PD CEN/TS 16163:2014

BSI Standards Publication

Conservation of Cultural Heritage — Guidelines and procedures for choosing appropriate lighting for indoor exhibitions

...making excellence a habit.™

National foreword

This Published Document is the UK implementation of CEN/TS 16163:2014.

The UK participation in its preparation was entrusted to Technical Committee B/560, Conservation of tangible cultural heritage.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 72633 0

ICS 97.195

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 May 2014.

Amendments issued since publication

Date	Text affected

TECHNICAL SPECIFICATION
SPÉCIFICATION TECHNIQUE
TECHNISCHE SPEZIFIKATION

CEN/TS 16163

April 2014

ICS 97.195

English Version

Conservation of Cultural Heritage - Guidelines and procedures for choosing appropriate lighting for indoor exhibitions

Conservation du patrimoine culturel - Lignes directrices et procédures concernant le choix d'un éclairage adapté pour les expositions en intérieur

Erhaltung des kulturellen Erbes - Leitlinien und Verfahren für die Auswahl geeigneter Beleuchtung für Innenausstellungen

This Technical Specification (CEN/TS) was approved by CEN on 14 October 2013 for provisional application.

The period of validity of this CEN/TS is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the CEN/TS can be converted into a European Standard.

CEN members are required to announce the existence of this CEN/TS in the same way as for an EN and to make the CEN/TS available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the CEN/TS) until the final decision about the possible conversion of the CEN/TS into an EN is reached.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.

EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. CEN/TS 16163:2014 E

Contents

Page

Foreword 4
Introduction 5
1 Scope 6
2 Normative references 6
3 Terms and definitions 6
4 Symbols 11
5 Sensitivity of cultural property to light 12
5.1 General 12
5.2 Mechanisms of damage 12
5.2.1 General 12
5.2.2 Photochemical 12
5.2.3 Radiant heating 13
5.2.4 Biological effects 13
5.3 Sensitivity and classification for cultural property 14
5.4 Limitations for total luminous exposure 14
6 Light measurement 15
6.1 Measurement of illuminance 15
6.2 Measurement of UV radiation 16
7 Exhibition lighting 16
7.1 General 16
7.2 Viewing conditions 16
7.3 Visual adaptation 16
7.4 Contrast ratios 17
7.5 Colour appearance 17
7.6 Colour rendering 17
7.7 Backgrounds to exhibits 18
7.7.1 General 18
7.7.2 Luminance of backgrounds 18
7.7.3 Colour of backgrounds 18
7.8 Glare 19
7.9 Modelling 20
7.10 Historic furnishings & interiors 21
7.11 Simulation and mock-ups 21
Annex A (informative) Characteristics of light sources 22
A.1 Daylight 22
A.2 Electric sources 22
A.2.1 General 22
A.2.2 Incandescent lamps 23
A.2.3 Fluorescent lamps 24
A.2.4 Solid State Lighting 24
A.2.5 Metal Halide lamps 26
Annex B (informative) Glasses and films characteristics 27

B.1 Glasses 27
B.2 Window films 27
B.3 Other protection 27
Annex C (informative) Filters 28
Annex D (informative) Relative damage 29
Annex E (informative) Lamps and lighting attachments 30
Bibliography 31

Foreword

This document (CEN/TS 16163:2014) has been prepared by Technical Committee CEN/TC 346 “Conservation of Cultural Heritage”, the secretariat of which is held by UNI.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this Technical Specification: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

Lighting is needed for many specific functions in museums and other cultural heritage buildings, for example, for research, conservation and permanent or temporary exhibitions. Lighting is one of the most important factors enabling visitors to fully enjoy works of art and other cultural property. In fact, lighting is a key medium in which visitors interpret and appreciate cultural heritage. Enough light is needed to see well but this may present a challenge when what is being viewed will deteriorate in the presence of light. Where cultural heritage is judged to be worth preserving for future generations it is essential to consider the controlled use of light. Indeed, light is an environmental factor, which is a threat to many objects. Alone or in combination with other environmental factors (temperature, humidity, pollution, etc.) light causes fading, discoloration and embrittlement of a wide range of materials. This damage is cumulative and irreversible: no conservation treatment can restore change of colour or loss in strength of materials damaged by light. Therefore, the challenge of museum exhibition lighting is to find an appropriate compromise between the long term preservation of the exhibit and the needs of visitors to view them within a suitable exhibition design. As an integral part of exhibition lighting, the following aspects should be considered:

— the conservation aspect, related to the sensitivity of the exhibit at different wavelengths of the incident radiant energy, the spectral composition of the light source and the total luminous exposure,

— the visual aspect, related to the impact of lighting on the visitor experience: lighting has to allow visitors to see exhibits on display, with the correct colour perceptions without glare, reflections or insufficient illumination,

— the design aspect related to the concept and position of the exhibition architecture, the point of view of the curator and all others involved in the scenographic and/or didactic objectives of the exhibition.

Due to its non-technical nature the last mentioned aspect cannot be dealt with in this Technical Specification.

This Technical Specification uses terms defined in European (EN 12665 and EN 15898) and International (CIE International lighting vocabulary) terminology standards, but their definitions have been adapted to the intended users of this specification.

1 Scope

This Technical Specification defines the procedures as well as the means to implement adequate lighting, with regard to the conservation policy. It takes visual, exhibition and conservation aspects into account and it also discusses the implications of the lighting design on the safeguarding of cultural property. This Technical Specification gives recommendations on values of minimum and maximum illumination levels. It aims to provide a tool for setting up a common European policy and a guide to help curators, conservators and project managers to assess the correct lighting that can assure the safeguarding of the exhibits. This Technical Specification covers lighting for heritage objects on exhibition in both public and private sites and does not consider lighting in other cultural heritage contexts such as open-air collections, etc.

2 Normative references

Not relevant.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
accent lighting
lighting focused on an exhibit or a group of exhibits to emphasize them

[SOURCE: CIE S 017/E:2011]

3.2
annual luminous exposure
H_m
total luminous exposure per year (unit: lux hours per years, lx h / a)

Note 1 to entry: One year of museum display is approximately 3 000 h. See also 3.35.

3.3
blue wool test: test for light fastness
certified set of eight pieces of wool each dyed with a different specific blue dye graded to fade after a set exposure to light

[SOURCE: ISO 105-B08:1995]

Note 1 to entry: This system is usually referred as Blue Wool Standard (BWS) and it is used in museums to assess the radiation exposure of materials. The eight wool pieces are numbered #1 to #8, each about 2 to 3 times as sensitive as the next. High sensitivity is defined as materials rated #1, #2, or #3; medium as #4, #5, or #6; and low as #7, #8. A panel of selected blue wool samples is left at the measurement point and after a period it can be seen which samples have faded and the dose of light received determined.

3.4
colour rendering
effect of an illuminant on the colour appearance of exhibits by conscious or subconscious comparison with their colour appearance under a reference illuminant

[SOURCE: CIE S 017/E:2011 or IEC-IEV:1987, 845-02-059]

3.5
colour rendering index
R_a
derived from the colour rendering indices for a specified set of 8 test colour samples

Note 1 to entry: *Ra* has a maximum of 100, which generally occurs when the spectral distributions of the light source and the reference light source are substantially identical.

[SOURCE: CIE S 017/E:2011 or IEC-IEV:1987-845-02-61 and CIE 015:2004]

3.6
colour temperature
T_c
temperature of a Planckian radiator whose radiation has the same chromaticity as that of a given stimulus (unit: kelvin, K)

[SOURCE: CIE S 017/E:2011 or IEC-IEV:1987, 845-03-049; see also CIE 015:2004]

3.7
cultural heritage
tangible and intangible entities of significance to present and future generations

Note 1 to entry: The term "exhibit" is used in this standard for cultural heritage. In specific professional contexts, other terms are used: e.g. "artefact", "cultural property", "item".

[SOURCE: EN 15898]

3.8
damage potential
Pdm
ratio of effective damaging irradiance and the illuminance at a point on the surface for a specific light source (unit : W/lm)

3.9
daylight
visible part of global solar radiation

Note 1 to entry: When dealing with actinic effects of optical radiation, this term is commonly used for radiations extending beyond the visible region of the spectrum.

[SOURCE: IEC-IEV:1987, 845-09-84]

3.10
daylighting
lighting for which daylight is the light source

[SOURCE: CIE S 017/E:2011]

3.11
daylight factor
D
ratio of the illuminance at a point on a given plane due to the light received directly or indirectly from a sky of assumed or known luminance distribution, to the illuminance on a horizontal plane due to an unobstructed hemisphere of this sky, excluding the contribution of direct sunlight to both illuminances

Note 1 to entry: Glazing, dirt effects, etc. are included.

Note 2 to entry: When evaluating the lighting of interiors, the contribution of direct sunlight needs to be considered separately.

[SOURCE: CIE S 017/E:2011 and IEC-IEV, 1987, 845-09-087]

3.12
dosimeter
indicator measuring total irradiant exposure during a given time

Note 1 to entry: The above definition is valid in the context of the present Technical Specification and concerns with the light measurement only.

