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Permanence and durability of commercial prints —

Part 22: Backlit display in indoor or shaded outdoor conditions — Light stability

Permanence et durabilité des impressions commerciales —

Partie 22: Écran rétroéclairé en intérieur ou en extérieur ombragé — Stabilité de la lumière

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

A list of all parts in the ISO 21139 series can be found on the ISO website.

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

Backlit display of prints is a market segment in context of commerce (advertisement, brand shops) and information (maps, directories). This use profile has specific spectral irradiance and environmental conditions which are different from e.g. general indoor or in-window display (ISO/TS 21139-21).

Backlit display applies with prints on transparent or translucent foils and/or prints on a textile. The document focusses on LED-based backlit units and on the other hand provides information on fluorescent-based backlit units for reference. These backlit displays may be installed indoor or in shaded outdoor conditions, for examples backlit display units in shelters and patios. Backlit displays which are subject to solar radiative heating or precipitation, introducing extensive temperature cycling, are excluded.

Prints on backlit display may fade or otherwise change in appearance due to various environmental stresses, including light, heat, humidity, atmospheric pollutants, or biological attack, and the combination of these factors. One of the most critical degradations is light fading caused by intense irradiation from the backlit unit as well as illumination from the viewing environment, which may represent various levels of intensity and degrees of spectral irradiance, depending on the installation site in a building, near to a window or in a shaded outdoor condition. The factors determining the exposure doses form either frontside or backside are introduced, and the severity of the actual spectral irradiance is expressed as a ratio to the standardized exposure condition "general indoor" as defined by ISO 18937-2.

The lighting design of the backlit display unit may cause inhomogeneity of the backside exposure of the print, which may in turn introduce inhomogeneous patterns of colour fading or discoloration leading to enhanced visibility of degradation (an example is illustrated in Annex B). The test method described in this document does not include the assessment of the impact from inhomogeneity of the backside exposure.

This document provides information about the test conditions for colour fading and discoloration applicable for the different types of display materials, including transparent or translucent films, fabrics as well as paper-based reflection prints. Furthermore, the document gives guidance for estimation of an equivalent exposure dose for the intended time of display, acknowledging the limitations of such generic extrapolations. The display use profile applies for digital and analogue prints.

This test method does not address the adverse effects of exposure to atmospheric pollutants, including ozone, and is also limited to the evaluation of colour changes and therefore does not require specific methods for the evaluation of physical properties, including changes of tensile strength, cockling etc. In the case that backlit materials are constructed from laminates, the aforementioned factors are of less importance.

The general concepts for the exposure characterization of prints on a backlit display provided in this document may also be considered in museum context with details defined by ISO/TS 18950.

Permanence and durability of commercial prints —

Part 22:
Backlit display in indoor or shaded outdoor conditions — Light stability

1 Scope

This document describes the test methods for light stability measurements of prints on transparent or translucent foils, sheets and paper or printed on a textile, which are displayed on backlit units installed in indoor or in shaded outdoor conditions, which are protected against direct precipitation and radiative heating. Installations of backlit display units in outdoor areas without shading, which are exposed to direct weathering and/or radiative heating, are excluded.

This document is applicable to the various product classes of "commercial prints" that are suitable for backlit display. These commercial prints often contain combinations of text, pictorial images and/or artwork.

This document provides guidelines for colour measurements, data analysis and also provides guidance for translation of test results into suitable image permanence performance claims considering the variability of backlit designs and environmental conditions.

This document is applicable to both analogue and digitally printed matter. Methods and principles apply to both, colour, and monochrome prints.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 18937-1, *Imaging materials — Methods for measuring indoor light stability of photographic prints — Part 1: General guidance and requirements*

ISO 18937-2, *Imaging materials — Methods for measuring indoor light stability of photographic prints — Part 2: Xenon-arc lamp exposure*

ISO/PAS 18940-1, *Imaging materials — Image permanence specification of reflection photographic prints for indoor applications — Part 1: Test methods*

ISO/TS 21139-1, *Permanence and durability of commercial prints — Part 1: Definition of use profiles and guiding principles for specifications*

ISO/TS 21139-21, *Permanence and durability of commercial prints — Part 21: In-window display — Light and ozone stability*

3 Terms and definitions

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

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

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

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

3.1 Measures of exposure severity

3.1.1
relative severity

$\rho_{RSI1/RSI2}$

ratio of density loss due to light fading for exposure under a given RSI1 in comparison to another given RSI2 with both exposures at the same level of illuminance E_v [klx], based on the evaluation of average light fading for a set of colorants used in digital prints

Note 1 to entry: For standardized RSI the relative degree of light fading obtained for the same exposure dose expressed in klx·h has been expressed in relative units to each other based on experimental data and an action spectrum model obtained for typical CMY colorants used in digital printing. The combined information of exposure intensity [klx] and $\rho_{RSI1/RSI2}$ is therefore equivalent to the description of a spectral exposure, see Annex A.

Note 2 to entry: Standardized RSI include daylight filtered Xenon-arc (see ISO 18930), window-glass filtered Xenon-arc for simulated in-window display or with additional UV blocking for general indoor display (see ISO 18937-2), fluorescent light (see ISO 18909) and LED light (see ISO 18937-3).

EXAMPLE In this method, $\rho_{RSI/GI}$ denotes the relative severity of a RSI under question compared to the condition of "General Indoor" exposure.

3.1.2
severity weighted exposure

$\tilde{E}_{RSI1/RSI2}$

measure of the exposure intensity of a given RSI1, where the illuminance E_v [klx] is weighted with the duty cycle τ [%] in application and with the *relative severity* (3.1.1) in comparison to a reference RSI2

Note 1 to entry: In this test method, the RSI of the general indoor filtered Xenon-arc test method as defined in ISO 18937-2 is used as the reference RSI, so RSI2 = GI. This spectral irradiance can be achieved using optical filters such as L-37 (Hoya Co.) and SC-37 (Fujifilm Co.).

Note 2 to entry: The severity weighted exposures of the frontside and the backside of a print display on a backlit unit are typically different because of different RSIs, duty cycles and/or intensity.

3.1.3
severity weighted exposure dose

$\tilde{H}_{RSI1/RSI2}$

measure of the severity weighted exposure that is accumulated during a nominal display duration time, t

Note 1 to entry: In this test method, the RSI of the general indoor filtered Xenon-arc test method as defined in ISO 18937-2 is used as the reference RSI, so RSI2 = GI ("General Indoor").

Note 2 to entry: The severity weighted exposure dose accumulated on the frontside and the backside of a backlit displayed print, respectively, are typically different and both contribute to colour fading.

