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MANAGING NATURAL LIGHT IN HISTORIC PROPERTIES

David Thickett [1]

ABSTRACT

Natural light is an essential feature of many historic interiors and significant views from rooms must often be retained. This paper will detail procedures developed to manage it and also elucidate the negative effect it can have on showcase performance and solutions.

Light plans have been developed to manage daylight. Monitoring natural daylight is challenging and blue wool dosimeters have been adopted. The preparation and measurement of these can significantly affect results and improved procedures have been developed. Monitoring of three hatchments at Lyddington Bede House indicated that in the position the hatchments, light and UV were sufficiently controlled by the stained glass in the windows. Mesh materials and neutral density films have been used to retain views whilst controlling daylight.

Within English Heritage's estate many historic properties contain showcases. Careful design is required to ensure adequate performance environmentally. In such situations, the room environments are frequently far from ideal and showcases are often required to perform environmental remediation for safe display of their contents. At St Peters church the surface temperature of archaeological bone displayed in showcases under stained glass windows found to have significant daily increases with predicted damaging decreases in surface RH. Simple geometry can indicate when direct sunlight can fall on showcases, mobile apps can dramatically reduce the time needed for calculations. Daylight even filtered through double blinds can affect some sensitive environmental control equipment. Examples of problems encountered and solutions will be presented. Light can dramatically increase off-gassing from showcase materials. At Apsley House allowing too much daylight onto showcases containing supposedly light insensitive objects chemically degraded the woollen display fabrics dramatically increasing the silver tarnish rate.

KEYWORDS Historic properties; Natural Light; Showcases

[1] English Heritage, david.thickett@english-heritage.org.uk

Introduction

Natural light is an essential feature of many historic interiors (Cannon-Brookes and Perry, 1996). Most of the interiors now in care, were designed before the advent of electric lighting in 1880 (Swan patent) and were either day-lit and used fires, gas lighting and candles at night. Depending on a property's history electricity will have been introduced to varying degrees. For example, the great hall of Audley End House, has only two electric points. Its presentation relies on side lighting from the magnificent windows.

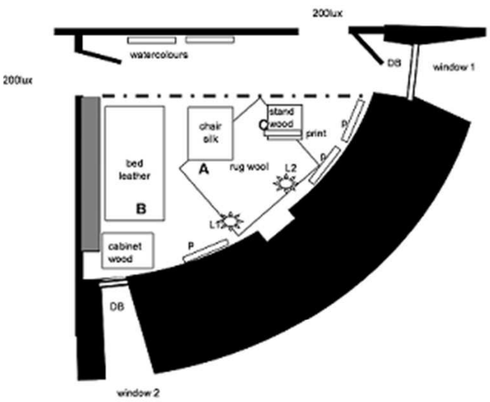
Historic House collections are often rich in textiles and other light sensitive materials. The original owners of many luxury country and town houses were well aware of the damaging effects of light on their expensive furnishing. Many of the practices of housekeeping developed in those situations have been modified and used in collections preventive conservation. A good documented example is the National Trust (UK) approach, with houses allocated as 1000, 1200, 1400 hours opening per year, generally April to October (Lloyd, 2002).

Vulnerable objects are covered in the closed period with traditional case covers. Most room lighting is through UV filtered side windows with sun blinds or sun curtains and shutters, to totally exclude light outside of opening and service hours. The dose is set equivalent to 50lux for a national museum, with opening 3000 hours per year. Light levels are therefore determined by the number of hours opening, so for a 1000-hour house, 150lux. This level is achievable in such situations by manually adjusting the blinds. Lower levels such as 50lux are only very rarely achievable in side lit historic interiors, without rendering some areas very dark. The presentation of historic interiors is based on historical evidence. Many houses are presented as if the occupants had just left, which is possible if the furnished house is acquired directly from the family. Alternatively, inventories, descriptions, prints or photographs are used to recreate rooms. This historical association places items in certain rooms and often locations within the room. These locations may not be ideal for light sensitive objects. Additionally, most historic houses do not have large reserve collections, so the opportunities for object rotation are very limited. The gardens of many houses were designed to present views from particular windows. It is highly desirable that these views remain visible from within some rooms. This presents significant challenges for keeping light exposure to sufficient levels for conservation of the collections in those rooms. Even if this can be achieved for the particular rooms (which are often only furnished with more robust material), these historic views destroy the eyes' natural acclimatisation and present issues for adjoining rooms.