3.13
effective damaging irradiance
E_{dm}
radiant flux per unit area at a point on the surface weighted by the relative damage action spectrum (unit: watt per square metre, W m^{-2})

3.14
effective irradiance
E_{eff}: $E_{eff} = \int E_{e,\lambda}\, s(\lambda)\, d\lambda$
irradiance weighted on the spectral sensitivity of the materials constituting the exhibit

3.15
exhibit
object on display illuminated by natural and/or artificial light

3.16
filter
any device that modifies or reduces a portion of the electromagnetic spectrum

Note 1 to entry: Common filters are: coloured and neutral filters, conversion temperature blue (CTB) and conversion temperature orange (CTO) filters, UV or IR absorbing filters. Neutral-density filters decrease the transmitted light by a known amount without selecting any particular wavelength.

3.17
illuminance (at a point of a surface)
E
ratio of the luminous flux $d\Phi$ incident on an element of the surface containing the point, to the area dA of that element (unit: lux, lx = lm·m^{-2})

Note 1 to entry: It represents the quantity of light impinging on a surface.

[SOURCE: IEC-IEV, 1987, 845-01-038]

3.18
infrared radiation
IR
part of the electromagnetic spectrum with wavelength longer than those of the visible radiation, from about 780 nm to tens of micrometres

3.19
irradiance
E_e
radiometric quantity; the radiant flux per unit area at a point on the surface (unit: watt per square metre, W m^{-2})

3.20
lamp
source made in order to produce an optical radiation, usually visible

Note 1 to entry: This term is also sometimes used for certain types of luminaires (see below).

[SOURCE: CIE S 017/E:2011 and IEC-IEV, 1987, 845-07-003]

3.21
light
radiation that is considered from the point of view of its ability to excite the visual system

Note 1 to entry: It corresponds to the so-called visible radiation in the range between 380 nm and 780 nm.

Note 2 to entry: In the field of conservation, this term sometimes extends the range outside the visible portion, including parts of the ultraviolet (UV) and near infrared (IR) regions.

[SOURCE: CIE S 017/E:2011]

3.22
luminaire
apparatus which distributes, filters or transforms the light transmitted from one or more lamps and which includes, except the lamps themselves, all the parts necessary for fixing and protecting the lamps and, where necessary, circuit auxiliaries together with the means for connecting them to the electric supply

[SOURCE: CIE S 017/E:2011 or IEC-IEV 1987-845-10-001]

3.23
luminance
L
quantity defined by the formula:

$$L = \frac{d\Phi}{dA \cos \vartheta d\Omega}$$

where

L is the luminance in a given direction or at a given point of a surface

$d\Phi$ is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle dΩ containing the given direction

dA is the area of a section of that beam containing the given point

$d\Omega$ is the solid angle

ϑ is the angle between the normal to that section and the direction of the beam

(unit: $cd \cdot m^{-2} = lm \cdot m^{-2} \cdot sr^{-1}$)

Note 1 to entry: It corresponds to the light coming from a surface.

[SOURCE: CIE S 017/E:2011 or IEC-IEV, 1987, 845-01-035]

3.24
luminous flux
Φ
photometric quantity derived from the radiometric quantity radiant flux (radiant power) by evaluating the radiation according to the spectral sensitivity of the human eye (as defined by the CIE standard photometric observer) (unit: lumen, lm)

Note 1 to entry: It is the luminous power emitted by a source or received by a surface.

Note 2 to entry: For the practical use of this document, in this definition, the values used for the spectral sensitivity of the CIE standard photometric observer are those of the spectral luminous efficiency function V(*λ*) (photopic vision).

Note 3 to entry: See CIE S 017/E:2011 or IEC-IEV, 1987, 845-01-22 for the definition of spectral luminous efficiency, 845-01-23 for the definition of the CIE standard photometric observer and 845-01-56 for the definition of luminous efficacy of radiation and ISO 23539:2005(E)/CIE S 010/E:2004.

3.25
luminous intensity
I
luminous flux per unit solid angle in that direction (unit: candela, cd = lm sr^{-1} ; sr = steradian)

Note 1 to entry: It is the luminous flux on a small surface, divided by the solid angle that the surface subtends at the source (CIE S 017/E:2011 or IEC-IEV, 1987, 845-01-31).

Note 2 to entry: The candela is the base SI photometric unit. For its definition, see CIE S 17/E:2011 or IEC-IEV, 1987, 845-01-050 or the BIPM SI Brochure.

3.26
lux
symbol lx; SI unit of illuminance

Note 1 to entry: For more information see CIE S 17/E:2011 or IEC-IEV, 1987, 845-01-052 or the BIPM SI Brochure.

3.27
photometric quantities
quantities that are based on the perception of radiation by the human eye and are valid only for visible radiation

3.28
radiant flux
Φ_e
radiometric quantity representing the radiant energy transported per unit time into a region of space by electromagnetic waves (unit: watt, W)

3.29
reflectance
ρ
ratio of the reflected radiant or luminous flux to the incident flux in the given conditions

[SOURCE: IEC-IEV, 1987, 845-04-058]

3.30
relative damage potential
ratio of the damage potential of a specific light source and the damage potential of the CIE standard Illuminant A (2 856 K) (equals to the incandescent lamp); it is dimensionless and assumes values between 0 and 1

3.31
relative damage action spectrum
$s(\lambda)_{dm,rel}$
describes the wavelength dependence of the photochemical damage properties, such as fading; it is dimensionless and assumes values between 0 and 1

$$s(\lambda)_{dm,rel} = \alpha(\lambda) \cdot \frac{1}{\lambda} \cdot f(\lambda)$$

where

$\alpha(\lambda)$ is the spectral absorbance

$f(\lambda)$ is a function of wavelength determined by the receiving material

Note 1 to entry: It is normalised at 300 nm so that $\mathbf{s(\lambda)_{dm,rel}}$ = 1 for λ = 300 nm (see also Figure 1).

[SOURCE: CIE 157:2004]

3.32
sensitive exhibits
museum exhibits, which can be more or less affected by electromagnetic radiations and/or other environmental factors

3.33
source
object that produces light or other radiant flux

[SOURCE: CIE S 17/E:2011]

3.34
spectral sensitivity
s(λ)
describes the wavelength dependence of the material properties, such as fading; it is dimensionless and assumes values between 0 and 1

3.35
total luminous exposure
H
photometric quantity; it is the product of the illuminance by the time of the exhibit exposure; it is measured in lux·hours [lx·h]

3.36
ultraviolet radiation
UV
part of the electromagnetic spectrum with wavelengths from 10 nm to 380 nm

Note 1 to entry: In the museum context UV is usually considered to include wavelengths up to 400 nm.

4 Symbols

The notations adopted in this TS are summarized below.

Table 1 — Symbols

Symbol	Unit [a]	Quantity
H_m	lux-hours per year, lx·h per year	Annual luminous exposure
R_a	1	Colour Rendering Index
T_c	kelvin, K	Colour temperature
P_{dm}	watt/lumen, W/lm	Damage potential
D	1	Daylight factor
E_{dm}	watt per square metre, $W \cdot m^{-2}$	Effective damaging irradiance
E_{eff}	watt per square metre, $W \cdot m^{-2}$	Effective irradiance
E	lux, $lx = lm \cdot m^{-2}$	Illuminance
E_e	watt per square metre, $W \cdot m^{-2}$	Irradiance
L	candela per square metre, $cd \cdot m^{-2} = lm \cdot m^{-2} \cdot sr^{-1}$	Luminance
Φ	lumen, lm	Luminous flux
I	candela, $cd = lm \cdot sr^{-1}$	Luminous intensity
Φ_e	watt, W	Radiant flux

ρ	1	Reflectance
***s(λ)**$_{dm,rel}$*	1	Relative damage action spectrum
s(λ)	1	Spectral sensitivity
H	lux·hours, lx·h	Total luminous exposure
a non dimensional units are indicated by 1		

5 Sensitivity of cultural property to light

5.1 General

Light is one of several environmental factors to be considered in establishing a conservation policy.

A prerequisite for optimal lighting is good knowledge of present environmental conditions in the exhibition area. This can be obtained by regularly monitoring lighting conditions by means of regular measurements to account for daily and seasonal variations. Regular monitoring is recommended also after the first set up to provide information on the environmental conditions, so that corrective actions can be taken if necessary.

5.2 Mechanisms of damage

5.2.1 General

Light may damage vulnerable exhibits by three mechanisms:

— Photochemical,

— Radiant heating effect,

— Growth of biological organisms.

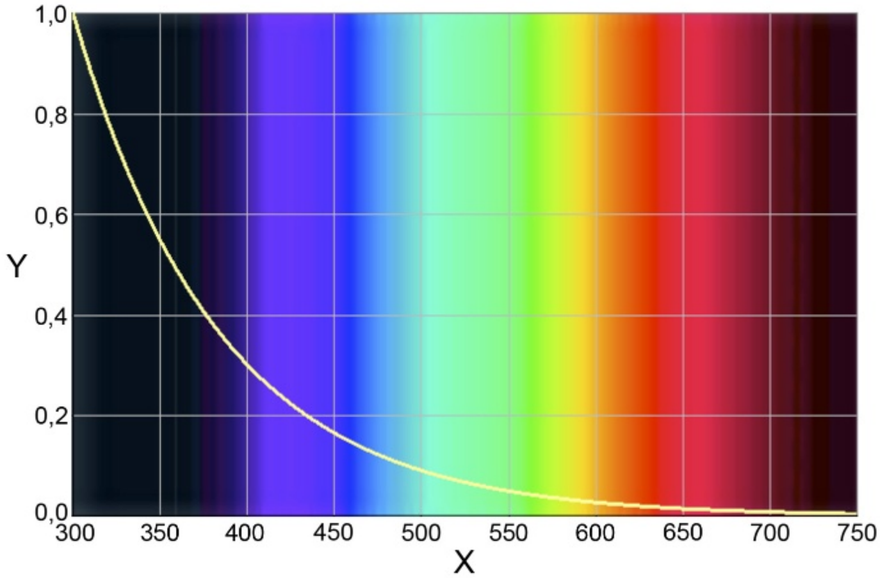
The extent to which materials deteriorate under given lighting conditions depends on their chemical composition, the characteristics of the light source, the illuminance levels and the length of exposure.