3.2 Exposure conditions

3.2.1
UV cut-on [wavelength]

$\lambda_{0,05\,\%}$

wavelength at which the cumulative intensity of a RSI $I(\lambda)$ has reached 0,05 % of its total integrated intensity over the spectral range of 295 nm to 800 nm

Note 1 to entry: $\int_{295\,\text{nm}}^{\lambda_{0,05\,\%}} I(\lambda)\,\mathrm{d}\lambda \Big/ \int_{295\,\text{nm}}^{800\,\text{nm}} I(\lambda)\,\mathrm{d}\lambda = 0,05\,\%$

3.2.2
shaded outdoor conditions
exposure to indirect terrestrial daylight in a shadow zone, that is characterized by the absence of radiative heating of the prints on backlit display

Note 1 to entry: The UV cut-on ($\lambda_{0,05\,\%}$) is in the range of 295 nm to 310 nm.

EXAMPLE Display in outside shelters and patios.

3.2.3
glass-filtered shaded outdoor display
exposure to *shaded outdoor conditions* (3.2.2) with optical filtering of the irradiance by the front screen material of the backlit display unit

Note 1 to entry: Backlit display units in shaded outdoor conditions practically always require a front screen in front of the print for reasons of electrical safety. Such a front screen is most often realized by safety glass or a similar suitable material. The UV cut-on of PVB laminated safety glass varies between 300 nm to 400 nm depending on its construction and its material formulation. For the purpose of this standard, 6 mm window glass is defined as reference for the filter transmission, acknowledging that the UV transmission of different types of front screens varies.

EXAMPLE Display in backlit units in shaded outdoor conditions with a safety glass front screen.

3.2.4
in-window display
exposure to indirect terrestrial daylight through standard architectural window glass (6 mm)

Note 1 to entry: The UV cut-on ($\lambda_{0,05\,\%}$) is around 320 nm.

EXAMPLE Display in store windows or in other glass-enclosed architectural constructions (hallways, lobbies, verandas), that face toward the outdoors.

3.2.5
general indoor display
exposure to indirect lighting, from due to filtering (through window glass) and shading is often the principal illumination

Note 1 to entry: The UV cut-on ($\lambda_{0,05\,\%}$) is around 350 nm.

EXAMPLE Display in store windows or in other glass-enclosed architectural constructions (hallways, lobbies, verandas), that face toward the outdoors.

3.3 Abbreviations

CCT correlated colour temperature (IEV ref: 845-23-068)

CIE Commission internationale de l'éclairage (International Commission on Illumination)

ΔE_{ab} colour difference defined in ISO/CIE 11664-4[2]

$\Delta E_{ab,\,ave}$ average of the colour differences of the patches of the test target (vs. initial)

$\Delta E_{ab,\,max}$ maximum of the colour differences of the patches of the test target (vs. initial)

ΔE_{00} colour difference ΔE2000 as defined in ISO/CIE 11664-6[3] klx·h — kilolux times hour

Mlx·h — megalux times hour

RSI — relative spectral irradiance in W/(m^2 nm)

GI — RSI defined by the test condition "General Indoor" – see ISO 18937-2

E_v [klx] — illuminance (visually weighted)

$\tilde{E}_v^{GI}$ [klx] — illuminance at the test condition of "General Indoor"

τ [%] — duty cycle

$\tilde{H}_{\Delta Eab}$ — severity weighted exposure dose at which a certain colour change ΔE_{ab} is observed

4 Use profile

4.1 General

This document describes a test method for prints on transparent or translucent foils and/or on textiles that are displayed on backlit units indoors or in shaded outdoor conditions, where the primary stress factors are exposure to light from both backside and frontside.

NOTE 1 Heat, humidity and atmospheric pollutants can also be stress factors, however this document focuses on light stability. Heat can have effects on prints that are displayed for long time periods on backlit units with elevated temperature, e.g. due to radiative heating by sunlight through window glass or due to dissipative heating from electrical appliances in poor-ventilated constructions of the backlit unit itself.

The use profile of commercial prints is described in general in ISO/TS 21139-1. It specifically describes test methods for backlit display indoor and in shaded outdoor conditions, defined as display use profiles A3 and B1 b) of ISO/TS 21139-1:2019, Table 3, respectively.

NOTE 2 The overall appearance of the displayed prints can also be affected by factors given by the backlit unit itself, including a non-homogenous distribution of the intensity and/or the correlated colour temperature (CCT) of the backlit lighting and/or changes of any other element of the backlit unit, e.g. yellowing of the front screen.

4.2 Parameters of backlit display

A backlit display unit is designed to provide a backside illumination of the print, such that the brightness of the displayed print is comparable to or larger than the light level of the surrounding viewing environment. Furthermore, the CCT of the lamps in the backlit unit is often selected to match the viewing environment, which is typically between 5 000 K to 6 500 K for naturally illuminated areas and 3 000 K or 4 000 K for some indoor installations.

The spectral irradiance, intensity, and homogeneity of the backside exposure of the print depends on the construction of the backlit unit. These parameters together with the duty cycle of the backside illumination determine the severity of the exposure of the print from its backside. Table 1 provides an overview of typical parameters associated with LED or fluorescent lamp illuminated light box designs.

The level of temperature increase of the print on backlit display is driven by the dissipative heating from the backlit lighting system in operation and the degree of air ventilation of the light box in a certain environment. The amount of temperature increase is larger in the case of poor air ventilation. Factors that reduce air ventilation include an airtight design of the housing, its eventual installation onto or especially into a wall, the use of a front screen and/or the display of a print on a foil (as opposed to a fabric with an open mesh structure). For heat sensitive materials the temperature increase above the surrounding temperature may have to be considered.

Table 1 — Parameters of backlit displays

Backlit displays		Illumination type[a]		
Display parameters		**LED**	**Bare-bulb Fluorescent**	**Glass-filtered Fluorescent**
Relative spectral irradiance (RSI)		see ISO 18937-3, phosphor-converted 'blue pumped' LED (5 000 K CCT)	See Annex A	see ISO 18909
Irradiance level E_v **at the backside of the print** [klx]		7 to 10		
Typical UV content[a]		no RSI below 400 nm, but intense blue emission peak at 450 nm	mercury lines at 313 nm and 365 nm[b]	
relative severity $\rho_{RSI/GI}$		0,73[a]	0,74[a]	0,64[a]
Temperature increase [K] **over ambient**	**non-ventilated (e.g. front screen and/or foil)**	+7	+15	+15
	ventilated (e.g. open front and mesh material / fabric)	+5	+10	+10
Duty cycle τ [%]		Between "x %" ('cyclic') and 100 % ('24/7')		

[a] See Annex A.

[b] The intensity of the UV lines at 313 nm and 365 nm, that are typically emitted from fluorescent lamps, depends on several factors, including the amount of mercury used in a specific type of lamp and the level of UV attenuation from the glass envelope of the lamp and the type and thickness of the phosphor layer. During the use time of the fluorescent lamps, pinholes can be introduced in the phosphor layer, which can increase the intensity of the UV emission lines over time. On the other hand, the UV lines will be largely attenuated when an UV absorbing (diffusor) screen is present in between the fluorescent lamps and the print on display. The glass-filtered fluorescent condition is realized most often, whereas the bare-bulb condition can be regarded as worst case.