Light plans

Light plans have been developed by several institutions to manage daylight. Essentially, a large number of measurements are taken ideally over several months. These guide the selection of measurement points that are then used to manually adjust the blinds and any artificial lights present to achieve set lux levels. Overall, the objective is to achieve a particular annual dose across a collection in a room. The plans often include indicative blind positions, sometimes for different times of the year and different sky conditions. An example is shown as FIG. 1.

Selection of the measuring points is critical. Two general approaches have been used. If the room contains a particularly significant or vulnerable object, then this can be defined as one of the points. The alternative is to try to define representative points.



p	oil painting on canvas
DB	double blinds
L1	40W incandescent bulb, 24microwatts/lumen
L2	40W incandescent bulb, 24microwatts/lumen

Position	Blinds				Shutters	
	Up	Midway	Down	Lights	Closed	Lights
A						
B						
C						
D						

Room: Duke of Wellington's Room | **Date: 20/02/2002**

Contents to be considered:

Chintz armchair
Silk bedcovers
Bed (leather and canvas)
Wallpaper (replica)
Carpet (replica)
Curtains (replica)
Prints (watercolour and monochrome)
Books
Wooden tables
Wooden chair
Wooden book stand

Light Sources:
Two windows, two electric lights on fireplace

UV control measures:
UV film on both windows

Light control measures:
Dark coloured Holland blinds and curtains on both windows, electric

Light control:

	Open Hours	Closed Hours	Closed Season	Functions
Proposed:	Eastern blind ¼ closed Southern blind fully closed	Blinds and curtains fully closed	Blinds and curtains fully closed	N/A

Desired lux level at recommended monitoring points when open to the
Maximum of 50 lux on armchair and bed.

Monitoring Points

A - Vertically at top of the armchair back

B - Horizontally on edge of silk bedcover, on corner nearest to chair

C - Vertically in middle of print on bookstand

FIG. 1 – Example of a light plan.

The height, direction and orientation of the meter must be defined as well for each point. In some situations, different points will be required at different times or day or the year. Depending on the opening hours, location, orientation and surrounding landscape, up to 40% of the annual light dose can be received when the room is closed to the public. Complete blackout is essential to meet conservation standards. Many historic properties have, or had, shutters that are ideal for this purpose, as well as providing enhanced security. Maintenance is essential and blind and shutter mechanisms need to work easily. The performance of UV films need checking annually and replacement can be required from between seven and fifteen years at 75µW/lumen. Many heritage institutions have lowered UV levels to 25 or even 10µW/lumen. Most new UV films will struggle to achieve 10µW/lumen with daylight. Additionally, as there is no standard for integrating the energy over the different wavelengths of the UV (unlike visible light), it is possible that under the same circumstances, one calibrated UV meter will read below that level, whilst a second from a different manufacturer will read above it. Tests with three commercial meters indicated significant discrepancy at low UV levels. Above 2010µW/lumen the meters read similarly within their reported errors. Without further standardisation, which does not appear likely, the only solution would be to use very expensive UV meters that record the power distribution. Even at 25µW/lumen, UV films will need replacing very frequently to maintain this level.

The light doses used are based on lighting standards. Thomson's (1988) original work was based on experiments by Lowe, which identified two levels:

- A very minimum, 50lux, at which a significant proportion of a population can discriminate when their eyes have acclimatized (generally this takes a few minutes);

- An optimum, 200lux, above which, for the majority of a population, no further benefit is achieved.

Above 300-500lux, more light actually reduces peoples' perception of detail. It is important to realise, that no light level is 'safe' and standards are about managing the rate of damage (Ashley-Smith et al., 2002). These levels have been expressed as doses in four sensitivity classes in the recent European technical specification, 'Conservation of Cultural Heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions standard' (BSI, 2014). The specification's no-sensitivity class, recommending no illumination limit for conservation, should be used with care. There is evidence that several of the materials listed can be affected by high light levels (Thorn, 2005; Thickett 2013; Thickett et al., 2013A). Recent developments have subdivided the sensitivity classes (Ruess, 2005), which is useful for practical implementation. The increasing use of micro-fading is a welcome development. It often proves a particular object is less sensitive than its type would suggest. This can be caused by the exact way it was manufactured or by previous exposure; destroying light sensitive dyes, pigments or reaction centres. Knowing an object's exact sensitivity can be especially helpful, because of the very limited opportunity for object rotation in historic interiors. The technique has recently been applied in situ for large, difficult to move objects such as state beds and carpets (Thickett et al., 2013B).