5.2.2 Photochemical

The absorption of light by a molecule or an ion can induce chemical changes, which result in changes of the mechanical properties and the colour of the material, thus altering the exhibit in an irreversible way. For the majority of light sensitive exhibits the damage is caused by the quantity of light (luminous exposure) and its spectral distribution. The effectiveness of damage exponentially increases with the decreasing wavelength. This means that usually the energy radiation of UV is much more damaging than blue light; blue light is more damaging than green light, and so on (see Figure 1).

Accordingly, it is recommended to minimize the presence of UV in display lighting. The maximum acceptable relative level of UV is 75μW/lm. This figure was originally chosen as it represented the amount of UV produced by tungsten lamps which were at that time regarded as safe for lighting exhibits. Indeed, lower relative levels of UV (such as 10μW/lm) can be attained either by using UV absorbers, on windows and electric light sources, or by employing sources with minimal or zero UV output, such as most white LEDs.

However, the elimination of UV for sensitive exhibits is not sufficient to avoid damage if visible light is not controlled and maintained below the values given in Table 3.



Key

X wavelength in nm

Y $s(\lambda)_{dm,rel} = e^{-0.012\ (\lambda/[nm]\ -300)}$

Figure 1 — Relative damage Y to photochemically sensitive surfaces versus wavelength X of incoming radiation

NOTE This graph is applicable for all Cat 2,3 and 4 exhibits (except newspapers), see also Table 2.

It has to be stressed that molecules, which make up the material, shall absorb radiation for a photochemical process to occur. For example, with a blue exhibit the blue light is being reflected from it and all other wavelengths absorbed by the material, so in this instance, green radiation will affect the exhibit more than blue or violet radiation. Accordingly, the spectrum of the lighting source has to be considered in comparison with the absorption spectrum of the more light sensitive molecules that occur in the material constituting the artefact by evaluating the effective irradiance.

Photochemical action of light by itself is independent of the surrounding environment, but the subsequent photochemical processes can be affected by other environmental factors such as temperature and relative humidity, oxygen and atmospheric pollutants.

5.2.3 Radiant heating

The energy supplied by radiation raises the temperature of the surface on which radiation impinges, depending on the amount of radiation that is absorbed, thermal conductivity within the exhibit, and convective exchanges. This may lead to expansion and thermal stress on the artefact, and desiccation, which can be caused by a decrease in local relative humidity due to the temperature rise. A higher temperature accelerates chemical reactions and photochemical processes. Radiation just beyond the visible red is called infrared radiation (IR) and is simply radiant heat. Thus, choosing light sources with little or no IR will reduce heat stress on the material being lit. However, it needs to be stressed that intense light could also produce heating effects.

5.2.4 Biological effects

Some phototrophic micro-organisms may live under specific wavelengths, particularly when combined with high relative humidity. Biological problems should be addressed by a team of specialists.

5.3 Sensitivity and classification for cultural property

Table 2 lists materials in four categories according to their sensitivity to light, but it does not consider possible damage due to heating effects.

Table 2 — Light Sensitivity classification of cultural property from CIE 157:2004

Category	Material description
1. No sensitivity	The exhibit is entirely composed of materials that are **insensitive to light**. Examples; most metals, stone, most glass, ceramic, enamel, most minerals.
2. Low sensitivity	The exhibit includes durable materials that are **slightly light sensitive**. Examples; most oil and tempera painting, fresco, un-dyed leather and wood, horn, bone, ivory, lacquer, some plastics.
3. Medium sensitivity	The exhibit includes fugitive materials that are **moderately light sensitive**. Examples; most textiles, watercolours, pastels, prints and drawings, manuscripts, miniatures, paintings in distemper media, wallpaper, and most natural history exhibits, including botanical specimens, fur and feathers.
4. High sensitivity	The exhibit includes **highly light sensitive** materials. Examples; silk, colorants known to be highly fugitive, most graphic art and photographic documents.

5.4 Limitations for total luminous exposure

The photochemical effect is cumulative and it is closely related to the total radiation absorbed by the exhibit. In the usual museum conditions the net photochemical effect on exhibits is the result of the total exposure. In other words, it is the cumulative effect on the exhibit lifetime, which matters. To assess the overall impact of light on an exhibit the annual luminous exposure is considered (expressed as lx•h per year).

Table 3 gives the recommended values of limiting illuminance and annual luminous exposure for the different classes of light sensitive exhibits. When more than one class of material is present, the limit to be considered corresponds to the most sensitive class.

Table 3 — Limiting illuminance and annual luminous exposure for different classes of light sensitive exhibit interpreted from CIE 157:2004

Material classification	ISO Blue Wool Standard (BWS)	Upper limit annual luminous exposure	Annual exposure time	Illuminance
1. Insensitive	-	no limit (for conservation)	no limit (for conservation)	no limit (for conservation)
2. Low sensitivity	7 & 8	600 000 lx·h per year	3 000 h per year [a]	200 lx
3. Medium sensitivity	4, 5 & 6	150 000 lx·h per year	3 000 h per year [a]	50 lx
4. High sensitivity	1, 2 & 3	15 000 lx·h per year	300 h per year [b]	50 lx

[a] Typical annual opening hours

[b] Resulting annual hours using 50 lx

The recommended limiting illuminances are based on the recommendations of diverse international authorities, such as AFE (Association Française de l'Eclairage), CIBSE (The Chartered Institution of Buildings Services Engineers) and IESNA (Illuminating Enginering Society of North America). These figures are a practical compromise between presentation and protection of exhibits in indoor exhibitions with lighting. If the limiting illuminance is exceeded, the rate of fade and damage to materials will increase. On the contrary, it has to be considered that lighting levels much below 50 lx, suggested for the Class 3 and 4, will result in poor viewing conditions and loss of perception of colour and surface details.

It should be taken into account that other physical or chemical factors (relative humidity, temperature, pollutants) can increase the adverse effects of light, so that in critical environmental conditions the above reported limits are strictly recommended. It has to be noted that in case 4 of the Table 3 15 000 lx•h /a corresponds to just 300 h exposure per year at a 50 lx illuminance (the minimum light level for discernment of colour and detail on an exhibit). Therefore, exhibits of high sensitivity to light should be removed from display into dark storage when their exposure limit is reached. Thus, a silk dress may be on permanent display at 50 lx, for eight hours per day, six days per week, for less than two months before reaching its annual exposure limit and needing to be put into dark storage. If the same dress was in a display case at 10 lx , but boosted by a proximity sensor to 50 lx when someone approaches, then the display period could be extended.

The actual damage potential of the spectrum of light from a particular light source on a particular material can also be taken into account to allow some flexibility in the annual exposure limits given in the Table 3. Annex D provides a summary of the relative damage potential for various combinations of light sources and filters.

6 Light measurement

6.1 Measurement of illuminance

Illuminance is measured with illuminance-meters, usually called lux-meters, using sensors that have a spectral response that matches that of the human eye. Several types of devices are available to measure indoor light levels, from simple hand-held meters to small units that transmit their readings back to a central data logger. Many of the hand-held meters have the measuring sensor on a lead that allows it to be placed on the surface being measured whilst the meter itself can be held close to the user so the readings can be easily seen. Meters should have a ‘hold’ button that allows a reading at arm’s length to be held until the meter can be brought close enough to be read. Measuring ranges for indoor illuminance-meters for conservation use should be in the range 10 lx to 10 000 lx and comply with CIE 69-1987 and EN 13032-1:2004+A1:2012. The devices should be calibrated annually to ensure accuracy.

When measuring light, the measuring sensor of the device should be placed at a number of positions where the light is perceived to be brightest: this will give a good guide to the peak illuminance on the exhibit. The measuring sensor’s surface should be placed on or very close to the surface of the exhibit being measured. It should be oriented parallel to the exhibit (flat on the surface) as the measuring sensor is calibrated to compensate for the varying angles that the light strikes the surface (cosine law). If the exhibit is not flat, the sensor should be parallel to the most exposed or vulnerable surface.

If the room is lit with electric light only, it is sufficient to take one set of measurements to determine the peak illuminance. The readings should be repeated and recorded periodically to take into account possible variations of lighting conditions. Special lighting during cleaning works and similar shall also be measured and taken into account in calculating the total annual luminous exposure.