For print materials with limited light stability a certain level of inhomogeneity of the backlit illumination (see example in Annex B) may be sufficient to introduce visible patterns of discoloration. The level of inhomogeneity of the light intensity, expressed as $2 \times (I_{max} - I_{min})/(I_{max} + I_{min})$, may typically range from 10 % to 50 % and stems from the light box design, including:

a) the position, geometry, and type of the lighting elements, such as e.g.

   1) array of linear lamps, e.g. LED lines, or fluorescent tubes,

   2) array of spot lamps, e.g. grid or matrix of individual LED spots, and

   3) continuous area illumination, e.g. edge-lit backside diffusor screen;

b) the efficiency of the light distribution by the combination of all optical elements:

   1) angular emission of the lighting elements, also considering lenses;

   2) diffusor screens;

   3) reflectivity of the inner walls.

Also, the reflectivity of the backside of the print itself, when mounted on the backlit unit, may contribute to the overall system illumination homogeneity.

4.3 Frontside exposure and environmental conditions

The frontside of the print is exposed by the ambient illumination that is present at the installation site of the backlit display unit. The corresponding environmental parameters may range between those typical for general indoor display [A2 of ISO/TS 21139-1:2019, Table 3], for in-window display [A1 of ISO/TS 21139-1:2019, Table 3] or for protected outdoor display [B1 b) ISO/TS 21139-1:2019, Table 3]. Users shall identify the most severe test condition anticipated for their display application and based on that condition estimate a typical amount of total light exposure during the defined display period. Guidelines are provided in ISO/TS 21139-1 and examples are given further below.

Table 2 — Characterization of standardized environmental display conditions

Environmental display parameters	General indoor display	In-window display	Glass-filtered shaded outdoor display
Relative spectral irradiance (RSI)	See ISO 18937-2 (General indoor display)	See ISO 18937-2 (In-window display) [a]	See ISO 18937-2 (In-window display) [a] *
UV filter function in the front screen of the backlit unit	Depending on their UV filtering characteristics some screen materials between light source and print may reduce the UV fraction, to which the print is exposed from the frontside or backside, respectively. Also, the supporting substrate (film) of the print may act as UV-filter for the corresponding direction of exposure.		
Informative: UV fraction[b]	4 %	6 %	6 %
Informative: $\lambda_{50\ \%\ T}$ [nm]	370 to 375	340 to 345	340 to 345
Informative: $\lambda_{0,05\ \%}$ [nm]	350 nm	320 nm	320 nm
Relative severity[c] $\rho_{RSI/GI}$	1,0[c]	1,2[c]	1,2[c]
Duty cycle τ [%]	12/24 (= 50 %) to 24/24 (= 100 %)	Typically, 12/24 (= 50 %)	Typically, 12/24 (= 50 %)

[a] The test method ‘in-window display’ of ISO 18937-2 with continuous light exposure is equivalent to the light stability test method stipulated in ISO/TS 21139-21.

[b] UV fraction is indicated as ratio of cumulative radiant energy in the range of 300 nm to 400 nm versus the cumulative radiant energy in the range of 300 nm to 800 nm (see ISO/TS 21139-1:2019, Annex D). For comparison: natural daylight has ~8 % UV fraction.

[c] Reference values from Annex A.

4.4 Equivalent test conditions

In the practical application, any of the combinations of Table 1 for backside exposure and Table 2 for frontside exposure could be observed. To reduce the variability of testing the concept of equivalent test conditions is applied in this test method and the equivalent exposure dose is determined.

In this method the concept of “severity weighted exposure” is applied, which allows to characterize the exposure intensity in terms of illuminance (lux), still considering the different UV content of a given RSI. More background on this approach is given in Annex A.

4.4.1 Severity weighted exposure condition

In a first step, the user of this method needs to determine the “severity weighted exposure” $\tilde{E}_{RSI/GI}$ of frontside and backside exposure, respectively, as given in Formulae (1) and (2). $\tilde{E}_{RSI/GI}$: represents a measure of light intensity E_v [klx], that is weighted with the duty cycle τ of the exposure and the relative severity $\rho_{RSI/GI}$ of the RSI of either side of the print, respectively, i.e. $\rho_{front/GI}$ or $\rho_{back/GI}$. The relative severity $\rho_{RSI/GI}$ provides a ratio of degradation due to photolytic action of exposure under a given RSI in comparison to that of the “general indoor” condition as defined in ISO 18937-2. Annex A provides reference values for the relative severity of typical colorants based on a general action factor model. As alternative, the relative severity can be evaluated based on the measurement of the spectral action factor[13] of a colorant set under investigation.

$$\tilde{E}_{\text{RSI at front/GI}}\left[\text{klx}\right]=E_{\text{v}}\left[\text{klx}\right]\cdot\tau\left[\%\right]\cdot\rho_{\text{RSI at front/GI}} \tag{1}$$

$$\tilde{E}_{\text{RSI at back/GI}}\left[\text{klx}\right]=E_{\text{v}}\left[\text{klx}\right]\cdot\tau\left[\%\right]\cdot\rho_{\text{RSI at back/GI}} \tag{2}$$

with

$\tilde{E}_{\text{RSI/GI}}$	is the severity weighted exposure;
E_{v} [klx]	is the illuminance (visually weighted exposure);
τ [%]	is the duty cycle;
$\rho_{\text{RSI/GI}}$	is the relative severity of the RSI incident on the frontside or the backside of the print compared to general indoor (see Annex A).

Table 3 provides examples of severity weighted exposure values $\tilde{E}_{\text{RSI/GI}}$ in standardized exposure conditions.

Table 3 — Examples of the evaluation of severity weighted exposure values $\tilde{E}_{\text{RSI/GI}}$

		backside exposure (from the backlit unit)		**frontside exposure (from the environment)**		
		#1	#2	#3	#4	#5
Exposure conditions		LED backlit (5 000 K CCT)	glass-filtered fluorescent backlit (CIE F6)	general indoor	indoor in-window display	glass-filtered shaded outdoor display
MIN	Relative severity $\rho_{\text{RSI/GI}}$ [c]	0,72[a]	0,58[a]	0,87[a]	0,87[a]	0,87[a]
	Example illuminance E_{v} in use profile (klx)[d]	10	10	0,5	3	20
	Example duty cycle τ (MIN)	50 %	50 %	50 %	50 %	50 %
	$\tilde{E}_{\text{RSI/GI}}$ [klx]	**3,6**	**2,9**	**0,22**[a]	**1,3**[a]	**8,7**[a]
MAX	relative severity $\rho_{\text{RSI/GI}}$ [c]	0,73[b]	0,64[b]	1,0[b]	1,2[b]	1,2[b]
	Example illuminance E_{v} in use profile (klx)[d]	10	10	0,5	3	20
	Example duty cycle τ (MAX)	100 %	100 %	100 %	50 %	50 %
	$\tilde{E}_{\text{RSI/GI}}$ [klx]	**7,3**[b]	**6,4**[b]	**0,5**[b]	**1,8**[b]	**12**[b]

[a] Evaluated with a screen between light source and print, that acts as extended UV filter, e.g. λ_{50} %T= 400 nm, typical for UV stabilized polycarbonate or PMMA.

