM to sunset in summer solstice. The critical reference point was selected on the SE wall, on a partition wall used to display paintings (Fig. 8-center).

At the Bush Museum, the maximum sunlight penetration occurred on the eastern side of the South wall mostly during early morning hours from April to September (between 5:30 AM to 6:40 AM). The critical reference point of this gallery was selected on the south wall where pictures and paintings of Mrs. Bush Foundation are located (Fig. 8-bottom).

![Fig. 8: ECOTECT models of Cushing Library third level gallery, September 21, 4:15 PM and 5:00 PM (top); SW windows of the Forsyth Galleries, March 21, 4:00 PM and 6:00 PM (center); and NE side of the Bush Museum gallery, June 21, 6:00 AM and 7:00 AM (bottom).](image)
1.3 Illuminance Levels: Measured and Simulated

Illuminance levels were calculated at the critical reference points of each gallery, using Desktop RADIANCE. The simulations were done for all daylight hours on a typical day (21st) of each month, and for the entire year.

At the Cushing Library, the total illuminance hours per year reached 1'386,026 lux-hr/yr. This amount is almost 3 times higher than the maximum recommended illuminance of 480,000 lux-hours/year for oil paintings, as defined in the ‘IES Recommended Practice for Museums’ (Reference 3). The average annual illuminance was calculated as 345 lux, which is over the maximum recommended illuminance level of 200 lux for oil paintings. The illuminance level during daylight hours was found to be above 200 lux more than 85% of the year. The highest illuminance values occurred mostly during the late afternoon hours throughout the year, with the highest value on September 21st at 3:00 PM.

At the Forsyth Galleries, the total illuminance-hour/year was calculated as 174,959 lux-hr/yr (considering the blinds closed at all times and windows covered with foam core panels). This value is below the maximum recommended by IES standards. However in May, June and July from 5:30 and 7:00 PM, the illuminance levels reached 713 lux, which is over the recommended 200 lux. Only during 10% of the annual daylight hours the illuminance levels exceeds 200 lux.

At the Bush Museum, the total annual illuminance-hour was 4'154,446 lux-hr/yr., which is almost 9 times higher than the IES recommended total exposure for oil paintings. The average annual illuminance was calculated as 904 lux, which is over the maximum recommended illuminance level of 200 lux for oil paintings. The illuminance level during daylight hours was found to be above 200 lux more than 98% of the year. The highest illuminance values occurred mostly during the early morning hours throughout the year, with the highest value on June 21st, at 6:00 AM.

Fig. 9 shows the hourly illuminance levels by month at the critical reference point under clear sky conditions of each gallery. Note the times when the illuminance levels are above 200 lux in each gallery.

1.4 Other measurements

Luminance levels were measured in the three galleries at the height of 5', standing at the center of the spaces and pointing at vertical surfaces every 30°, generating a luminance rose. Results showed highest values in the direction of the windows. At the Bush Museum the highest luminance value is located towards the NE direction (Fig. 10), where the windows are. Fig. 11 shows other luminance measurements taken at the Bush Museum gallery, with extremely high contrast ratios equal to 1:176 at eye level.

Fig. 9: Cushing Library third floor gallery (top), Forsyth Gallery (center), and Bush Museum gallery (bottom).

Fig. 10: Luminance rose (fL) of Bush Museum gallery.
Vertical illuminance measurements at eye level (5') were measured to assess visual adaptation in the galleries. Fig. 12 shows the values along the Bush Museum gallery as visitor move throughout the space. The maximum value of 137 fc (1,474 lux) was measured in the NE side of the gallery, whereas the minimum value 11 fc (118 lux) was measured along the typical bay of the gallery.

3. CONCLUSIONS

The most notorious problem in the three galleries is the sunlight penetration over the display areas. This sunlight can damage the valuable artwork collection. In two of these galleries, the annual lighting levels are 3 to 9 times the maximum recommended illuminance levels. Windows without any sun control also creates glare problems to visitors due to high illuminance levels and disturbing reflections over the display cases and video screens. Visitors at the Bush Museum experience high visual contrasts from excessive brightness surfaces of the large glazing areas, as they arrive from the windowless permanent exhibition galleries. The Forsyth Gallery, in addition, has problems of overheating associated with its SW windows. Curators and facility managers of these galleries had to find simple solutions to control the extremely high illuminance levels over the display surfaces, keeping the blinds closed at all times, adding foam core boards and additional display panels to block the window openings. All these solutions reduce the amount of light in the galleries, making them more dependent on electric lighting during daylight hours.

3. RECOMMENDATIONS

Solutions to improve the lighting conditions of the three galleries are: (1) control sun entrance by adding exterior shading devices to the windows to reduce the entrance of light and heat, wherever possible include trees and vegetation to filter light and provide shading, (2) sun control in interior spaces by using baffles and louvers (combination of opaque and translucent) to diffuse light, (3) use dark tinted glass to reduce light levels, and low-E coatings to control heat, (4) use glass with low UV transmittance (T-uv below 5%), (5) if not possible to reduce the light levels to 200 lux in galleries, use it to display least susceptible materials (i.e. metal, stone, glass, ceramic), (6) use an active window system where transmittance can be adjusted from 1% to 70% depending on the exterior conditions (Reference 4), and (7) limit light damage to susceptible artwork by keeping track of the total illuminance-hour/year of objects.

Curators and facility managers have expressed their interest in incorporating some of the above strategies to their buildings. For example, at Forsyth Galleries where changes cannot be done to the façade treatment, the addition of miniaturized sunscreens with a shading percentage of 50% or higher can help to control the overheating problems on the glass. Some RADIANCE simulations were done of the shading elements and light control devices, to show the improvements in the space.

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3. REFERENCES

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