If the room is lit with daylight, one set of measurements is not enough because light levels change with the weather, time of day and season. To establish the annual exposure in day lit spaces the monitoring should be done throughout one year to take into account the daily and seasonal variations. To do this readings have to be taken at regular intervals during each day of the year and the readings properly evaluated to arrive at the annual exposure expressed in lx·h per year. To make this process easier, automated data loggers are available that can log the light levels from one or more light sensors over the year and provide an annual figure.

The use of pre-existing data from external sources, such as meteorological offices, and modelling can be adopted if an early estimate of annual exposure is required.

The effective damaging irradiance can be measured with an adapted irradiance sensor in consideration of the definition of the relative damage action spectrum $s(\lambda)_{dm,rel}$. Another possibility is to calculate the effective damaging irradiance by using the irradiance of the light source at the different wavelengths.

A qualitative evaluation of the total luminous exposure can also be obtained by disposable sensors such as Blue Wool Standard cards or similar passive indicators or dosimeters, which fade or change their colour when exposed to light in a pre-defined way. These allow a user-friendly and satisfactory indication of the light dose received, expressed in terms of lx·h per year.

6.2 Measurement of UV radiation

The shorter wavelengths (UV and blue) have the highest energy and therefore cause the most damage to exhibited materials. As UV light is not normally required for vision (except for the display of fluorescing materials) it is advisable to filter this out or use low UV emitting light sources. To measure the level of UV light falling on exhibits, special UV meters are needed. There are two types available: absolute UV meters and relative UV meters. Some meters give both absolute and relative readings.

Absolute UV meters give a direct measurement in microwatt per square centimetre ($\mu W/cm^2$) of the UV falling on the measurement sensor. The relative UV meter was specially developed for museum use and measures the proportion of UV radiation present in the light. It gives a reading in microwatts of UV per lumen of light (μW/lm).

At present there is no standard for the spectral sensitivity of the measurement sensor used in relative UV meters so meters from different manufacturers may be measuring slightly different regions of the UV spectrum. The spectral sensitivity shall be verified to be suitable for museum use.

7 Exhibition lighting

7.1 General

The purpose of exhibition lighting is to present the exhibits in such a way that they may be studied and appreciated. In most cases this means providing a lighting system that enables fine detail to be examined to reveal the form, colour and texture of the exhibit. In some instances, the overall appearance of the display may be more important than the visibility of the individual exhibits, in which case some form of “effects” lighting may be required.

In general, exhibition lighting should provide a balance between a general wash of light and some form of accent lighting. It will also require a balance between the luminance and colour of the exhibit and its background. Exhibition lighting should also have good colour rendering properties and should be provided in such a way that it is not intrusive or causes discomfort or disability glare. The techniques of exhibition lighting may vary depending on the particular exhibits and whether they are freestanding or displayed in showcases. The basic philosophy, however, will be the same.

7.2 Viewing conditions

Usually, we see exhibits because they contrast with their background or surroundings. This general characteristic applies to everything we see, whether it is letters on a page or artefacts in a showcase. In general, we are looking for the exhibits to be not only visible but also to attract attention, adding the element of interest to visibility. Contrast should therefore be considered carefully when designing a display or a lighting installation. Similarly, labels need to be produced where the text has a suitable size and contrast with the background. Lighting then becomes a matter of providing the light on the labels that makes them as visible as the exhibits without competing with them.

It is also necessary to consider the shape / form of the exhibits, and particularly any textural quality. Having made the exhibit as a whole stand out, the detail should also be revealed. This will depend on the direction of light falling onto the exhibit at the most appropriate angle. The correct contrast and direction of light flow are therefore important in creating the best viewing conditions.

7.3 Visual adaptation

The eye reacts automatically to the brightness of a field of view adjusting rapidly for small changes in brightness and more slowly to larger changes. The eye becomes adapted to the general brightness of a space over a few minutes (for bright to dark) or several seconds (for dark to bright) and can then perceive exhibits and surfaces lit over a reasonable range above and below that level, known as the adaptation level. Most people have experienced this effect when moving from a brightly lit foyer into a dark cinema or theatre. In the foyer all exhibits and surfaces can be seen well but when moving into the much darker space it is difficult to find your way around. However, after a few minutes the eye adapts and all exhibits in the space become visible.

In museums and galleries this can be a problem when moving from very brightly lit entrance halls into exhibition spaces or when moving from a general gallery into one where extremely light sensitive exhibits, such as works on paper and textiles, are displayed at very low light levels. Where possible the lighting designer should discuss this issue at an early stage with the architect and exhibition designer and create lobbies or labyrinths between spaces with widely different lighting levels with the aim of aiding adaptation. These lobbies should be lit to an intermediate or graduated level between that in the two adjoining spaces. If there are displays of interpretive material in these lobbies then so much the better as visitors will dwell longer in them looking at the material and so helping the slow adaptation process.

It has to be stressed that allowing gradual adaptation to different light levels is helpful to the viewer but there is a limited advantage on the acuity and contrast sensitivity. This means that decreasing illuminance always results in poorer viewing conditions.

7.4 Contrast ratios

Given that an exhibit is to stand out to some degree against its background, it will be necessary to decide the contrast ratio required. This can be defined as the ratio between the luminance of the exhibit and the luminance of the background or surroundings. It shall be remembered, however, that luminance depends on both the illuminance falling on the exhibit and its reflectance. Thus, from the knowledge of the reflectance of the exhibit, the background materials used and the general lighting, the illuminance on the exhibit can be selected according to the effect required. (Alternatively, for light-sensitive materials where the maximum recommended illuminance is known, the ambient level on the background can be measured.)

Typically, the contrast between the illuminance on the exhibits and the general lighting of the gallery space (which is normally taken to be the average vertical illuminance) should range from 1:1 for no emphases, to 3:1 for moderate emphasis and to 10:1 for dramatic emphasis. If the contrast is significantly greater than this, viewing exhibits may become difficult as the level of illuminance on the exhibit will be much brighter than the level of visual adaptation of the viewer. It will also be necessary to limit the brightness (luminance) of the lighting equipment in normal directions of view. This is often not properly considered in museums and galleries, and insufficiently screened luminaires cause glare and visual discomfort.

Some form of accent lighting will usually achieve the highlighting of exhibits and so information will also be required about beam distribution. Many lamps and luminaires are available with different beam shapes and sizes. These range from very narrow to relatively wide beam; light beams can also have a soft or hard edge as preferred. Designers are advised to consult manufacturers for detailed information.

7.5 Colour appearance

The colour appearance of the light – whether it is cool white (above 5 300 K, typically daylight) or warm white (below 3 300 K, typically incandescent lamps) (see also EN 12464-1) – can have an effect on the mood of a space and the exhibits in it. If the exhibits are lit with a light source warmer than the general or background lighting then they will stand out more. However, if this is taken too far the effect may be garish or distracting. Lighting exhibits with a cooler light source to the background is normally less successful unless for a particular effect (for instance, lighting items that are meant to convey a ‘chilly’ feeling to the viewers). To avoid problems it is suggested that this effect should be tested with the particular display.

7.6 Colour rendering

Different light sources may have different effects on the perceived colours of exhibits depending on their colour rendering. An important point is that the colour of the light is no guide to its colour rendering properties.

Two sources may appear to be of similar colour appearance, but have different spectral distributions and hence different colour rendering performance. If there is little green in the spectrum of the light reaching an exhibit then no green of that shade can be reflected back, however green the exhibit might be. The Colour Rendering index *(R_a)* of a light source is measured on a scale up to 100. Light sources with R_a greater than 90 are considered to be very good, while those with R_a below 80 will normally not be appropriate for lighting exhibits in museum and galleries.

The colour rendering quality of a light source depends on its spectral distribution. Although incandescent lamps have a colour rendering index near to 100, their spectrum is biased towards the red. Thus, reds and oranges within exhibits may appear emphasised compared with their appearance in daylight, but the general colour balance is not seriously disturbed. On the other hand, some discharge lamps distort the appearance of the colours of exhibits and their background because of irregularities in their spectral distribution.

When tungsten-halogen lamps are dimmed the colour appearances changes and the light becomes far warmer – more orange. To avoid this effect the lamp wattages should be selected carefully so that the lamps do not need to be dimmed by more than about 20 %. For spaces where exhibition illuminance may be changed from 200 lx to 50 lx it is advisable to change the lamp wattages or to have an additional set of lights available for boosting the lighting from the lower to higher level. It is also possible to introduce neutral density filters or meshes to some types of spotlight so as to reduce the amount of light without affecting the colour rendering: this does however increase the heat within the luminaire and gives no reduction in the lighting load. With fluorescent lamps and LEDs dimming has little effect on the colour rendering.

7.7 Backgrounds to exhibits

7.7.1 General

The background against which an exhibit is seen not only influences the effectiveness of a display, but can also affect the adaptation state of the eye. Visual adaptation is dependent on two factors – luminance and colour.

7.7.2 Luminance of backgrounds

If the background areas within a space are significantly lighter or darker than the exhibit, this will alter the adaptation state of the eye, thus reducing the ability to see fine detail. The effect of contrast depends on the situations. For example, if dark exhibits are displayed against a light background, only a silhouette of the exhibits will be seen because the luminance ratio between the exhibit and background is too large for good visibility of the exhibit. Conversely, if light exhibits are shown against a darker background, the detail and shape of the exhibits will be appreciated because they are brighter than the average luminance range within the field of view.