[b] Evaluated with RSI typical for use profile, see Table 2.

[c] See Annex A.

[d] Illustrative set-points estimated based on ISO/TS 21139-1:2019, Clause 4 and Table 3.

In Table 3, two main cases are identified:

— For backlit display in glass-filtered, shaded outdoor conditions, the severity weighted exposure of the frontside from the environment is typically equal to or up to 4x larger compared to the severity weighted exposure from the backlit unit.

— For backlit display in indoor conditions, the severity weighted backside exposure from the backlit unit is typically considerably larger (up to ~35 times) than the severity weighted frontside exposure from the ambient environment. The relative severity of a backside illumination by LED and/or by fluorescent lamps is rather comparable (see Annex A).

NOTE 1 Backlit display units for indoor display of soft signage are often designed without a front screen.

Annex D provides an overview of accelerated laboratory test conditions that would potentially correspond to the exposure conditions in Table 3: each test condition is associated to a defined RSI with a characteristic effective UV cut-on wavelength, for which its relative severity $\rho_{\mathrm{RSI/GI}}$ has been determined (see Annex A). For reasons of practicality and comparability, the test method "general indoor" (GI) display of ISO 18937-2 (see entry #3 in Table D.1), is chosen as the unique standard method for the exposure of the frontside and the backside of the prints in this test method, respectively, see 5.3.1. The test is conducted at a set-point of the illuminance $\tilde{E}_{\mathrm{v}}^{\mathrm{GI}}$ between (50 ± 2) klx to (80 ± 3) klx in the specimen plane.

NOTE 2 The use of a lower level of the set-point value results in proportionally longer durations of the accelerated test, see 4.4.2.

4.4.2 Equivalent test duration

To define the test duration *T* of the frontside and backside exposures, a nominal display duration time *t* is defined. Criteria for the selection of such representative display durations include worst case scenarios for the anticipated use profile or other criteria agreed upon between parties. From the nominal display time, *t*, the equivalent test dose $\tilde{H}_{\mathrm{RSI/GI}}$ is calculated for frontside and backside exposure separately as given in Formulae (3) and (4):

$$\tilde{H}_{\mathrm{RSI\,at\,front/GI}}\left[\mathrm{klx\cdot h}\right]=t\left[\mathrm{h}\right]\cdot\tilde{E}_{\mathrm{RSI\,at\,front/GI}}\left[\mathrm{klx}\right] \tag{3}$$

$$\tilde{H}_{\mathrm{RSI\,at\,back/GI}}\left[\mathrm{klx\cdot h}\right]=t\left[\mathrm{h}\right]\cdot\tilde{E}_{\mathrm{RSI\,at\,back/GI}}\left[\mathrm{klx}\right] \tag{4}$$

with

$\tilde{H}_{\mathrm{RSI/GI}}$ is the severity weighted exposure dose for the *RSI* incident on the frontside or the backside, respectively;

$t[\mathrm{h}]$ is the exposure duration.

The corresponding durations *T* of the frontside and backside test exposures, respectively, are determined as the exposure time needed to provide the equivalent dose $\tilde{H}_{\mathrm{RSI/GI}}$ under given test conditions $\tilde{E}_{\mathrm{v}}^{\mathrm{GI}}$ [klx] as givne in Formulae (5) and (6):

$$T_{\mathrm{front}}\left[\mathrm{h}\right]=\tilde{H}_{\mathrm{RSI\ at\,front/GI}}\left[\mathrm{klx\cdot h}\right]/\,\tilde{E}_{\mathrm{v}}^{\mathrm{GI}}\ \left[\mathrm{klx}\right] \tag{5}$$

$$T_{\mathrm{back}}\left[\mathrm{h}\right]=\tilde{H}_{\mathrm{RSI\ at\,back/GI}}\left[\mathrm{klx\cdot h}\right]/\,\tilde{E}_{\mathrm{v}}^{\mathrm{GI}}\ \left[\mathrm{klx}\right] \tag{6}$$

Table 4 — Examples of test durations *T* for typical backlit display use profiles

	Example 1		**Example 2**		**Example 3**	
Display configuration	Backside	Frontside	Backside	Frontside	Backside	Frontside
	LED backlit (5 000 K CCT)	general in-door, with no front screen	LED backlit (5 000 K CCT)	indoor in-window display, with a UV filtering front screen	LED backlit (5 000 K CCT)	Glass-filtered shaded out-door display
	In the application					
Relative severity $\rho_{RSI/GI}$ [1]	0,73	1	0,73	0,87	0,73	1,2
Illuminance in application E_v [klx]	10	0,5	10	3	10	20
duty cycle τ[1]	50 %	100 %	100 %	50 %	50 %	50 %
$\tilde{E}_{RSI/GI}$ [klx] see Formulae (1) and (2)	**3,65**	**0,5**	**7,3**	**1,305**	**3,65**	**12**
Nominal display du-ration t [h]	4 320 (180 d)	4 320 (180 d)	2 160 (90 d)	2 160 (90 d)	8 640 (360 d)	8 640 (360 d)
$\tilde{H}_{RSI/GI}$ [Mlx·h] - see Formulae (3) and (4)	**15,8**	**2,2**	**15,8**	**2,8**	**31,5**	**103,7**
	with the test conditions: RSI = GI, duty cycle τ = 100 % and set point $\tilde{E}_v^{GI}$ = 80 klx)					
Exposure side	front	Back	front	back	front	back
T [h] – see Formulae (5) and (6)	**197**	**27**	**197**	**35**	**394**	**1 296**

Table 4 provides illustrative examples of the calculation of the test durations based on Formulae (1) to (6) for three display configurations, which are combinations of frontside, and backside exposure given in Table 3.

4.5 Relevance of use

Based on the concept of an equivalent exposure dose, this test method defines the light fading test procedure that is used to obtain a table or plot of colour changes versus cumulative exposure dose under standardized equivalent test conditions.

Results obtained via this approach are subject to limitations as explained in ISO 18937-1, including the assumption of reciprocity. This method applies the equivalent exposure dose for frontside and backside on individual replicates of the prints under test. Without an actual correlation study, it cannot be assumed that the colour changes observed separately for the frontside, and the backside exposure would simply add up for simultaneous exposure typical for actual use. On the other hand, the larger of the colour changes observed for frontside and backside exposure, respectively, can only be regarded as the lower estimate of the combined, overall colour change. The main use of this method is the benchmark of print materials and/or backlit display units under standardized test conditions. The estimated display duration time until a certain colour change is observed in actual use may differ from the standardized display duration obtained via this method.

To assess the relative severity of the exposure of a specific backlight display unit for a range of different print materials, that are intended for display on this unit, the relative severity of the exposure of the print as displayed on the backlit unit is determined according to Table 3.

When comparing results of light fading obtained on print material exposed according to this test method versus display on an actual backlit unit, that is installed in ambient conditions representative for intended use ("live-test"), the following shall be considered:

— The homogeneity of the exposure level on the display box is typically limited, i.e. the actual test conditions depend on the position of the test material (target) on the display box – see example in Annex B.