Light plans need to take into account the visitor route (which ideally will be influenced by the light sensitivity and levels of the different rooms). For example, at Osbourne House the nursery and Queen Victoria's bedroom have very sensitive black dyed silk textiles requiring a light level of 50lux. Other rooms prior to these on the tour route are at 200lux. The light plan has the lux level stepping down to 150 and then 100lux in the prior two rooms to acclimatise the visitors' eyesight to the low light levels.

Monitoring daylight

Monitoring natural daylight is challenging. In totally artificially lit spaces, the lighting needs to be set up once' and then only monitored very periodically to measure bulb aging and slipping of fixtures. It should be mentioned that a robust system is required to replace with the same bulbs and ensure fixing angles and dimming etc. are retained. Regular calibration is required for all monitoring equipment and light meters have been observed to under or over-read by up to 50%, without calibration. The intensity of daylight in a building can change rapidly and constantly. Whilst some data is generally better than no data, spot illumination readings can be misleading with daylight. Several organisations have suggested one, two or three manual readings a day, if continuous data is not available (Council for Museums, Libraries and Archives, 2004). Forty continuous reading data files from six English Heritage properties were examined. Annual lux doses were calculated from the hourly data. The data was then reduced such that readings from 9am, 12am and 3pm only were used to generate the annual exposure. The calculated doses are shown in FIG. 2.

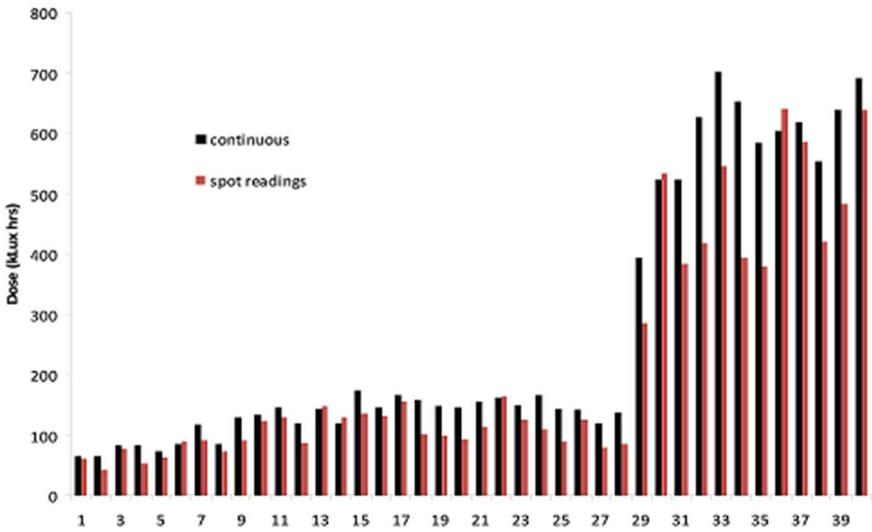


FIG. 2 - Doses from daily readings.

As can be seen, the spot readings differ significantly from the continuous doses, by up to 36%. In most instances (85%) they are lower and frequently much lower, which would give a falsely re-assuring estimate of the light exposure.

The impact of frequency of automatic measurement was also assessed. Twelve loggers were set to run at 60s intervals. Additionally, two yearly sets of monitoring compared loggers running at 60minute intervals with old proportional dose monitors. All loggers were calibrated using dimmable fibre optic lights at 50, 200, 500, 1000, 5000 and 10 000lux against a recently purchased light meter with calibration certificate.

The doses measured, using different intervals of the data and with the proportional dose monitor (FIG. 3), show less than 5% difference.