It is important, therefore, that the luminance ratio between background and exhibit is not too large or too small. Since the luminance of an exhibit and its background is a function of the reflectance of the materials and the lighting level, care should be taken when selecting these values.

The above described effect decreases with increasing size of the exhibit and will vanish if the exhibit fills the complete field of view.

7.7.3 Colour of backgrounds

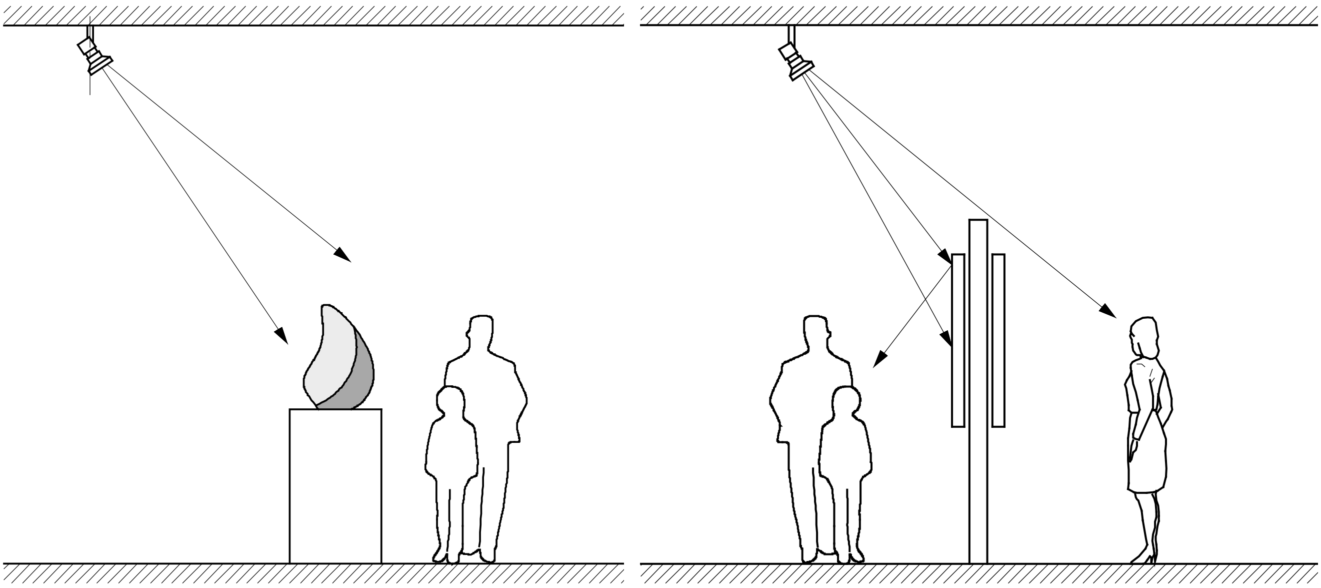
Just as the luminance of a background can affect the adaptation state of the eye, so can its colour. A strong coloured background will cause the chromatic adaptation mechanism to shift the perceived colours towards the complementary colour of the background. For example, a strong green background will have the effect of making a white exhibit appear pink. Large wall areas of a strong colour would also tint the light reflected back from it thus, affecting the colour of the light flowing across the gallery.

The lighting designer should discuss proposed colours and background textures with the architect or exhibition designer and fully understand the design intent before finalising lighting decisions. If the lighting designer has concerns he should endeavour to have a mock up built to allow the design team to assess the effects of colour and lighting decisions.

7.8 Glare

Glare is caused when luminaires, windows or other sources of light, seen either directly or reflected, are too bright compared with the general brightness of the field of view. It is important to eliminate glare from light sources and their reflections as they have a detrimental effect on visibility. Glare can impair vision (disability glare) or cause visual discomfort (discomfort glare).

In galleries and museums, glare could cause severe problems however, by rectifying factors such as relative siting of the exhibits, light sources and observers would usually allow the designer to overcome these issues. For example, direct glare from spotlights can usually could be avoided by ensuring that they are not elevated above about 35°. In certain locations providing glare shields or baffles to those lights could obscure the bright lamp from sight (Figure 2).



a) Light at high angles can cause glare to those viewing objects. Angles of elevation above 35° lead to more glare for viewers. Greater risk for glare at higher angles

b) Low partition walls allow glare from lamps to be seen.

Figure 2 — Glare

When looking at exhibits housed in a display case that is not internally illuminated, visibility is often impaired by the presence of reflections of outside light sources, illuminated displays or other exhibits. This reflected glare may be minimised by using anti-reflection glass, careful arrangement of the angle of the glass, or by internal lighting (Figure 3).

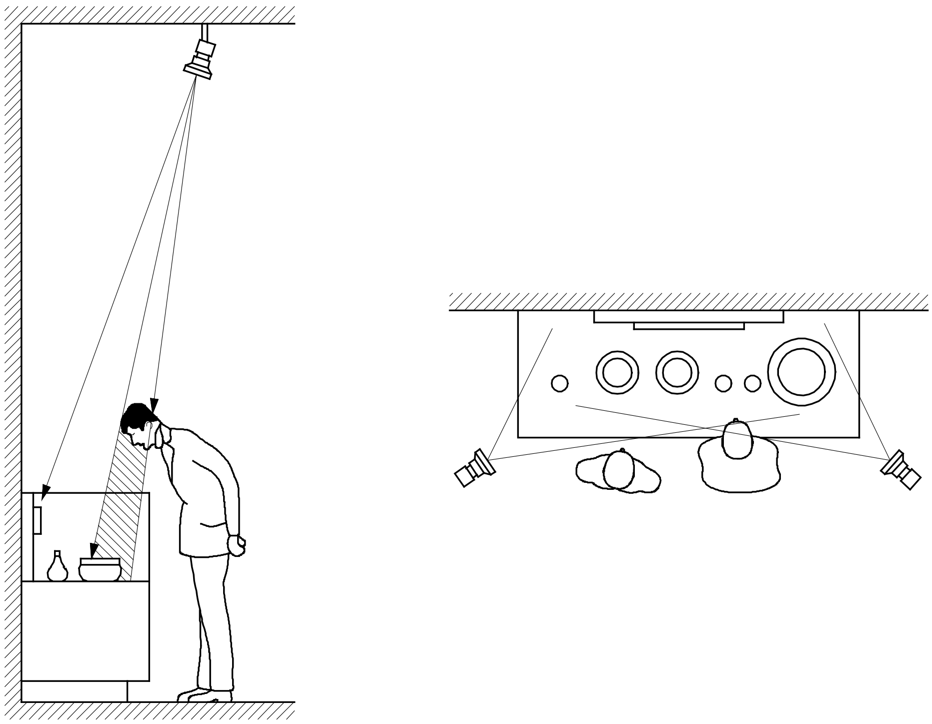


Figure 3 — Examples of recommended lighting arrangements for display boxes

Glare should not be confused with glitter and sparkle, which are characterised by points or patterns of high brightness caused by light reflecting from jewellery or polished metal exhibits. Usually the effects of glitter and sparkle are too small to affect adaptation and vision, but will often improve the display.

In addition to glare directly from lamps, fittings that allow light leaks or back scatter from exposed reflector lamps frequently could cause distraction and unwelcome reflection patterns in glazed displays. Lights with full enclosure of the lamp with no light emitted except in the intended direction should generally be selected.

7.9 Modelling

Modelling effects of light reveal the shape and texture of exhibits. The degree and type of modelling will depend on the angle of the light reaching an exhibit and on how diffused it is. Highly diffused frontal lighting tends to flatten shape and form, and reduce the perception of texture. In paintings, such lighting may also cause veiling reflections that reduce tonal and colour contrasts. Using just strong directional light from a concentrated source could give a harsh effect, due to the strong highlights and sharply defined shadows produced. Such lighting is well suited for displaying carving in low relief. On paintings, a degree of directional light can also enhance the appreciation of the brushwork.

Daylight (without direct sun) usually produces soft modelling. This can be localised to some extent by manipulating the position and size of windows and roof lights, or by obscuring them with screens or louvres. The changing character of daylight is not necessarily a disadvantage, and may even be welcome for the lighting of sculpture where subtle modelling effects are essential to effective display. If the exhibit would not be damaged by exposure to direct sunlight, this could be used to enhance the modelling effects.

Spotlights, which provide beams of light, are used to create visual accents, modelling and highlights in the exhibits. The size of the beam is important to determine whether one beam will be sufficient to illuminate the exhibit, or if several overlapping beams will be required. Most beams are conical in shape so a description of the beam angle and the distance of the light from the exhibit should be sufficient to work out the coverage. The beam angle defines the angle beyond which the intensity falls below half the maximum luminous intensity. The light falling outside the main beam is described as spill light. The amount of spill light will affect the contrast that ultimately can be achieved. For example, a beam with a lot of spill light will illuminate the background as well as the exhibit, reducing the contrast and, therefore, the emphasis of the exhibit itself. A focused beam provides a much sharper cut-off leading to a more defined effect on the exhibit and less effect on the surroundings.

The best modelling for a given exhibit can be found by simple experiment with a hand-held spotlight on a flying lead. This can also allow other, sometimes conflicting, requirements of the lighting, such as freedom from glare, to be considered at the same time so that the best overall solution can be devised.

