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Original article

# An evaluation of daylight distribution as an initial preventive conservation measure at two Smithsonian Institution Museums, Washington DC, USA

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ABSTRACT

This paper presents the results of a light levels survey conducted at the Donald W. Reynolds Center for American Art and Portraiture in Washington DC. The museum space is shared by the National Portrait Gallery and the Smithsonian American Art Museum. After six years of extensive renovations, the building reopened to the public in July 1, 2006. The structure was not originally designed to house a museum collection since it contains numerous openings such as windows, doors and skylights, which provide a path for natural radiation to enter the building and come in contact with the artworks. From a preventive conservation standpoint, this is an important problem since sensitive works of art in the collection may be subjected to damage caused by light exposure. Environmental data loggers installed throughout the museum were programmed to take successive measurements every 10 min for 24 h a day, 7 days a week and 52 weeks a year. This light levels assessment started in November 1, 2007 and finished in October 31, 2008. This study presents a new method for determining natural radiation exposures registered in exhibition spaces that rely on both electric lighting and natural lighting, considering the growing trend of using daylight illumination in museums.



## 1. Research aims

The main objective of the study was to evaluate the relative distribution of light throughout different exhibition areas of the Donald W. Reynolds Center for American Art and Portraiture, during a light levels survey of one year. The initial goal of the research was to establish and develop a measurement methodology that helped to assess natural and artificial lighting contributions in spaces where both types of radiation are employed. The investigations also had the intention of verifying the effectiveness of current preventive conservation measures used to minimize the solar illumination reaching the interior spaces of the building.

This study forms part of a comprehensive preventive conservation program, which includes various lines of research. First, light-fastness surveys of museum materials using micro-fading spectrometry have been conducted jointly with the aim of investigating the exposures capable of inducing noticeable color changes. Second, an investigation of the reciprocity principle of light exposures has also been performed with the objective of identifying deviations, which are dependent on light-stability of the material. Third, different illumination ratios employed throughout the museum have allowed devising a method for estimating the photometric exposures received by objects on display. This procedure takes into account the higher illuminance levels experienced by the object due to the use of direct light sources in addition to indirect sources. The final goal is the establishment of lighting exhibition guidelines at the two museums based on results gathered during the previously described research campaigns.

## 2. Introduction

Museum personnel often face the challenge of lighting and preserving objects on display since there should be a balance between pleasing viewers with adequate light levels that permit correct appreciation of artifacts, while addressing the possible amount of energy striking the object's surface. Natural lighting is often preferred over electric lighting when illuminating works of art, because the first one provides a more pleasing rendering effect due to its spectral power distribution. However, natural lighting has a large component of UV radiation, which is known for its detrimental effects to the artwork. Therefore, this type of radiation needs to be minimized. Museums worldwide have traditionally used the maximum recommended levels of illumination proposed by Thomson [1]. The difficulty relies on applying these guidelines without conducting a systematic light monitoring program, which helps to

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**Table 1**
Summary of various recommended annual exposure limits for susceptible museum artifacts.

| Recommending organization | Low sensitivity (klx h/y) | Moderate sensitivity (klx h/y) | High sensitivity (klx h/y) |
|---|---|---|---|
| Illuminating Engineering Society of North America | Variable | 480 | 50 |
| Heritage Collections Council, Australia | – | 507–650 | 127–200 |
| Canadian Conservation Institute | – | 1000 (ISO 4)[a] | 100 (ISO 2) |
| Commission Internationale de l'Éclairage | 600 | 150 | 15 |

[a] These values are based on light-fastness ratings established by the International Standard Organization (ISO).

qualitatively and quantitatively evaluate the visible light and UV radiation present in museum exhibition spaces. The spectral distribution of the light source is an important aspect of this kind of study since similar illuminance levels may contain different amounts of UV radiation depending on the source. The source with a higher UV component, usually natural lighting, is more damaging than its equivalent electric source. Current accepted levels of UV radiation are 35 and 75 microwatts per lumen ($\mu W\,lm^{-1}$) for highly sensitive and moderately sensitive objects, respectively [2]. Every museum preventive conservation policy must take into account the sensitivity to light of artists' materials found in their collections before establishing adequate light levels for their objects.