— In a "live test", other stress factors including air pollution and humidity are typically not controlled and the actual spectral conditions and duty cycles may differ from the standardized conditions.

— Provided additional spectro-radiometric characterization of the display and the ambient illumination as well as control of the environmental factors and of the duty cycles of frontside and backside exposure, a "live test" could be useful to set the generalizations inherent in this method into perspective. However, this document does not provide the details for such a characterization that would be required to qualify a "live-test" on a display box as an alternate test method for light exposure.

5 Test methods

5.1 General

In this test method the exposure of the frontside and the backside of the print are applied separately on individual replicates of the print materials under test, which means separate testing and individual reporting of test results from frontside and backside exposure.

The overall durations of the frontside and backside exposure is determined based on the total equivalent dose in intended use – see Formulae (3) and (4) - under consideration of the test conditions - see Formulae (5) and (6) in 4.4.

In backlit units without a screen front (e.g. soft signage), atmospheric pollutants may be effective depending on the display environment, where a high rate of exchange of non-filtered outdoor air can be expected. For such applications, the test of resistance to fading under ozone exposure should be considered in addition to this method, following the stipulations of ISO/TS 21139-21. However, many prints for this application are laminated, which is very effective against pollutants. Or else they are printed with UV curing technology which is also not sensitive to pollutants.

5.2 Sample preparation

5.2.1 Outline

Sample specimens shall be prepared with the specific procedures applicable for the actual prints to be evaluated. The printing equipment, the driver setting, the media, and finishing shall be recorded.

5.2.2 Test target

A simplified sRGB test target as defined in ISO/PAS 18940-1 shall be used for the light fading test – see Annex C. In addition, other test patterns or application related images can also be used depending on the purpose of the test.

NOTE It is noted that an sRGB based test target will not create pure CMYK colour patches, but (more or less) mixed colours as in the application.

5.2.3 Sample labelling and marking

Specimens shall be coded with a unique label for their identification. Also, frontside and backside of the specimens shall be marked, respectively, to guarantee their proper orientation during the test and the measurement.

5.2.4 Storage conditions between printing and light exposure test

The storage conditions in the period between printing and the start of the light exposure test, as well as between the end of the light exposure and the data measurement shall be controlled to a suitable level that eliminate unintended changes of the prints during these waiting times. This requires storage of the prints in an ambient environment (temperature, relative humidity, and air flow around the stored prints) in dark or low light intensity conditions, such that the cumulative exposure during storage and handling is smaller than 1 % of the test exposure dose. In any event, the time between printing and the start of the light exposure test shall be less than two months.

5.2.5 Reference samples

Extra specimens may be prepared for each print material under test for use as reference samples. When this is done, the extra specimens shall be sealed in an opaque or dark enclosure and stored at a cold place with the temperature of no higher than 20 °C, so that they can either be measured with the exposed sample specimens simultaneously or can be assessed visually by comparing the exposed sample specimen with the unexposed sample specimen side-by-side.

5.2.6 Backing of the specimens

The specimens are usually backed during exposure. Suitable backing materials include non-reactive and non-yellowing white material such as 100 % cotton cellulose mount board (100 % 'rag' board) or metal (white-painted aluminium).

5.3 Light exposure

5.3.1 Test method and filter condition

Xenon arc lamp equipment according to ISO 18937-2 shall be used with filter conditions that provide the RSI equivalent to “general indoor” conditions.

5.3.2 Light intensity

The test is conducted at an illuminance level $\tilde{E}_{\mathrm{v}}^{\mathrm{GI}}$ between (50 ± 3) klx to (80 ± 3) klx in the specimen plane. The exposure is applied continuously with a duty cycle of 100 %.

NOTE The choice of the illuminance setpoint changes the actual duration of the accelerated test according to 4.4.2.

The light intensity shall be maintained and controlled as stipulated in ISO 18937-1. In addition, ISO 18937-2 provides information on the calibration of the illuminance control in the specimen plane.

It is recommended that known specimens are tested in parallel to check that the results of the reference materials show the consistent results with the previous tests.

To maintain a uniform and consistent light level, all sample positions of the test chamber 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 levels.

5.3.3 Temperature and humidity

The set point of the uninsulated black panel temperature shall be 35 °C or less, and the set point of the chamber air temperature shall be between 21 °C to 27 °C, respectively. The relative humidity ishall be set to and 50 %RH. These settings should be adjusted to ensure that the specimen temperature is kept at around 30 °C which is a typical temperature of the prints displayed on ventilated LED power backlit units.

The temperature, relative humidity and air quality shall be maintained and controlled as stipulated in ISO 18937-1.

5.3.4 Duration of the light exposure

The duration of exposure shall be determined based on the total exposure that is anticipated for the use profile considering intensity, relative severity and duty cycles, respectively, of both frontside and backside exposure separately, as well as the light intensity and the relative severity of the exposure condition in the test – see 4.4.2.

The test duration depends on the purpose of the test and is determined according to one of the following two methods:

a) For the test of a specific display configuration, the test shall be conducted for twice the expected equivalent exposure dose in Mlx·h (see examples in Table 4).

b) For the general test of a print system, a test duration equivalent to an exposure of 80 Mlx·h is required.

5.4 Exposure of the frontside of the print

5.4.1 Specimen mounting for frontside exposure

For testing of the frontside of the print, the specimens are mounted in the test chamber with their frontside facing towards the test lamp.

5.4.2 Duration of the frontside exposure

For the test of a specific display configuration, the frontside exposure shall be conducted for twice the expected equivalent exposure in Mlx·h. This dose value is used to calculate the duration of the frontside exposure T_{front} [h] according to Formula (5) in 4.4.2.

For the general test of a print system, the test duration is determined to provide 80 Mlx·h.

5.5 Exposure of the backside of the print

5.5.1 Specimen mounting for backside exposure

For testing of the backside of the print, the specimens are mounted in the test chamber with their backside facing towards the test lamp.

5.5.2 Duration of the backside exposure

For the test of a specific display configuration, the backside exposure shall be conducted for twice the expected equivalent exposure in Mlx·h. This dose value is used to calculate the duration of the backside exposure T_{back} [h] according to Formula (6) in 4.4.2.

For the general test of a print system, the test duration is determined to provide 80 Mlx·h.

6 Measurement

6.1 General

A spectrophotometer shall be used when making colour measurements. The colour of the patches shall be measured before and after the light exposure with the spectrophotometer pointing at the frontside of the print. This applies to both frontside and backside exposed specimens. It is also required to measure colour changes at least at five intermediate sampling times meaningfully distributed over the total exposure duration to allow for interpolation.

EXAMPLE The following sampling scheme is quite common: 3d, 1w, 2w, 3w, 4w, 5w, 6w, 8w.

