TECHNICAL SPECIFICATION

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Imaging materials — Photographic prints — Effect of light sources on degradation under museum conditions

Matériaux pour l'image — Épreuves photographiques — Effet des sources de lumière sur la dégradation dans des conditions de musée

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 42, *Photography*.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

One of the typical uses of prints in museums is their display in a permanent or temporary exhibition under ambient light or artificial illumination. In general, prints may fade due to various environmental stresses, such as light, heat, humidity, pollutants, or biological attack, and the combination of these factors. A museum can fully or partially control and suppress most of those factors. However, light is necessary for display and will cause some degradation over time[1].

This document will provide guidance on how to assess light exposure-related damage to analogue and digital photographic prints under museum display conditions for particular print materials sets. The choice of the light source with the lowest damage potential depends on the specific material types in the mix and the spectral irradiance of the light source.

The document can be of benefit to curators, conservators and lighting designers to select the display lighting with the lowest possible damage potential to an exhibition. It can serve the manufacturers for lighting materials to develop particular solutions for the museum.

Depending on the use case, material type and conditions, a two-tier evaluation may be possible.

Tier I evaluation is useful for comparison of different light sources, namely, to identify the light source that will result in smallest image fading (ΔE) under a given exposure level (lx-h).

Tier II evaluation is useful to estimate appropriate illumination levels (lx) to reach intended display duration, if the following conditions are met (see Annex A for detailed discussion):

a) the museum is able to display the work with a light source having the same relative spectral irradiance (RSI) as the one used for the testing; and

b) a set of representative test samples is available that have the same types of colourant and substrate material as the display work, and

c) the assumption of linearity of image fading in response to different levels of light intensities (reciprocity) is verified, for which test results under different combinations of illumination intensity (lx) and duration (hours) are compared.

A test method of light stability for simulated daylight in indoor display is described in ISO 18937. Future ISO 18937-1 is a description of a general test method and future ISO 18937-2 is a test method with xenon light but which does not cover the particular museum display use case. Therefore, the covered range of environmental conditions and wavelength of light is broader than what is required for this document. It would be difficult to translate the test results following ISO 18937-1 into a specification for museum print display requiring practically no degradation.

This document follows the recommendations of ISO/TS 21139-1:2019, Clause 4[2] for the definition of a museum use profile and specifications, although the museums use case is not in the scope of ISO/TS 21139-1.

Imaging materials — Photographic prints — Effect of light sources on degradation under museum conditions

1 Scope

The test method in this document is intended to be used to characterize and compare the degradation of a set of print materials under exposure to particular light sources, eventually including optical filter combinations, under museum environmental conditions. The document covers typical types of indoor light sources commonly found in a museum including indoor daylight, LED, and incandescent light.

This document is applicable to analogue and digital reflection photographic prints.

NOTE Examples of photographic prints covered by this document are prints made with digital printing technologies such as inkjet, electrophotography, and thermal dye transfer, as well as prints made on silver halide colour paper but not prints made on black and white silver halide paper.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18913, *Imaging materials — Permanence — Vocabulary*

ISO 18937:2020, *Imaging materials — Photographic reflection prints — Methods for measuring indoor light stability*

ISO 18944, *Imaging materials — Reflection colour photographic prints — Test print construction and measurement*

3 Terms, definitions, and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 18913 and the following abbreviations apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

NOTE SAA also maintain a terminological database:

— SAA online glossary available at https://www2.archivists.org/glossary

3.1
Mlx-h
abbreviated from Mega lux hour, a unit of light exposure, product of illuminance and time

3.2
spectral irradiance
SI
spectral power distribution
SPD
power per unit area per unit wavelength of an illumination

3.3
relative spectral irradiance
RSI
relative distribution of irradiance power per unit area per unit wavelength, across (and normalized in) a given range of wavelengths. In this document, the wavelength range of interest is from 300 nm to 800 nm

3.4
duplicate
one of multiple copies of an object made at the same time from the same master

3.5
limiting exposure
accumulated exposure level in *Mlx-h* (3.1) or kJ/cm^2 which causes unacceptable level of deterioration

3.6
safe display duration
estimated accumulated display duration that will not cause a change exceeding the level accepted by the user

Note 1 to entry: Generally, accumulated intermittent exposures will have the same effect as one long exposure to the same overall level. The safe display duration can be split into several periods

3.7
Planckian radiator
ideal thermal radiator that absorbs completely all incident radiation, whatever the wavelength, the direction of incidence or the polarization

Note 1 to entry: This radiator has, for any wavelength and any direction, the maximum spectral concentration of radiance for a thermal radiator in thermal equilibrium at a given temperature

Note 2 to entry: A Planckian radiator is sometimes called "black body".