7.10 Historic furnishings & interiors

When an historic building (e.g. castle, ancient palace, church) is being exhibited, appropriate lighting shall be provided. If a room is exhibited by itself because it is furnished with period artefacts (e.g. frescoes, furniture, tapestry), then the visible lighting shall be appropriate for the interior. Additional concealed lighting could be used to provide proper highlighting of items or features in the space. When the building is primarily used for displaying exhibits or pictures, however, a different approach is necessary. Advice given in previous sections of this document should be considered, but the actual methods by which the exhibits are lit would depend on the circumstances. For example, it may be considered appropriate to use modern display techniques designed and installed in such a way that the integrity of the building is maintained.

7.11 Simulation and mock-ups

Before specifying a particular lighting technique for displays, whether freestanding or in a showcase, the designer could consider producing a computer simulation and/or a physical mock-up of the design to ensure that it provides the performance required. This is also useful to demonstrate a design approach to others who may not have experience or knowledge of the types of lighting that is available or possible. Such mock-ups do not need to be an elaborate or an expensive construction, but they should be sufficiently detailed to test the proposal and to identify any deficiencies in the lighting equipment and its installation. It could avoid costly mistakes and problems in the final installation.

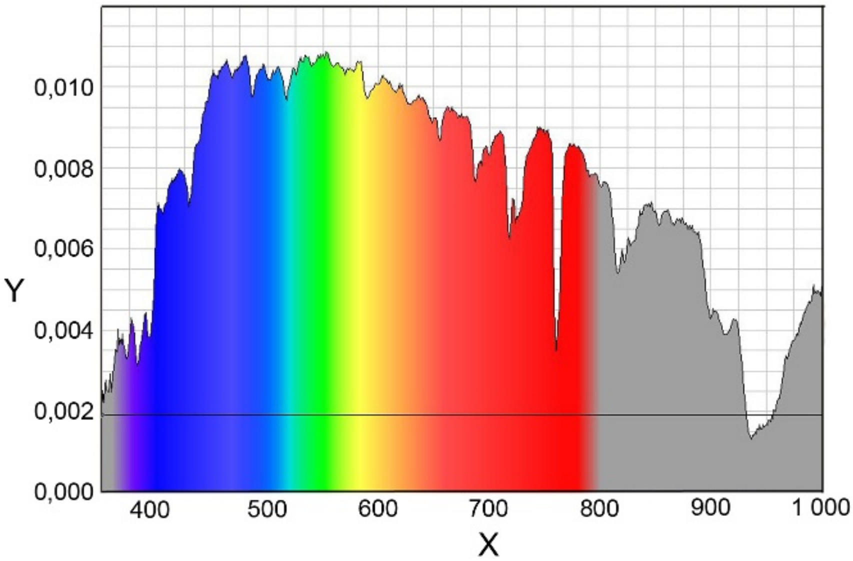
Annex A
(informative)

Characteristics of light sources

A.1 Daylight

Daylight comprises both light direct from the sun and sunlight scattered by particles in the atmosphere.

Besides visible light, solar radiation contains, among others, ultraviolet and infrared radiation. Its spectral content, intensity and spatial distribution, in the exhibition space depend on weather conditions, day hour, season of the year, latitude and the orientation of windows. It can be modified by the use of different glasses, curtains and so on. Accordingly, the colour temperature can span a very wide range: it can be as low as 2 500 K (sun at sunset) and as high as 20 000 K (clear blue sky in a continental area) or even more in particular conditions and sites. Also the illuminance can vary to a large extent (up to several ten thousand lx for direct sun light).



Key

X wavelength, nm

Y spectral radiance, W/steradiant•m^2•nm

Figure A.1 — Daylight lamp Tc = 5400 K

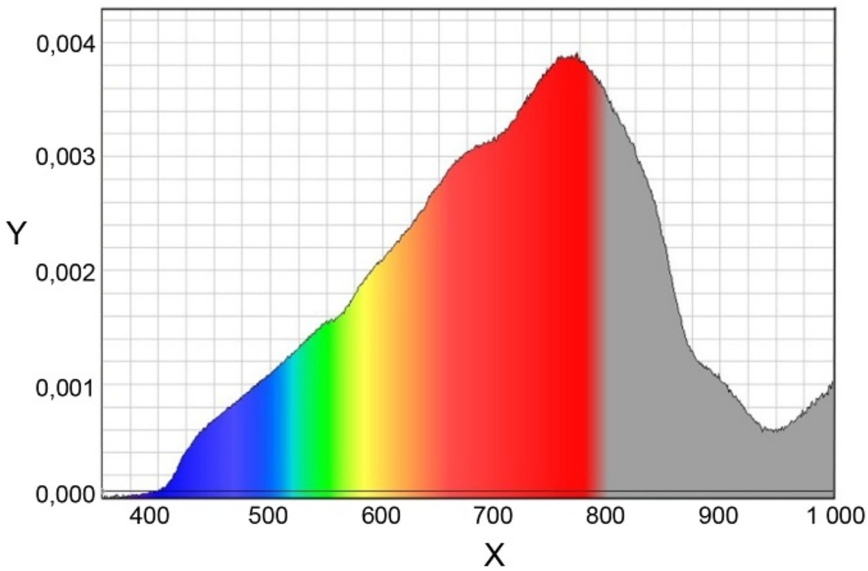
A.2 Electric sources

A.2.1 General

Until the widespread introduction of electric lighting in the middle of the nineteenth century all lighting was generated by flame sources. The cost and difficulties involved with their use ensured that they were always treated as secondary light sources to daylight. Reliance on such sources for lighting over several thousand years has affected expectations of light levels, visibility and colour temperature, as all such sources have low colour temperatures ~ 2 500 K. Compared to flame sources, electric lighting is a clean and less risky alternative and became the preferred light sources during the twentieth century. It was, however, only with the development of such sources with focused beams, that attention was concentrated on exhibits by making them brighter than their surroundings thus allowing much of current exhibition design practice to develop. The introduction of fluorescent and metal halide light sources in the second half of the twentieth century gave rise to concern for the spectral characteristics of light sources and this was accompanied by a growing appreciation of the potential damage caused by light on sensitive materials. These concerns encouraged a widespread shift from day lighting to electric lighting for exhibitions and more recently the choice of light sources available has been extended to solid state light sources, notably LEDs. The characteristics of each available lights sources need to be carefully considered before they are employed. Many commonly used incandescent light sources, including the less efficient spot bulbs, are being withdrawn in the EU (see the Commission Regulation EC n. 244/2009) and this process is due to continue during the duration of this document.

A.2.2 Incandescent lamps

The early artificial light sources (e.g. candles, oil lamps, gas lamps, etc.) were all incandescent sources, i.e. emitted radiation originated from heated materials. At present, the only incandescent sources in use are tungsten-based lamps. A tungsten filament is heated by the passage of an electric current, resulting in an emission spectrum that approximately follows the black body radiator. In tungsten-halogen lamps the light bulb is filled with a halogen gas to increase the life time of the lamp. Most of the radiation emitted by tungsten lamps is in the near infrared region and only a small fraction of UV radiation (about 2 % of the visible radiation) is emitted. Although the ultraviolet radiation emitted by tungsten-halogen lamps is greater than that from tungsten lamps, as mentioned above, some models of tungsten-halogen lamps sold in the EC and US have an ultraviolet filter incorporated in the glass envelope to reduce ultraviolet emission below the level emitted by a standard tungsten lamp. The addition of the halogen gas shifts the emission peak towards the shorter wavelengths and, accordingly, the colour temperature rises from about 2 700 K (tungsten filament) to about 3 200 K. R_a (about 100) is excellent.



Key

X wavelength, nm

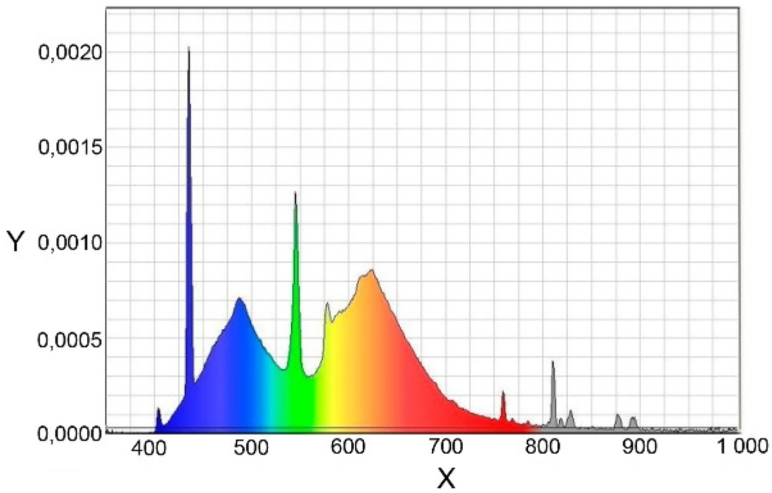
Y spectral radiance, W/steradiant•m^2•nm

Figure A.2 — Tungsten halogen dichroic lamp Tcp = 3 000 K

For energy savings use only ECO or IRC type of halogen (less 30 % energy). Luminous efficacy of the complete lighting system is 15 - 23 lm/W and the life duration is > 2 000 h. These lamps are easily dimmed with an increase of lifetime of the source, but a reduction of colour temperature.

