TECHNICAL SPECIFICATION

ISO/TS 21139-1

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Permanence and durability of commercial prints —

Part 1: Definition of use profiles and guiding principles for specifications

Permanence et durabilité des impressions commerciales —

Partie 1: Définition des profils d'utilisation et des principes directeurs pour les spécifications

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Foreword

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

A list of all parts in the ISO/TS 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

This Technical Specification ISO/TS 21139 (all parts) defines use profiles and test methods for permanence and durability testing of printed matter for use in the context of commercial applications, which resemble a wide range of product and usage classes (see e.g. ISO/TR 19300). Product classes included are commercial production prints (flyers, brochures), transactional and stationary prints, signage, newspapers and periodical prints, book printing as well as packaging printing. These commercial prints often contain combinations of text, pictorial images and/or artwork. Prints for non-commercial use, including prints used and displayed in consumer home environments and prints exhibited or stored in museum context, are outside the scope of this document.

A use profile describes typical environmental and other stresses characteristic for the conditions under which a printed sheet or object is typically used. Also certain (implicit) expectations for retained print properties under these conditions may be connected to a particular use profile. These need to be explicated and linked to observed failure modes and assessed as measureable changes of image parameters, including the various dimensions of image quality and physical integrity of the print.

For permanence testing either single or combined stress factors are applied in accelerated laboratory tests that aim to simulate the degradation observed in field use. ISO/TS 21139 (all parts) defines test methods that are appropriate to simulate exposure in use profiles of printed matter in a variety of uses. Furthermore, requirements for reporting of permanence test results are given as guidance for translation of test results into use profile performance, also addressing limitations of “year calculations” due to restrictions of accelerated testing and variability in actual display conditions.

In the context of service life testing of identification cards defined in ISO 24789-1 and ISO 24789-2, a matrix of stresses and evaluations has been defined to simulate various application profiles of such plastic cards. ISO/TS 21139 (all parts) may be developed in an analogous way in a future revision.

Permanence and durability of commercial prints —

Part 1: Definition of use profiles and guiding principles for specifications

1 Scope

This document defines use profiles for commercial prints in terms of typical environmental stress factors and any mechanical and chemical stress factors to be considered additionally in their application.

Methods and principles defined in this document apply to the various product classes of "commercial prints" that, following the terminology of ISO/TS 19300, include commercial production prints (flyers, brochures), transactional and stationary prints, signage, newspapers and periodical prints, book printing as well as packaging printing. These commercial prints often contain combinations of text, pictorial images and/or artwork. Prints for non-commercial use, including prints use and display in consumer home environments and prints exhibited or stored in museum context, are outside the scope of this document.

For each use profile a set of suitable accelerated test methods for the leading environmental and/or mechanical or chemical stress factors is defined for representative testing. Guidance is given for translation of test results into suitable image permanence performance claims considering the variability of actual use in comparison to reference use profiles.

The test methods and guiding principle described in this document apply to both, analogue and digitally printed matter, and the corresponding test targets from the ISO 12647 series are used. 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 5-4, *Photography and graphic technology — Density measurements — Part 4: Geometric conditions for reflection density*

ISO 2836, *Graphic technology — Prints and printing inks — Assessment of resistance of prints to various agents*

ISO 5626, *Paper — Determination of folding endurance*

ISO 12647-7, *Graphic technology — Process control for the production of halftone colour separations, proof and production prints — Part 7: Proofing processes working directly from digital data*

ISO 12647-8, *Graphic technology — Process control for the production of half-tone colour separations, proof and production prints — Part 8: Validation print processes working directly from digital data*

ISO 13655, *Graphic technology — Spectral measurement and colorimetric computation for graphic arts images*

ISO 18930, *Imaging materials — Pictorial colour reflection prints — Methods for evaluating image stability under outdoor conditions*

ISO 18936, *Imaging materials — Processed colour photographs — Methods for measuring thermal stability*

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

ISO 18941, *Imaging materials — Colour reflection prints — Test method for ozone gas fading stability*

ISO 18946, *Imaging materials — Reflection colour photographic prints — Method for testing humidity fastness*

ISO 18947, *Imaging materials — Photographic reflection prints — Determination of abrasion resistance of photographic images*

ISO 18948, *Imaging materials — Photo books — Test methods for permanence and durability*

IEC 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 + 12 h cycle)*

IEC 60068-2-38, *Environmental testing — Part 2-38: Tests — Test Z/AD: Composite temperature/humidity cyclic test*

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 http://www.iso.org/obp

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

3.1
application profile
set of parameters that, in total, define the conditions of use specified for an application

[SOURCE: ISO 24789-1:2012, 3.1.2]

3.2
use profile
total set of environmental, mechanical and/or chemical conditions to which a printed product is subject to during a particular use

3.3
stress factor
element of the environmental, mechanical and/or chemical conditions to which a printed product is exposed

Note 1 to entry: A particular combination of stress factors defines a particular use case and material degradation results from the complex interaction between the processes triggered by the presence of stress factors.