3.8
print material set
defined mix of print materials comprising types of print technology and historic period representative for a collection of print materials to be displayed under a specific display light

4 Use profile

4.1 General

This document describes how to evaluate the light stability of a set of photographic print materials on display under museum environmental conditions. The prints are displayed either framed or un-framed, continuously or intermittently lit, mounted on a wall or in an exhibition case. The use profile requires that the indoor environmental conditions are monitored and precisely controlled.

4.2 Stress factors in museum use profile

Most museum standards require light levels to be adapted to the light fading sensitivity of the colour print, in order to avoid any visible change. However, for light sources such as LED or OLED, that cannot be described as Planckian radiators, the illumination level is no longer sufficient to characterise the irradiance on a print. The use of illumination level and RSI in the 300 nm to 800 nm range is required to characterize a display condition.

Table 1 shows the set of stress factors to be considered in order to decide whether this document may be used. This document shall only be applied to prints intended for display under museum conditions, where the stress factors apart from light are within the recommended range of Table 1.

Table 1 — Assessment of stress factors

Stress factor	Permitted level
temperature	typical day-night cycle of temperature in the range 18 °C to 24 °C
relative humidity	30 % to 55 %
ozone	low ozone level (<2nl/l)[3]
other pollutants	as indicated in reference[4]
biological agents	absent

NOTE The acceptable level of pollutants depends on the types of materials in the collection, some of which can exhibit a particular sensitivity to certain types of pollutants. For example, dye based inkjet prints can be very sensitive to ozone. Sensitivity to ozone can be tested as per ISO 18941[3].

Throughout this document, the term degradation means degradation due to light exposure only. Apart from stress during display, colour prints can suffer damage from shipping, handling, and mounting. The sensitivity to bending, folding and abrasion may vary widely among materials and should be taken into consideration when preparing the display. However, mechanical stress such as abrasion and folding are not part of the display conditions and thus not considered in the document.

5 Test method

5.1 General

The material set is tested by exposure to a single light source with a particular relative spectral irradiance (RSI). An additional test shall be run with the light source of a different RSI. The test specimens from the set are exposed to light for a certain duration under well-defined spectral conditions and controlled humidity and temperature. The colour change from the initial state is measured after the exposure. Potential other changes are visually assessed. The test duration shall be determined in accordance with ISO 18937:2020, 5.6.

Museums usually apply additional UV filtering through the use of special window glass, shades, framing or other protections. For assessing the safe display duration for an actual display with a filtered light source, all filters shall be included. A typical museum long-pass UV cut-on filter is described under 5.4.2.

NOTE One definition of museum-grade UV-filter, sometimes referred to as Thomson specification, requires transmission of the optical filter to be 0 % at 320 nm, <1 % at 380 nm, and <50 % at 400 nm.

5.2 Sample specimen preparation

5.2.1 Outline

Manufacturers interested in knowing how their contemporary materials perform under museum display conditions can apply the test method of this document to contemporary materials and freshly made prints as described in 5.2.2.

However, in the museum environment, the possibility of being able to make new prints with the materials of interest is the exception. Most museum objects are older than 20 years and the print materials they were made with may no longer be available. The choice of an appropriate print material set will require some research and evaluation.

NOTE References and institutions that help to identify unknown print materials, or that maintain an on-line identification database, are given in References [5][6][7].

In spite of considerable effort, it may be difficult or impossible to find a good match of materials. In this case, a meaningful test cannot be done.

5.2.2 Contemporary materials

If a contemporary photographic work comes with a detailed record of how it was printed including media material, set of inks, method of printing (equipment and settings used), and post-printing finishing, and all the above are still available on the market, the exact same settings shall be used to make test prints.

The standard test pattern for printing as described in ISO 18944 shall be used. Other test patterns may be used if required by the application. A minimum requirement of the test target is to have two levels of YMCK values as well as a grey wedge with at least 4 levels and the minimum density of the print. Optional levels of Y, M, C, R, G, B, Grey (Y+M+C, or K), and other important colours, such as skin colour, can be included.

Printing and conditioning of samples shall be done in accordance with ISO 18944.

One set of printed sample specimens serves as control and needs to be stored in a dark, cool or cold place with pollutant levels as specified in Table 1. This set can be used as a reference to compare with the test print to track the visual impact of image fading and other changes to the materials after light exposure (such as physical damage, or edge bleeding/diffusion, or loss of glossiness, etc.). At least one set of replicate sample prints is required for the exposure to understand and mitigate the variability of exposures.

5.2.3 Historic materials

Museum objects are unique and there is often no possibility to utilize samples of real art colour prints for testing purposes. Destructive testing cannot be done on original art objects. Expendable duplicate originals or other duplicates of real museum materials made with material from the same manufacturer at the same time can be used to determine the safe display duration (see Annex A).