A.2.3 Fluorescent lamps

Fluorescent lamps are based on discharge of electricity between two electrodes in a tube filled with low pressure vapour or gas (typically mercury). The tube is coated with phosphors, which re-emit radiation in the visible region when they absorb the UV radiation generated by the electric discharge. The emission spectrum of these lamps is a continuum over which the emission lines of the gas are superimposed. The colour temperature and the colour rendering index of fluorescent lamps depend on the blend of phosphors and they span, as a rule, from 3 000 K up to about 6 500 K and more (7 500 K, 8 800 K and 15 000 K) and R_a from 80 to 98, respectively.



Key

X wavelength, nm

Y spectral radiance, W/steradiant•m^2•nm

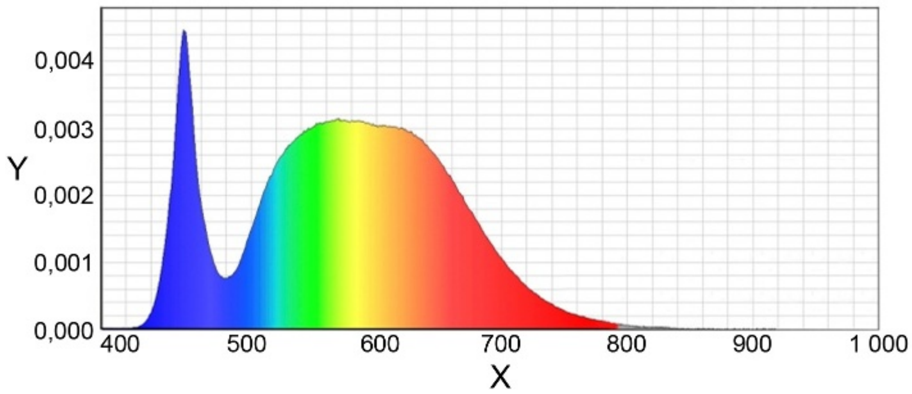
Figure A.3 — Fluorescent tubular lamp Tcp = 5 000 K

Luminous efficacy of the complete lighting system is 75 - 95 lm/W and the life duration > 20 000 h. These lamps are easily dimmed when equipped with appropriate dimming ballasts.

A.2.4 Solid State Lighting

Solid-state lighting (SSL) is a type of lighting source that uses semi-conducting materials to convert electricity into light. We distinguish: light-emitting diodes (LEDs), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED).

At present, LED’s are more and more widely used for lighting in museums and galleries. They are based on semiconductors, which emit light after application of a suitable voltage. Individual LEDs emit a single colour of light, however, it is possible to obtain white light if the surface of UV or blue LEDs is coated with fluorescent materials emitting in the green to red region. This converts the original emitted colour and produces a clean white light. Colour temperature of white LED’s can vary between 3 000 K and 6 000 K.

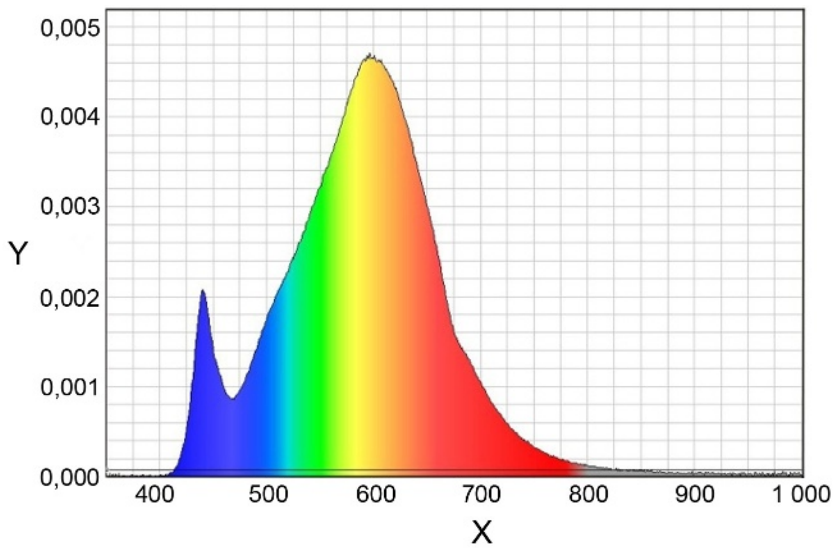


Key

X wavelength, nm

Y spectral radiance, W/steradiant•m²•nm

Figure A.4 — LED 20 W Tcp = 4 100 K



Key

X wavelength, nm

Y spectral radiance, W/steradiant•m²•nm

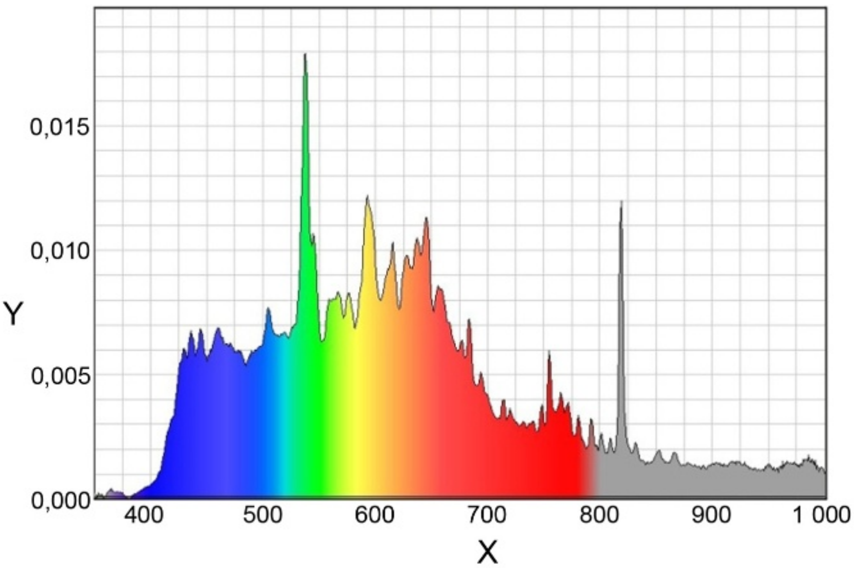
Figure A.5 — LED 10 W Tcp = 3 100 K

Luminous efficacy of the complete lighting system is 70 - 95 lm/W at present, with a R_a of about 80. LEDs with a higher R_a (up to > 95) are available and preferable but with a lower luminous efficacy. Luminous efficacy and R_a are increasing with each new generation. The life duration (for 70 % of luminous flux) is about 50 000 h and more but should be better in the future with technical development. The life duration is a function of the thermal dissipation and any increase of the operating temperature, especially for the high power LEDs (power greater than 1 Watt), will reduce life. It's possible to dim these sources when equipped with appropriate dimming drivers.

OLEDs and PLEDs are a rapidly developing technology and these lights are generally produced in the form of a flexible panel or screen. This potentially makes them useful for back lighting of transparencies.

A.2.5 Metal Halide lamps

These are gas discharge lamps, like fluorescent lamps, but under a higher pressure. The discharge takes place in a small space: the burner, in which mercury is added to rare earth and other metals halides. For high quality lamps, the emission spectrum consists of a multitude of lines equivalent to a continuous spectra of up to a R_a near 95. Latest ceramic burners offer greater stability of the flux and colour temperatures. For these lamps colour temperature is between 3 000 K and 6 000 K. The powers for exhibitions areas ranges from 20 to 400 W, with a life ranging from 10 000 h to 15 000 h and luminous efficiency greater than 90 lm/W. They exist with a low amount of UV radiation.



Key

X wavelength, nm

Y spectral radiance, W/steradiant•m^2•nm

Figure A.6 — Metal halide lamp

Annex B
(informative)

Glasses and films characteristics

B.1 Glasses

Glasses differ not only in their physical and chemical characteristics but also by their properties, for example solar protection, light control and protection against ultraviolet radiation.

— Clear glass, standard or tempered, filters out a small proportion of the ultra violet radiation. The overall transmission of visible light depends on the thickness and number of sheets making up the window,

— Tinted glass of neutral hue, reduces transmission without distorting the colour of the light,

— Reflective glass provides solar protection by reflecting predominantly infra-red light, reduces the luminous flux transmitted into the space but will change the colour temperature and colour rendering of the daylight. The strong reflection of the solar radiation can cause reflected glare to those outside,

— Laminated glass incorporates a butyral or polyvinyl film in a layer between two sheets of the previous glass types; laminated glass also provides a high level of security and can provide UV protection (95 %).

B.2 Window films

To improve the performance of existing clear glass windows, a self-adhesive film can be added. Different kinds of films can be used:

— neutral density films, which reduce the overall transmission of daylight through the window without distorting the colour of the light (available in various densities),

— UV protection films eliminate up to 99 % of ultraviolet radiation, (can be incorporated in neutral density films to both reduce UV and visible transmission at the same time),

— reflective or semi-reflective solar films reduce penetration of infrared radiation. They serve as a good supplement to UV protection.

Older windows may have glass of historic significance, which can be damaged by the application of films. Accordingly, direct application of films to old glasses should be avoided.

B.3 Other protection

Windows can be equipped with architectural implements such as shutters, curtains and blinds, outside or inside. The effectiveness of these devices is improved if they are put outside rather than indoors although their operation and maintenance becomes more difficult. They can be operated manually, electrically or even automatically.