The colours of all patches of the test targets shall be measured before and after the light exposure, both incremental and final according to the sampling scheme. For all patches the corresponding colour differences between the intermediate and final measurements versus the initial colour readings shall be calculated based on CIELAB 1976 (ΔE_{ab})[2][3][4] and tabulated for further evaluation – see ISO/PAS 18940-1.

NOTE The CIE 1976 colour difference, ΔE_{ab}, has been chosen as the image parameter of this method for practical reasons, acknowledging that this may represent a compromise for applications that would typically communicate colour changes in terms of ΔE_{00} values. It is reported that ΔE_{ab} corresponds well to the visual impression of the fading[1]. ΔE_{ab} has been chosen for its simplicity and the possibility to also address colour changes >5, which are out of scope of ΔE_{00}.

6.2 Measurement conditions

Colour measurements shall be performed in transmission mode using the d/0° or 0°/d measurement geometry with the backside of the printed sample facing towards the light source. The measurement condition M1 described in ISO 13655 shall be used to provide a D50 equivalent UV excitation for optical brightening agents and fluorescent inks, if present. If no optical brightening agents are present and no fluorescent inks are tested, measurement condition M2 is accepted as alternate.

NOTE 1 ISO 13655 provides background for the choice of M1 or M2 conditions.

NOTE 2 Measurements in so-called "transflection mode", i.e. measurement of a transparent or translucent material in reflection geometry in combination with a diffuse white backing, result in non-equivalent readings of colour pathes since the effective optical path of the measurement light and therefore the absorption, is at least doubled compared to measurements in transmission. This limits the evaluation of colour in the high density patches, typically resulting in an underestimation of the measured colour changes.

It is required, that an instrument with the same measurement geometry shall be used during the test, and it is highly preferred that the same instrument should be used.

The patches in the test targets must be sufficiently larger than the combined dimension of measurement spot size and positioning reproducibility of the patch reader. For prints on substrates with a periodic structure (e.g. textile with a mesh) the equivalent diameter of the measurement spot needs to be at least five times larger than any period structure size of the material. This spot size can also be realized by averaging an equivalent number of measurements at different positions within a colour patch.

Backlit materials may attenuate the measurement light in different ways, including e.g. the partial opacity of translucent print materials per se or lateral light losses observed in thick transparent sheet material.

NOTE 3 Print materials with thickness of typically >1 mm can cause substantial misalignment of illumination spot and measurement spot in transmission measurement mode, which results in artificially "dark" readings of the colour patches.

Therefore, the so-called 'relative colorimetric evaluation' is applied, in which the measurement on the D_{min} area of the non-aged material is applied as the white reference $X_0Y_0Z_0$ for the calculation of the CIELAB $L^*a^*b^*$ values of the individual colour. All tristimulus values are calculated from the measured spectra based on the CIE 1931 (2°) observer and the illuminant D50.

7 Data analysis

7.1 General

The processing and the analysis of the measured data for the test target (see Annex C) is defined in ISO/PAS 18940-1. Colour readings are collected for all colour patches at the intermediate sampling times and the individual colour differences are evaluated. From these, the average of ΔE_{ab} of all patches of the specified test target shall be calculated for each intermediate sampling time (partial exposure dose) and for the total exposure dose. In addition, also the maximum colour changes (of the patch with the largest colour deviation) should be calculated and included in the graphical representation of the data, also indicating the name of that colour patch.

The values of the average colour changes over all patches, $\Delta E_{ab,\ ave}$ at each intermediate sampling (expressed by the "general-indoor"-equivalent exposure dose in Mlx·h), shall be plotted for frontside and backside exposure, separately, and these plots are analysed further using either of the two following methods:

A. Determine the colour difference $\Delta E_{ab,H,}$ resulting from a specific exposure dose level in the plot of ΔE_{ab} vs. exposure dose $\tilde{H}$, which is representative of the intended backlit display application

B. Determine the exposure dose $\tilde{H}_{\Delta E ab}$ required for the colour difference to reach a specific value of ΔE_{ab}. Here, the specific value of ΔE_{ab} is used for reporting the "Image Quality Parameter".

Method A is applicable when the concerned exposure dose is specified, e.g. the cumulative year equivalent exposure dose for a given display box in a defined environment, while Method B is applicable when the exposure dose is not specified.

Method B is recommended to compare display materials in general.

For translation of the test results into use case performance, consideration of the endpoint criteria and the environmental conditions of the use case are the deciding factors. However, endpoint criteria and environmental conditions are not specified in this document.

7.2 Image quality parameter for data analysis

The image quality parameter, the specific value of ΔE_{ab} for data analysis, can be determined based on the application and purpose of the prints. Depending on the purpose of a specific display application, for some uses even a colour change of ΔE_{ab} = 1 can be problematic, while for other uses, prints with colour changes in the order of ΔE_{ab} = 10 may still be displayed effectively.

7.3 Equivalent test conditions

Identify the equivalent test conditions for the intended display conditions (backside, frontside), either by assignment of the general standardized display conditions provided in Clause 4 (with additional background and examples in ISO/TS 21139-1) or by measurement of a specific display configuration installed in a specific environment, including *RSI*, intensity, duty cycle of the frontside and backside exposure, respectively, as well as ambient conditions and temperature of the print. See Annex B for an example of measurements.

7.4 Estimation of time to reach certain change

From the plots of colour change versus the "general indoor" equivalent exposure dose $\tilde{H}$ (in terms of klx·h or Mlx·h) the equivalent dose value for a specified colour change $\tilde{H}_{\Delta E ab}$ according to Method B is derived or the colour change for a defined equivalent dose $\Delta E_{ab,H}$ is determined using Method A.

The formulae and the examples in 4.4.2 are used to relate the equivalent exposure dose to the time of the display and the time of the test, respectively.

NOTE 1 There is no method available to estimate display life for the combined action of light and ozone, as non-linear interactions between both degradation modes can be present depending on the nature of the underlying print technology. Furthermore, also the susceptibility of the light stability of a print to elevated humidity can depend on the printing technology and the printing material.

The users of this standard are reminded that results from accelerated tests cannot perfectly match degradation in actual use because of the limitations of accelerated testing. Published “time-based ratings” according to this method are regarded as *“time (years) in-standardized-test-conditions”* and therefore do not necessarily match with time (years) in actual use. This is often a matter of dispute if communication is not detailed enough in that respect.

NOTE 2 The use of the Blue Wool Scale rating is discouraged as described in ISO/TS 21139-1.