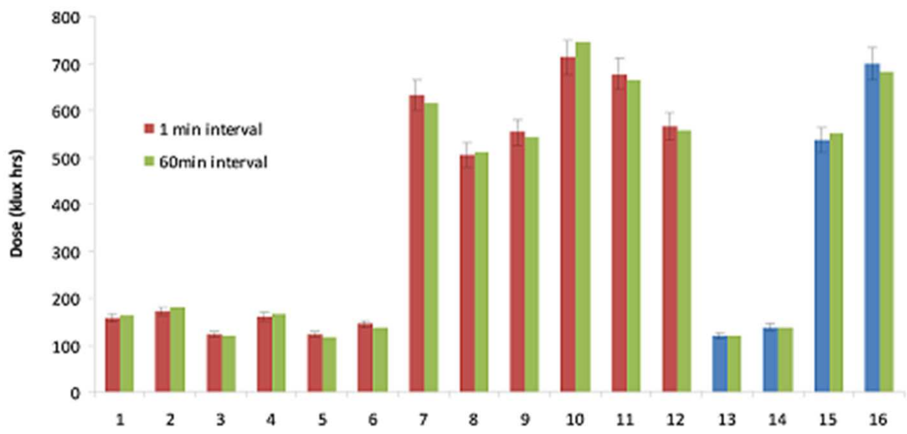


FIG. 3 - Doses from collecting data continuously, every minute and every hour.

The frequency of measurement for automatic equipment appears to have little affect when above hourly. However, where blinds, shutters or curtains are used the relative timing of measurements can dramatically affect the dose, especially with limited opening hours. For example, if a room has the shutters open four hours a day, the measurement interval is hourly, on the hour and the shutters are opened at 12.01 and closed at 15.59, the dose will be underestimated by almost 50%.

Light exposure is the most difficult environmental parameter to measure accurately for an object. The dose will depend heavily on the exact position, and it is generally only possible to at best measure at the edge of an object. In historic interiors, the presence of modern monitoring equipment is more intrusive than museum and gallery settings, and locations are often the subject to much debate. For paintings and works of art on paper, it is often curatorially acceptable to locate equipment at the top of the frame, but less so at the edges and underneath. With side lighting from windows, this position will often under-represent the light dose experienced by the lower portions of the object.

Blue wool, BW dosimeters have been adopted to monitor light doses in historic houses (Bullock and Saunders, 1990). Whilst it is possible to assess the results by visual comparison to grey scales, and this is the method they were initially designed for, the discrimination is very coarse and of limited use for the relatively low annual doses required in most historic houses, even with the most sensitive BW1. Reading after several years gives much better results. Colorimetry gives much finer discrimination and removes observer bias. As the wool surface is uneven, the measurements will vary with position and direction of the colorimeter head, relative to the weave of the wool. The most accurate measurements will be achieved by re-produceably repositioning the colorimeter head over the same area. Several colorimeters have viewing windows that aid in this and English Heritages blue wools incorporate a Melinex mask with a 3mm diameter hole to allow accurate repositioning. The dyes used on BW1 appears to have some pH sensitivity, and direct contact with some acid free cards causes a colour change. It is prudent to test any materials used in the dosimeter with accelerated aging, in direct contact with the BW to avoid this effect. English Heritage use Melinex masks to reposition the colorimeter head and Conservation by Design M8733 2-ply card. Location of BW dosimeters will affect the fading observed. The dosimeter should be aligned at the angle of the object surface of interest. Otherwise the cosine effect can introduce large errors in measurements. If the object presents several differently aligned surfaces, several dosimeters may be required if accuracy is desired.

The original publication for using BW as a light dosimeter, published a calibration curve using a Microscal tester. Each batch of BW requires separate calibration and can vary by as much as 50% in response to a given light dose with defined spectral distribution. That work found little effect of RH on the response curve. However, more recent work in actual historic houses has shown up to 20% difference between BW dosimeters response and measure lux doses (Thickett et al., 2007). This may be due to temperature, and partly explained by the presence of oxidising pollutants; nitrogen dioxide and ozone. The sources of these pollutants are such that if one is present at a low level, the other is likely to be present at a higher level. Ozone is most frequently naturally derived (in the absence of high exposures of sunshine, so certainly in northern Europe), so is likely to be higher in rural locations. Nitrogen dioxide is mainly derived from traffic, so is present in higher concentrations in urban centres. The inverse relationship found in many locations between the two pollutants has been recognised (Roberts-Semple et al., 2012). Calibration of a batch of BW can be undertaken with a standard daylight fastness tester, Microscal or Xeno. It can also be undertaken using natural daylight if suitable windows exist in historic properties. If the BWs are placed close to the window, it is likely that cooling will be required, as temperatures of up to 60ºC can be reached and this will alter the calibration and lead to much apparent higher doses from BW at room temperature. Small peltier type units provide a convenient way to cool BW for calibration. This approach has the advantage of exposing the BW to similar pollution levels.