Annex C
(informative)

Filters

The light emitted by a source, whether a halogen lamp, a discharge lamp, or a fluorescent lamp, needs often to be modified in its spectral distribution and/or its distribution in space in order to accomplish good illumination. Filters may be used for this purpose on many types of spotlight.

Filters are constituted of a transparent material or translucent, origin mineral (glass) or organic (plastic). They have optical characteristics such as transmission, absorption and reflection. There are two different types of filters: glass filters, themselves divided between filters by absorption and filters by reflection of the unwanted party of the spectrum, and plastic filters , for example polyester or polycarbonate.

There are different filters categories:

— UV absorbing (to reduce the proportion of UV in the light beam).

— Infra-red absorbing (to reduce the proportion of IR (heat) in the light beam).

— Neutral density (reduces intensity of light by 25 %, 50 % or 75 % without changing the colour quality).

— Conversion (to increase or decrease the colour temperature).

— Colour correction (for example to dim the greenish part of a fluorescent lamp).

— Coloured (saturated colours to deliberately produce striking coloured effects).

— Diffusion (for diffusion and softening of the beam).

— Mixed (for example neutral density, conversion and diffusion).

Annex D
(informative)

Relative damage

The damage potential results from the ratio of the damaging irradiance and the illuminance on the exhibit. It differs with the emission curves of the light source (see also Figures A.1 to A.6).

The relative damage potential given in Table D.1 refers to the photochemical action of unfiltered incandescent light. Regarding the relative damage potential it is possible to estimate the typical effect of a light source with and without filters compared with an incandescent lamp.

For example: the daylight through double glass windows is more than two times damaging as the light from an unfiltered incandescent lamp with the same illuminance on the exhibit.

Table D.1 shows typical data. If it is intended to use the relative damage potential to argue illuminances or presentation times that differ from those given in Table 2, it is necessary to calculate the relative damage potential with the specific spectral distribution of the light sources (by means of measured data or data provided by the manufacturer).

The usage of edge filters with cut off wavelength up to 420 nm may slightly affect the colour rendering and colour appearance.

Table D.1 — Typical relative damage potential for various light sources (methods to calculate the damage potential for specific light sources are given in CIE 157:2004)

Light source	**Without filter**	**Edge filter Cut off wavelength in nm**			**Window glass (floatglass)**	
		380	400	420	single	double
Daylight (D65)	2,80	1,85	1,60	1,25	2,40	2,30
Incandescent lamp (CIE SI A)	1,00	0,90	0,85	0,80	0,95	
Low voltage halogen lamp	1,20	1,00	0,90	0,85	1,10	
Fluorescent lamp cool white (4 000 K)	1,20	1,10	1,05	0,90	1,15	
Fluorescent lamp warm white (3 000 K)	1,05	0,90	0,85	0,75	1,00	
LED cool white (4 000 K)	0,95	0,95	0,95	0,90	0,95	
LED warm white (3 000 K)	0,75	0,75	0,75	0,75	0,75	

Annex E
(informative)

Lamps and lighting attachments

For general lighting of a space for cleaning and maintenance work, suspended, ceiling mounted or recessed fluorescent or LED lights should be used.

Spotlight and fittings for highlight use ceiling mounted or recessed spotlights, or track mounted spotlights. Only the latter gives the choice to change the type of spotlight for specific lighting (focused projector, profile spot, wall washer, etc.). It is possible to add different fittings to a spotlight, such as a louver for glare reduction, snoots for reducing spill light, barn-doors for blocking a part of the beam, and filter attachments.

Fibre optic systems: the use of optical fibres has many advantages: a) little aesthetic impact on the exhibit on display; b) their flexibility makes it possible to illuminate cases of limited accessibility (for instance in showcases); c) the optical fibres can cut the UV and IR radiation and reduce heating, and the light source, whatever it is, can be placed far from the exhibits; d) finally, external maintenance of the light source adds security to the system, because frequent opening of display cases are avoided.

Bibliography

[1] EN 12464-1, *Light and lighting - Lighting of work places - Part 1: Indoor work places*

[2] EN 12665, *Light and lighting - Basic terms and criteria for specifying lighting requirements*

[3] EN 13032-1:2004+A1:2012, *Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 1: Measurement and file format*

[4] EN 15898, *Conservation of cultural property - Main general terms and definitions*

[5] ISO 105-B08:1995, *Textiles - Tests for colour fastness - Part B08: Quality control of blue wool reference materials 1 to 7*

[6] AFE. *La lumière et la protection des objets et spécimens exposés dans les musées et galeries d'art*. Société d'Edition LUX, Paris, 1997

[7] AFNOR. Couleurs - Eclairage et protection contre la lumière des objets colorés exposés dans les musées et galeries d'art, FD X40-502, Paris, 1963

[8] AFNOR. Prescriptions de conservation des documents graphiques et photographiques dans le cadre d'une exposition, Norme AFNOR Z 40 010, Paris, 2002

[9] ASHLEY-SMITH J., DERBYSHIRE A., PRETZEL B. The continuing development of a practical lighting policy for works of art on paper and other object types at the Victoria and Albert Museum, preprints of 13 ICOM-CC triennial meeting Rio de Janeiro, 22 – 27 September 2002, ed: Roy Vontobel, Preprints Vol. 1 pp 3 - 8, James & James (Science Publishers) Ltd, GB, 2002 ISBN: 1-902916-30-1

[10] AYDINLI S., HILBERT G., KROCHMANN E., KROCHMANN J. On the Deterioration of Exhibited Museum Objects by Optical Radiation, Division 6 Report, CIE Technical Report. *CIE-Publ.* 1991, **89** pp. 25–36

[11] BROMELLE N.S. The Russell and Abney Report on the Action of Light on Water Colours. *Studies in Conservation*. 1964, **9** pp. 140–152

[12] BACCI M., CUCCI C., MENCAGLIA A.A., MIGNANI A.G., PORCINAI S. Calibration and Use of Photosensitive Materials for Light Monitoring in Museums: Blue Wool Standard 1 as a case study. *Studies in Conservation*. 2004, **49** pp. 85–98

[13] CAMUFFO D. *Microclimate for Cultural Heritage*. Elsevier, Amsterdam, Second Edition, 2013

[14] CIBSE. Lighting Guide LG8: Lighting for museums and art galleries, London, 1994

[15] CIE 089/3:1991, On the deterioration of exhibited museum objects by light, CIE Technical Collection 1990 - ISBN: 9783900734268

[16] CIE Technical Report, CIE-Publ. 89, S. 25-36, 1991, ISBN: 9783900734268

[17] CIE 157:2004, *Control of Damage to Museum Objects by Optical Radiation ISBN: 9783901906275*

[18] CIE 015:2004, *Colorimetry, 3rd edition ISBN: 9783901906336*

[19] CIE S 010/E:2004 (ISO 23539:2005) Photometry - The CIE system of physical photometry

[20] CIE S 017/E:2011, ILV: International Lighting Vocabulary

[21] IEC/CIE 017.4-1987 *International lighting vocabulary, part 845, ISBN: 3900734070*

[22] CUTTLE C. Light for Art's Sake – Lighting for Artworks and Museum Displays, Butterworth-Heinemann, Oxford, Burlington, 2007. ISBN-13: 978-0-7506-6430-1 and ISBN-10: 0-7506-6430-4

[23] Direction des musées de France, Eclairage, Muséofiches, DMF, Paris, 1998

[24] EZRATI J.-J. *Théorie, technique et technologie de l'éclairage muséographique*. Editions AS, Paris, 2002

[25] IBN. Code de bonne pratique de l'éclairage des oeuvres d'art et objets de collection, NBN L13-003:1980, Bruxelles, 1980

[26] IESNA. Museum and art gallery lighting: a recommended practice, RP-30-96, New York, 1996, ISBN: 087995132X 9780879951320

[27] ISO 23539:2005 (CIE S010/E:2004) Photometry -- The CIE system of physical photometry, ICS: 17.180.01

[28] Italian Ministry for Cultural Properties and Activities, Atto d'indirizzo sui criteri tecnico-scientifici e sugli standard di funzionamento e sviluppo dei musei, D.M. 10.05.2001, Gazzetta Ufficiale Repubblica Italiana n. 244, Suppl. Ord. Serie Gener. 19.10.2001

[29] MICHALSKI S. *Damage to objects by visible and ultraviolet radiation in "Lighting in Museums, Galleries and Historic Houses"*. Museums Association, London, 1987, pp. 3–16.

[30] MICHALSKI S. The lighting decision. In: *Fabric of an Exhibition: An Interdisciplinary Approach, Preprints*. Canadian Conservation Institute, Ottawa, 1997, pp. 97–104.

[31] SHAW K. Lighting the show, Manual of museum exhibitions, Lord and Lord (Editor), Altamira Press, 2001, pp. 207-214, 437-441. ISBN: 0759102341 ISBN 13: 9780759102347

[32] THOMSON G. The Museum Environment, Second Edition, Butterworths, London, 1986. ISBN: 0750620412 ISBN 13: 9780750620413

[33] WYPYCH G. *Handbook of Material Weathering*. ChemTec Publishing, Toronto, 2008

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

bsi.

...making excellence a habit.™