8 Test report

The report of test results shall include the following mandatory elements for minimum reporting, and some reporting options in addition:

a) details of printed specimens, including printing system (printing technology), ink set, printing substrates, printer and driver settings;

b) test target used for the test (measured patches);

c) reference to this test method and to the test condition ISO 18937-2 “general indoor” with the actual test parameters used;

d) parameters of the colour measurement (transmission geometry, colour measurement condition);

e) statement, whether the relative severity of the exposure condition was determined based on the reference values for the RSI’s in Annex A or based on the individual action spectrum of the dye set(s);

f) test results for the frontside exposure:

1) graph of the average $\Delta E_{\text{ab, ave}}$ and maximum $\Delta E_{\text{ab, max}}$ versus the “general indoor” exposure dose $\tilde{H}$;

2) the referenced *RSI* of the frontside exposure and its relative severity value compared to “general indoor”, see e);

3) optional: the average colour change $\Delta E_{\text{ab,ave}}$ and the maximum colour change $\Delta E_{\text{ab,max}}$ for a specific “general indoor” equivalent exposure dose $\tilde{H}$ = 80 Mlx·h using Method B;

4) optional: the “general indoor” equivalent severity weighted exposure dose $\tilde{H}$ at which a specific colour change $\Delta E_{\text{ab, ave}}$ is observed, $\tilde{H}_{\Delta E\text{ab}}$.

g) test results for the backside exposure:

1) graph of the average $\Delta E_{\text{ab, ave}}$ and maximum $\Delta E_{\text{ab, max}}$ versus “general indoor” exposure dose $\tilde{H}$;

2) the referenced *RSI* of the backside exposure and its relative severity value compared to “general indoor”, see e);

3) optional: the average colour change $\Delta E_{\text{ab,ave}}$ and the maximum colour change $\Delta E_{\text{ab,max}}$ for a specific “general indoor” equivalent weighted exposure dose $\tilde{H}$ = 80 Mlx·h using Method B;

4) optional: the “general indoor” equivalent severity weighted exposure dose $\tilde{H}$ at which a specific colour change $\Delta E_{ab,\,ave}$ is observed, $\tilde{H}_{\Delta E ab}$.

h) the boilerplate sentence *“The colour changes were determined for the frontside and the backside exposures separately in accordance with ISO/TS 21139-22. When evaluating the results, it shall be considered, that the colour changes, that are reported for both exposure sides separately, are active at the same time in the final application (backlit display) and therefore represent a lower limit of the combined changes.”*

i) optional: results from an ozone stability test according to the reporting requirements of ISO/TS 21139-21.

When there is any difference from the standard test method or standard measurement conditions described in this document, those differences shall be also reported.

Annex A
(normative)

Relative severity of the relative spectral irradiance

A.1 General

The use of reference values for the relative severity, $\rho_{RSI/GI}$, allows one to express the effect of light fading under a given RSI, which would be fully represented by a radiometric measure of irradiance [W/(m^2·nm)], by a simpler approach, namely the ratios of relative photometric illuminance [lux = lumen/m^2]. This approach simplifies the requirements for the measurement apparatus to determine the intensity of exposure to which the specimens are subjected to in the backlit display application and in the accelerated exposure test, respectively.

The relative severity $\rho_{RSI/GI}$ of various standard *RSI* has been evaluated based on a general action spectrum approach: for a wide range of colorants typically used in photographic materials, Jung and Hofmann[9] have correlated the relative amount of light fading expressed as ΔD with the relative spectral irradiance RSI(λ) used in the actual light fading test and the UV/VIS absorption spectra $A_{Dye}(\lambda)$ of the colorants, respectively.

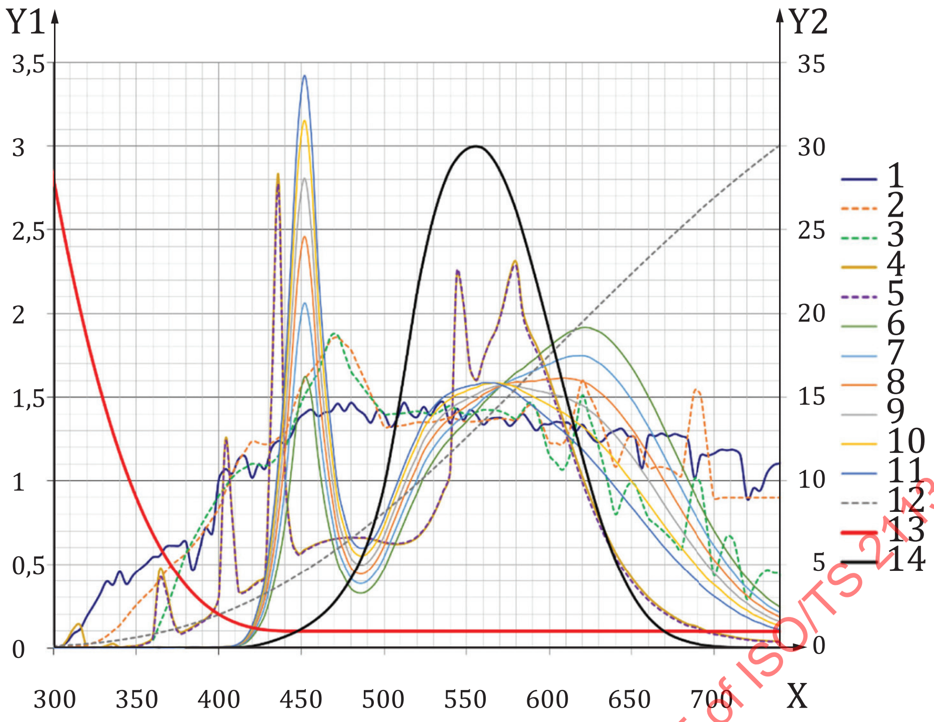
$$\rho_{RSI_i/RSI_j} = \frac{1}{n}\sum_{I=1}^{n}\frac{\Delta D(RSI_i, Dye_I)}{\Delta D(RSI_j, Dye_I)} \text{[average for more than 20 different colorants Dye}_I\text{]}$$

$$\frac{\Delta D(RSI_i, Dye_I)}{\Delta D(RSI_j, Dye_I)} = \frac{\int_{\lambda=300}^{750} RSI_i(\lambda)\cdot A_{Dye\,I}(\lambda)\cdot f_{action}(\lambda)\cdot d\lambda}{\int_{\lambda=300}^{750} RSI_j(\lambda)\cdot A_{Dye\,I}(\lambda)\cdot f_{action}(\lambda)\cdot d\lambda} \quad \text{(A.1)}$$

NOTE The integrals in A.1 are calculated numerically as a summation over the given wavelength range with a wavelength partition $\Delta\lambda$, that is smaller than4 nm.

The pairwise ratios of light fading ΔD for the investigated range of colorants and *RSI* could be consistently described with relation A.1 using a parameterized, generic spectral weighting function $f_{action}(\lambda)$, which is spectrally multiplied with the UV/VIS absorption spectrum $A_{Dye}(\lambda)$ of a colorant over the range of 300 nm to 750 nm, that has been measured on the 100 % printed patch of each colorant *I*. The spectral product of $A_{Dye}(\lambda)$ and $f_{action}(\lambda)$ represents the “action spectrum” of the given colorant.

When the RSI data are intensity normalized to the same level of illuminance [klx], the integral over the action-spectrum-weighted *RSI* data can be interpreted as a measure of the relative photolytic action that the RSI would introduce in terms of light fading of these colorants. This ratio is denoted relative severity ρ_{RSI_i/RSI_j}.