High dynamic range imaging has recently been applied to historic house interiors. This measurement method uses a series of digital camera images at different exposures to produce an image of a large portion of a room calibrated for lux levels on the surfaces (Mardaljevic et al., 2009).

Light control

Stained glass has some ability to reduce light and UV transmission. Monitoring of three hatchments at Lyddington Bede House indicated that their positions were such, that light and UV were sufficiently controlled by the stained glass in the window and shading from other buildings and trees. The exact exposure at any point in a room is determined by the room and window dimensions, reflectivity of internal surfaces, the room's orientation and surrounding features. Manual calculations have been developed to assess this (Cannon-Brookes and Perry, 1996; Thorn 2005). The detail of when a point will be in direct line of the sun depends additionally on opening times of shutters and potentially foliage on trees at different times of year. Apps, such as Sunseeker, are now available to show the sun's position at any time on any day of the year. This means the calculations are now trivial, instead of several hours work. The smart phone or tablet is placed at the position of the object of interest and pointed towards each window in turn. It is possible to calculate on what days the blinds will need to be lowered to block direct sunlight. Sunseeker can be used to estimate the blind positions for each day.

Full modelling is now possible for the illumination levels in day-lit interiors (Eibl, 2015; Mardaljevic, 2015). Unlike hygro-thermal building modelling the building fabric does not introduce large amounts of uncertainty, as only measured surveys are required. The transmission properties of historic glazing will often need to be measured, as they can vary from published glass values. Such modelling requires careful validation with measurements to ensure accurate results. However, once complete, the model can be used to investigate different scenarios, use of different blinds, positions, neutral density films, etc. It can be used to position light monitoring in the most effective location.

The library at Brodsworth Hall has particularly significant views of the gardens and the blinds are only lowered to just above eye level. A neutral density film (Sun-x MT65) was applied to the window to reduce light doses. For most of the room this was successful, although doses within 2m of the window are reduced, but still higher than desirable. A survey of visitors indicated that they had perceived no visible difference in the view, to that from other different orientation rooms without neutral density film.

Several historic houses are moving towards mesh blinds, often fixed to allow some perception of views whilst facilitating light control. In most situations, such materials will not reduce the light levels to 200lux without the additional use of adjustable black out blinds. There is also a concern that the exact geometry of the mesh cross section may cause light to reflect into the room, with high albedo materials. English Heritage is presently undertaking testing on 60 blind materials. The tests will assess transmittance at several angles and UV and NIR transmission also.

Amongst the earliest uses of mesh, were the Victoria and Albert Museum in the mid-1990s. Mesh blinds were first used in English Heritage for the Whitby Abbey visitor centre, in 2003. The Victoria and Albert Museum selected a Mermet Matt blind. This was combined with two layers of MT20 film to reduce daylight transmission to 0.5%, giving an average of 250lux near the window and 50lux deeper into the gallery. The same material was used at Kenilworth Castle gatehouse in 2009. Reinstatement of the sixteenth century garden, made opening the view from the second-floor gatehouse desirable. The material was installed in a compression mount in the lower half of the window, with the blinds down to just above eye level. This arrangement kept light levels below 200lux in the showcase less than 1m away, experiencing direct light from the window. Unfortunately, this material is no longer available.

Historic Royal Palaces have been testing Smart Tint since early 2015. This is a clear polymer material (85% transmittance), that turns translucent (41% transmittance) when an electrical current is applied. The film also offers protection for ultraviolet (99%) and infrared (90%) radiation. This material is being trialled using a compression mounting on clear glass windows at the Great Watching Chamber in Hampton Court Palace as part of the Tudor tapestries environmental protection research project (Vlachou, 2015).