The usual case is that there are no duplicates and that the exact same material is not available. If the print technology and the time period of when the object was printed is known, the light degrading potential of new light sources on a particular type of historic material can be assessed with a selection of expendable prints made with the same print technology from the same historical time period. If the type of print material was made by several different manufacturers, the test set should include at least the major manufacturers at the time. However, this approach only allows one to make a relative ranking of the degrading potential of light sources and shall not be used to estimate the safe display duration for an actual museum object.

5.2.4 Selection of suitable test patches on historic materials

In the case of duplicates or expendable historical materials, colour patches have to be selected from the image itself, which is not the usual test pattern. A selection of suitable test patches should contain all colorants that were used in the print technology on three levels of lightness, light (L^* about 70), medium (L^* about 50) and dark (L^* about 30 or darker). Typical analogue photographic colour print materials for example have 3 colorants, digital colour prints may have up to 12 different colorants that can make up an image. Mixtures of colours on one patch are acceptable. Grey areas or skin tone areas are often suitable patches with two or three colorants present. In addition, one patch with very little or no colourant - possibly at the edge - should be selected to represent the minimum density of the print.

A magnifier with 50 times to 200 times enlargement can be used to identify the colorants in the patches. For a spectrophotometer with a 3 mm aperture, the patches should have a diameter of at least 4 mm and be mapped on the print with a precision at least 1 mm to allow the exact positioning and re-positioning after each test.

NOTE One way to obtain the required positioning precision is to prepare a mask with punch holes.

The precision of re-positioning shall be verified before the exposure test by measuring the selected spots multiple times and demonstrating that the standard deviation of the measurements is less than $\Delta E_{76} \leq 2$.

For duplicates, at least two sets of patches should be chosen as described above, either on the same print or on two similar prints. Due to the selection of not fully identical print patches, a much greater variability of the results is to be expected compared to tests done on a printed test pattern. Other patches on the same samples can be used as a reference if exposure is avoided by a light tight cover material.

5.2.5 Reference sample specimens

Reference specimens can be colour prints with known light stability or other colour materials with known light stability.

Museums often use the Blue Wool Scale (BWS) as defined in ISO 105-B04[9] as a dosimeter and as a scale to express light stability in terms of "Blue Wool Scale" with level 1 marking "fugitive" to level 8 "exceptional". The BWS is exposed together with the specimen under test. This document does not recommend using the BWS as a dosimeter. State-of-the art test equipment has calibrated UV and visible light dosimeters that measure cumulative doses with much smaller uncertainty than BWS cards. In addition, the response of BWS cards to the combined stress factors of light, temperature and humidity is not the same as for the various printing technologies. However, BWS ratings are still very common in museums for various objects. Therefore, it might be desirable to also express colour fastness of digital prints in BWS ratings. For that purpose, one may refer to CIE 157[9]. Users should be aware that BWS ratings depend on RSI of the light source and are highly susceptible to the level of relative humidity during the test (see ISO 105-B02[7]).

5.2.6 Backing of the specimens

The sample and reference specimens are usually backed during the exposure test. Suitable backing materials include non-reactive and non-yellowing white material such as 100 % cotton rag board or metal (white-painted aluminium or stainless-steel plate).

5.2.7 Dummy sample

In a light exposure chamber, all sample positions shall be filled with samples, or with dummy samples which are equivalent in average density or reflectance to the actual test samples, for both light exposure tests and for the calibration of light, temperature, and humidity. Dummy samples maintain the same air flow pattern and reflected light conditions in the test chamber independent of the number of real samples.

5.3 Light exposure

5.3.1 Outline

Test results obtained for a given material set using one light source cannot predict the behaviour under a light source with a different RSI. To predict degradation for light sources with different RSI, the individual action spectra of colorants in the print have to be known[11]. However, measuring action spectra is time consuming. In many cases, it may be preferable to measure the light fastness of the particular print material set for each type of light source. Results and the predictions made for that material set are only valid for the light source that was used in the exposure test, for example for filtered daylight, incandescent illuminant A, or a certain LED with a particular RSI. The type of light source shall be an integral part of any reporting of data and of safe display duration for the print material set.

As the actual museum display lighting may not be known or it may change over time, it is helpful to know the light stability of colour print materials to different standardized light sources typical for museum display. This does not allow one to predict a safe display duration, but it allows one to choose the light source with the lowest damage potential among the tested light sources. This document stipulates several typical museum light sources for testing degradation damage potential: Xenon-arc lamp, incandescent light, and LED light. Equipment that can achieve the test conditions stipulated in 5.3.3, 5.3.4 and 5.3.5 shall be used.