Key

X nm

Y1 W/m²/nm

Y2 f_{action}[1]

1 natural daylight (ASTM G173)

2 window glass filtered Xe-arc

3 general indoor filtered Xe-arc

4 bare-bulb fluorescent

5 glass-filtered fluorescent

6 blue-pumped LED 1 (CCT 3 089 K)

7 blue-pumped LED 2 (CCT 3 504 K)

8 blue-pumped LED 3 (CCT 3 957 K)

9 blue-pumped LED 4 (CCT 4 450 K)

10 blue-pumped LED 5 (CCT 5 029 K)

11 blue-pumped LED 6 (CCT 5 625 K)

12 illuminant A (2 856 K)

13 action factor model

14 visual

Figure A.1 — Several RSI's normalized to 100 klx

Figure A.1 shows various *RSI's* that are of interest in the context of backlit displays. The series LED 1 to LED 6 refers to phosphor-converted '*blue pumped' LEDs* with their different CCT values noted in brackets, respectively.

The *RSI* "*daylight + PC screen*" mimics the effect of a UV filter with a 50 % transmission at 400 nm, which is typical for UV stabilized polymer screens such as Polycarbonate (PC) or Poly-(methyl-methacrylate) (PMMA). The legacy RSI "*glass-filtered fluorescent CIE F6*" is provided for comparison. The other filter conditions (*window-glass* and *general indoor*) are defined for the Xenon-arc based test methods in ISO 18937 for simulation of in-window display and general indoor display, respectively.

Table A.1 summarises the relative severity of several RSI based on the action spectrum analysis. The standard deviation denotes the variability across the > 20 colorants considered. Note that for RSI's with larger spectral differences to "general indoor" the uncertainty of the predictions of the simplified action spectrum model become larger. Figure A.2 provides a visualization of these data.

The severity index is highly preferable to the 'damage potential' of CEN 157, because it does not only look at the RSI of the irradiant exposure but also at the materials and their absorption. It will thus capture the interaction much better. Referencing it to a standard light source provides the experimental data. However, as every 'data approach', it may not be applicable to some specific cases and therefore has reference character only.

If the individual spectral action factors of a given colorant system are available[13], the relative severity ratios can preferably be evaluated based on those rather than using the reference values, as this would overcome the simplifications mentioned before.

Table A.1 — Relative severity $\rho_{RSI/GI}$ of various RSI vs. "general indoor" filtered Xenon-arc

Illuminants (RSI)	**Relative severity** $\rho_{RSI_i/GI}$	
	Average	StDev
natural daylight (ASTM G173)	1,52	0,20
window glass filtered Xenon-arc	1,19	0,06
general indoor filtered Xenon-arc	**1,00**	**0,00**
daylight + PC screen (400 nm)	0,87	0,09
for info: bare-bulb fluorescent CIE F6	*0,74*	*0,15*
glass-filtered fluorescent CIE F6 (ISO 18909)	0,64	0,14
blue-pumped LED 1 (CCT 3 089 K)	0,59	0,24
blue-pumped LED 2 (CCT 3 504 K)	0,63	0,20
blue-pumped LED 3 (CCT 3 957 K)	0,66	0,17
blue-pumped LED 4 (CCT 4 450 K)	0,69	0,14
blue-pumped LED 5 (CCT 5 029 K)	0,73	0,12
blue-pumped LED 6 (CCT 5 625 K)	0,75	0,09

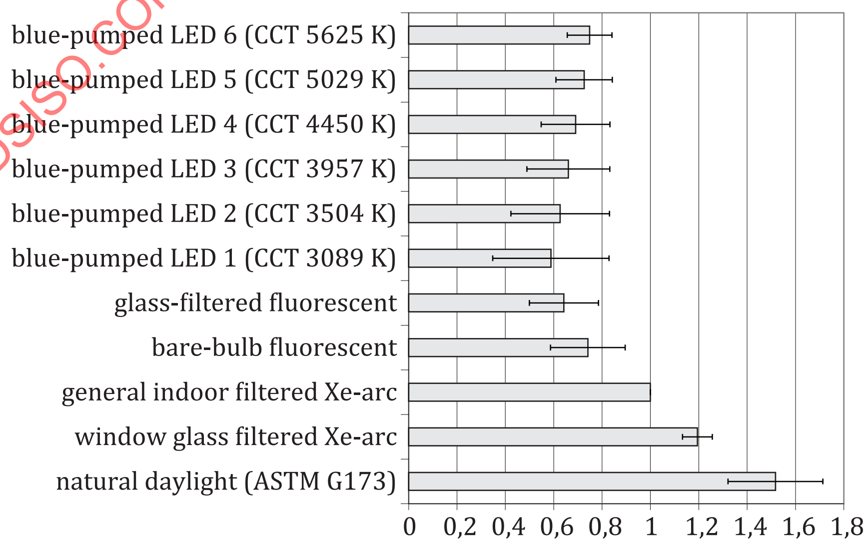


Figure A.2 — Relative severity $\rho_{RSI/GI}$ of various RSI vs. "general indoor" filtered Xenon-arc (graphical visualization of table A.1)

For the colorants investigated, the *RSI* of *glass-filtered fluorescent CIE-F6* as defined in ISO 18909 has a relative severity very close to that of a phosphor-converted *'blue pumped' LED with 3 500 K CCT*. Therefore, backlit units with these two types of lamps can be considered equivalent in terms of testing colour fading over a wide range of printing materials.

On the other hand, the effect of varying correlated colour temperature (CCT) of phosphor-converted 'blue pumped' LEDs is rather limited (see Figure A.2). Towards the very low end of warm white LEDs with a CCT of ca. 3 000 K, the relative severity drops to ca. 80 % of the level characteristic of the LED with ca. 5 000 K, but the uncertainty of the relative severity calculation increases, as indicated by the standard deviation.

Annex B
(normative)

Characterization of an example LED light box

B.1 General

A light box for backlit display of soft signage has been characterized. The LED lamps are mounted inside a white coated housing, which serves as diffusing cavity. The dimensions of this backlit unit are ca. 600 mm × 420 mm × 60 mm (H × W × D). Strips of individual LEDs are mounted on the back panel forming a 6 × 4 grid of individual LEDs with ca. 10 cm vertical and horizontal distance and about 5 cm distance to the frame. The LED lamps are equipped with optical lenses that introduce a donut like light diffusion with enhanced emission at about 30° compared to the normal of the backplane.

NOTE In backlit units with edge-lit design, the LEDs are mounted on the side of glass or plastic sheets: the injected light intensity is distributed across the sheet by light piping. Light scattering is purposefully introduced, e.g. by surface structures (roughness), to couple out an amount of the intensity, so that a diffuse backlit illumination is obtained. Overall dimensions, thickness of the sheet and amount of scattering determine the homogeneity and intensity of edge-lit units.

The light intensity of the backlit unit has been measured with a spectro-radiometer with a diffuse probe that is positioned in the mounting plane of the print i) at the positions of the LED rows and ii) in between LED rows as indicated in Figure B.1. The resulting illuminance distribution is shown in Figure B.2.