Impact of daylight on showcase environments in historic buildings

Within English Heritage's estate, many historic properties now contain showcases. Careful design is required to ensure adequate showcase performance environmentally. In such situations, the room environments are frequently far from ideal, and showcases are often required to perform significant environmental remediation for safe display of their contents. At St Peters church, the surface temperature of archaeological bone displayed in showcases under stained glass windows found to have significant daily increases with predicted decreases in surface RH, within 2% of damaging levels (Thickett, 2008). This emphasizes the care needed with such situations. The intrinsic nature of historic properties can limit installation of light control. The stained glass could not have films adhered to it, the window framing was architecturally important, so blinds could not be fitted, and the light filtering through the stained glass was thought an essential component of the interior. Simple geometry can indicate when direct sunlight can fall on showcases, FIG. 4. As described previously, mobile apps can dramatically reduce the time needed for calculations.

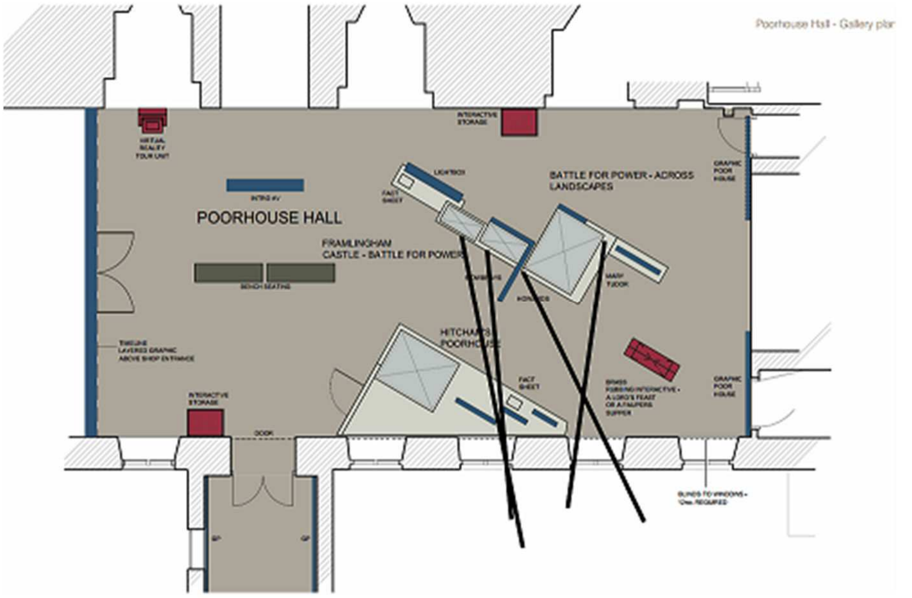


FIG. 4 - Framlingham.

Daylight, even filtered through double blinds can affect some sensitive environmental control equipment. An exhibition in Kenilworth Castle gatehouse uses Miniclima EBC08 and EBC09 units to provide tight control of the RH (+3%) in six showcases.

The majority of the cases easily met the loan specifications. One showcase initially showed short-lived RH peaks between 2 and 4 p.m. on most days, taking it out of specification for the loan object in it. No obvious temperature perturbation was associated with these RH changes. Sunlight had been observed to strike the plinth containing the Miniclima unit at around this time in the afternoon during installation, before the blinds were lowered.

Although visible light was kept below 200lux, it was suspected that infrared emission from the heated blind was heating the dark brown plinth. The surface temperature was measured on the outside and inside of the plinth using Pt 100 sensors and a SR007 datalogger, and the internal air temperature inside the plinth was monitored with a Meaco transmitter. FIG. 5 shows a 24-hour period with the effect observed.