The importance of measuring the light levels in museum buildings due to potential detrimental effects to sensitive works of art on display has been indicated by several authors [3–5]. Some researchers [6,7] have incorporated annual photometric exposure limits, for works of art on paper, which are based on the maximum recommended levels published earlier by Thomson. Various authorities in the museum lighting research field have published a series of guidelines which include annual exposure limits for susceptible artifacts [8–11]. A summary of these recommendations is presented in Table 1. These maximum recommended values are based on International Standard Organization (ISO) light-fastness classifications. These ratings are then converted to exposures based on available data on the fading of typical museum materials. Moreover, annual exposures can be extrapolated to determine the approximate number of years that a material would require to experience a perceptible color change. The differences in maximum allowable exposures observed in Table 1 are mainly due to the number of hours per day and days per year in which these values are based. For example, a maximum annual exposure of 50 klx h for high sensitive materials recommended by the Illuminating and Engineering Society of North America (IESNA) is based on illumination at 50 lx, for 8 h in a day over a period of 125 days in a year. In contrast, the Canadian Conservation Institute (CCI) recommends a limit of 100 klx h $y^{-1}$ for a fugitive material that belongs to the ISO 2 class. This value is based on 8 h per day and 250 days per year, at the same illumination level. In the CCI scale, an ISO 2 material displayed for 250 days per year is expected to experience a perceptible color change after 10 years (1.0 Mlx h exposure). The same type of material exhibited for 125 days per year, as specified in the IESNA guideline, would take twice as long to reach the same degree of damage. A guideline proposed by the Commission Internationale de l'Eclairage (CIE) in 2004 divides the materials into four categories based on their responsiveness to visible light. Although initially the CIE standard may seem too restrictive, the scales become equivalent after carefully examining the types of materials belonging to each category. For example, materials such as oil paintings classified as moderately sensitive in the three other scales belong to the low responsivity group in the CIE system. Therefore, a comparison of the CIE and IESNA guidelines reveals that the maximum recommended exposures for oil paintings are 600 and 480 klx h $y^{-1}$, respectively.

Numerous investigations on the interaction of light with museum materials [12–14] and the use of dosimeters to estimate photometric exposures in museums [15,16] have been conducted. Bacci et al. have developed a new kind of light dosimeter, which consisted of a mixture of photosensitive dyes and a polymer applied on a paper substrate [16]. In this paper, the authors accurately mention some of the problems related to measuring light levels in the museum, which can be divided into three principal areas. First, the difficulty of measuring radiation coming from mixed sources (natural and artificial) and subjected to seasonal changes. Second, extrapolations of point measurements often provide uncertain cumulative photometric exposures. Third, placement of an illuminance meter next to each object is unmanageable and results in elevated costs for the institution. Despite all of these aspects, a few studies concentrate on proposing a systematic methodology for evaluating natural and artificial radiation levels and presenting results derived from field measurements [17,18].

For all the above-mentioned reasons, this work presents a new promising methodology for cultural institutions interested in quantifying the distribution of natural radiation in their exhibition spaces. This study includes three major innovative aspects. First, photometric and UV radiation readings were recorded continuously every 10 min for an entire year. This has provided the opportunity of examining separately the data from any desired interval of a day, month or year. Second, the illuminance data presented parallel with the cumulative exposure curves offers an original way of evaluating the results, since daylight behaviors can be easily inferred from the combination charts. Third, this new method offers the possibility of separating the radiation into its natural and artificial components. This separation is based on the assumption of a constant artificial lighting baseline in illuminance and a discernable natural radiation signal at specific times of the day. Continuous measurements are important since they permit to evaluate changes throughout the day and those taking place at different times of the year. Comparable exhibition areas can be evaluated by determining the natural lighting distribution of one area, which then allows extrapolating the results to similar locations within the building. Finally, data loggers provide a more accurate method for calculating total photometric exposures when compared to estimations obtained from light dosimeters.

### 2.1. The Old Patent Office Building

The Old Patent Office Building is the third public structure constructed in early Washington DC after the White House and the United States Capitol. It was designed by American architect Robert Mills in the Greek Revival style characteristic of the 19th century in the United States [19]. The construction of the building begun in 1836 and it was completed in 1868. The Old Patent Office Building has witnessed many important historical events throughout its history and it was employed by several government agencies before it was converted into a national museum. The building is a National Historic Landmark and was included in the National Register of Historic Places of the United States of America in 1966. Two major renovations took place during the 20th century, resulting in a transformation of the space from office spaces into exhibition galleries. After the most recent six-year renovation, the building reopened to the public in July 1, 2006, and was renamed The Donald W. Reynolds Center for American Art and Portraiture. This historical