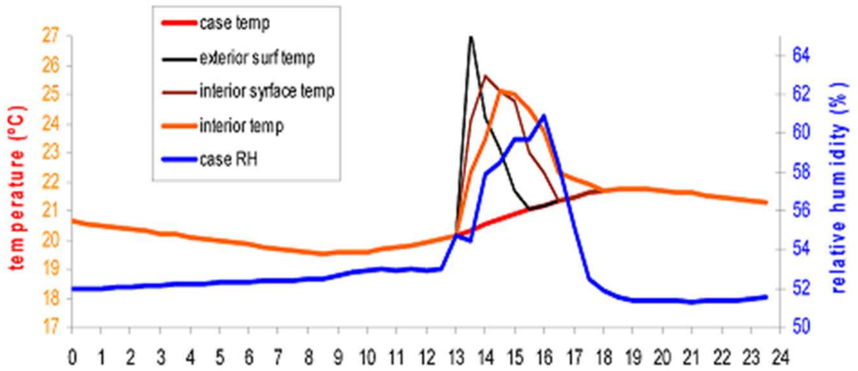


FIG. 5 - Kenilworth.

As can be seen, the exterior surface temperature of the plinth rises sharply around one pm. The interior surface temperature follows this increase more slowly and is heated for longer. The air temperature inside the plinth rises by 3°C and the RH in the case rises. The problem was solved by adding two fans to the plinth casing to ensure sufficient air-flow to remove the heat swiftly. Opening the view from the window with the mesh did not impact on the case performance with the fans running.

Light can dramatically increase off-gassing from showcase materials. At Apsley House, London, a significant collection of silver is displayed in original 1840s, and recent replica showcases. As the gallery contains mainly silver and china, light control was not a priority under the previous management regime.

English Heritage took over management of Apsley House in 2005 and instigated a light plan to manage the exposure of silk banners displayed at high level in the room. Monitoring of silver tarnish rates and hydrogen sulfide concentrations inside the showcases and room were undertaken to optimise preventive conservation for the silver collection. A blue woollen fabric had been installed in the showcases in 1992 and tests had shown it was unsuitable for use with silver (Daniels and Ward, 1982). Tarnish rates were measured in all ten cases containing silver, to prioritise replacement of the fabric, which was relatively expensive to achieve. FIG. 6 and 7 show the silver tarnish rate and hydrogen sulfide concentration in showcases, between windows for 30 day periods under the old regime, with the blinds raised and the new regime using the light plan.

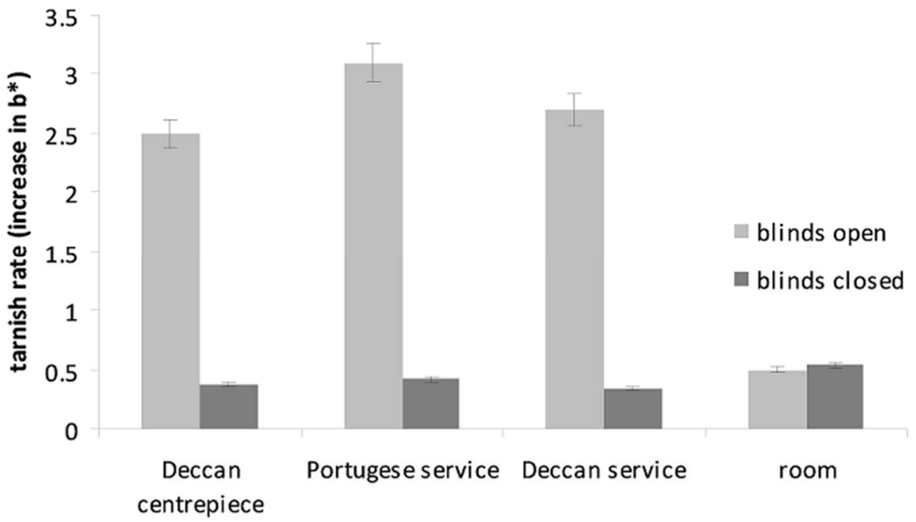


FIG. 5 – Silver tarnish.

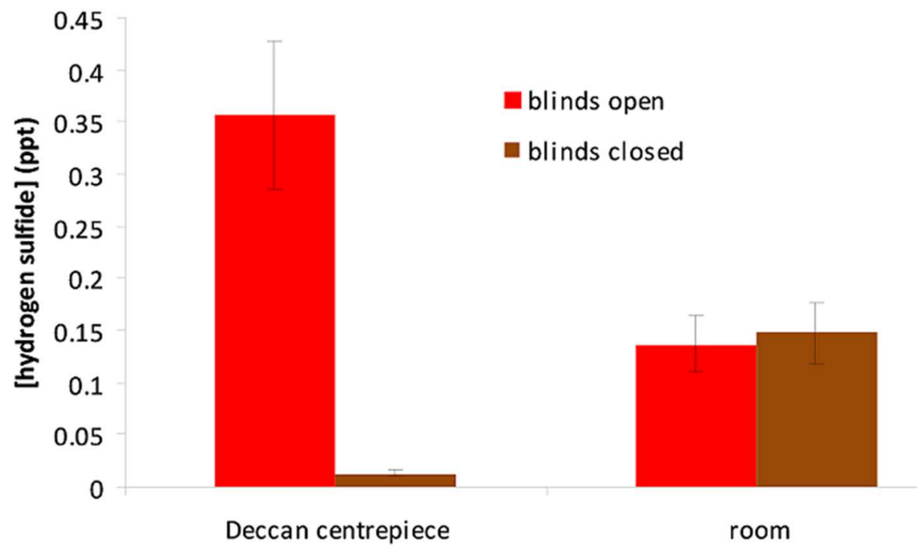


FIG. 6 - Hydrogen sulfide concentration.

As can be seen, the hydrogen sulfide and tarnish rates are significantly higher when the showcases are exposed to UV filtered sunlight. The hydrogen sulfide and tarnish rates are similar in the room over the two periods. To further investigate small samples of the blue fabric were taken from areas exposed to light and those under card labels. The samples were analysed with Fourier transform infra-red spectroscopy and the area of the cysteic acid peak in the second derivative at 1046cm^{-1} determined as a measure of wool degradation (Odlyha et al., 2007). Results are shown in FIG. 7.

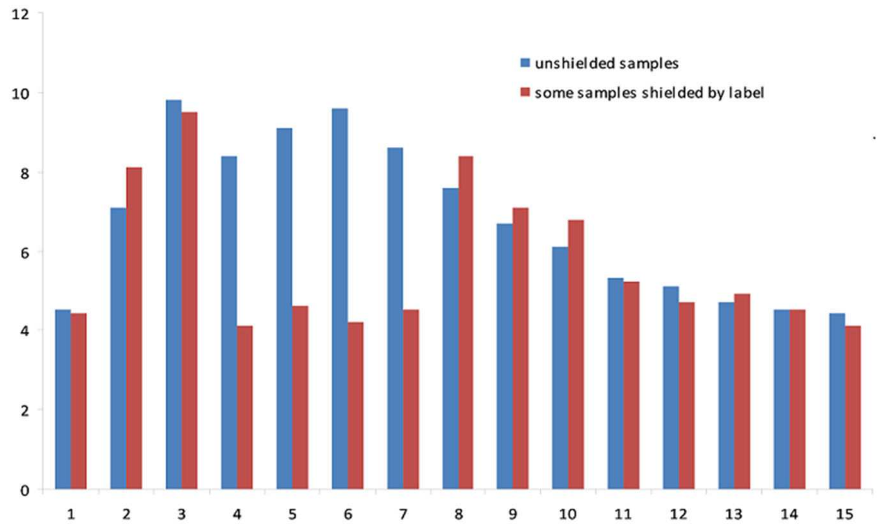


FIG. 7 - Cysteic acid area.

Points 2-11 experience sunlight, whilst points 1 is shielded by the case frame and points 4-7 are under a label. The unexposed wool is significantly less chemically degraded.

Conclusion

Managing daylight to provide conservation conditions in historic properties presents a number of challenges. Light plans have been developed to overcome many of these. Measurement of light doses with automated systems is mainly accurate at hourly and more frequent measurement rates. Manual measurements can however, significantly underestimate doses. Blue Wool dosimeters measured with colorimeters are a convenient method. Their preparation and measurement can significantly affect results and strict procedures need to be adapted for accurate and precise results. Mesh materials and neutral density films have been used to retain historic views, whilst controlling daylight. Modelling can significantly improve both measurement and optimise control.

Daylight can have negative effects on showcase performance. Excessive surface temperatures risk vulnerable organic materials even when showcase RH values appear not to be too low. Near infra-red heating through double blinds can impact the performance of Peltier based dehumidification systems (which are very common), through heating the compartment with the equipment. Off-gassing can also be dramatically increased under daylight illumination.

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