Note 2 to entry: Leading environmental stress factor include light, heat, humidity, and air pollution. Examples of mechanical stress factors are scratching, abrasion, bending, flexing, folding, tearing, and pressure. Example of a chemical stress factor is the contact to a liquid, including water, solvent, sweat, oils and detergents.

3.4
test target
set of colour patches or line elements based on which a change in image quality attributes can be evaluated

EXAMPLE The print control strips described in ISO 12647-8.

3.5
endpoint
defined measurable densitometric, colorimetric, or physical change in a print parameter used to define the point at which a print is no longer usable or acceptable in a particular application

Note 1 to entry: not to be confused with end of test, defined as the point at which a test is terminated after a pre-defined level of physical or chemical stressor has been applied or after an accumulated exposures of the stresses which is determined based on the assumption of the exposure level of the use or the required level of longevity for the product. For example, if the product is expected to be used for 10 years under 250 lx-12 h light level, the test duration in lux-hours should be 250 lx × 12 h per day × 365 days per year × 10 years. A safety factor can be applied to accommodate any experimental errors that may exist.

Note 2 to entry: Limit can for example represent the just visible change or the acceptability of an articulate change in view of the specifications of the use profile.

3.6
permanence
<image> ability to remain chemically and physically stable over long periods of time

3.7
durability
<image print> resistance of an image print to physical, mechanical, chemical and/or environmental stresses in conditions of use, until the end of useful life

Note 1 to entry: In some cases, these stresses can be controlled by the user, like frequency and mode of handling resulting in abrasion of scuff marks. In other cases, stresses are eventually out of control of the user, including strain caused by dimensional changes of the print material arising from repeated humidity and/or thermal cycling in the course of day/night transitions. Other stresses with limited control are exposure to UV and/or reactive airborne pollutants. Those stresses may attack the physical integrity of the material(s) that constitute the printed sheet or object, manifesting themselves for example as cracking, blistering, delamination or brittleness of layers.

3.8
digital print
print where the image is printed directly from the digital domain

Note 1 to entry: Digital printing is a process for text and image reproduction with a colour marker on a medium using a marking device, on which the marking information is generated from digital data directly to the medium. It differs from traditional ink-based printing on which the marking information is generated from a form produced offline prior to imaging on the medium.

Note 2 to entry: Offset printing in its various form as defined in ISO 12647 series is mostly still categorized as “analog printing” even though data stem from digital domain like in case of computer-to-plate systems.

[SOURCE: ISO 18913:2012, 3.52, modified — The word "directly" was added in the definition, Note 1 to entry has changed and Note 2 to entry was added.]

3.9
digital printing system
system that prints one unique iteration at a time for either variable data or classical printing applications including but not limited to electrophotographic and ink jet marking engines

[SOURCE: ISO/TS 15311-2:2018, 3.1]

3.10
transflective print
print on a translucent support that is designed to partially transmit and reflect light, so that print can be viewed both in reflection by means of front illumination or in transmission by means of back illumination

Note 1 to entry: Front and back illumination may be present at the same moment in time.

3.11
product and usage class
category that combines graphic products that have been developed for the same marketing purpose

[SOURCE: ISO/TR 19300:2015, 2.4, modified — The term "use case" was replaced by" product and usage class".]

3.12
book printing
printing of books and publishing of monographs (reference books, photo-books, comic, paperback, textbooks and directories)

3.13
commercial printing
printing for graphic products for commercial applications such as catalogue, advertisement (flyer, pamphlet, leaflet, direct marketing, free magazines) and other (manuals)

3.14
newspaper and periodical printing
printing for graphic products for newspaper (colour, black and white) and periodical magazines (monthly, weekly)

3.15
package printing
printing for graphic products for packages, including rigid and flexible packaging, such as beverage carton, cardboard container, corrugated box, label, sticker, snack and retort pouch

3.16
sign printing
printing for graphic products for indoor or outdoor display (poster, banner, textile, billboard and wrapping decoration)

3.17
transactional and stationary printing
printing for graphic products for direct mail (direct marketing) and advertisement (flyer, pamphlet, leaflet, free magazine)

4 Guiding principles

4.1 Image stability in view of use profiles

The image permanence and print durability performance of printed sheets and objects depend on two aspects:

a) the kind of level of stresses, which the printed matter undergoes in intended use, and

b) the user expectations on retention of properties. This can often be a matter of dispute when these are not defined in advance.

A use profile for printed matter is thus defined by two aspects, namely

— a set of stresses present in the intended use of the printed product that may result in degradation of the printed image or loss of physical integrity of the printed matter, and

— a certain level of retained image quality and print integrity that is expected to assure intended use.

Examples of use profiles include various types of display situations and/or handling stresses in printed product, including printing products for signage, packaging, newspapers, periodicals, trade books, business forms, flyers, and direct mailings.

4.2 Stresses in use profiles

Typical stresses in use profiles can arise from general environmental conditions of display and storage and/or the presence of particular mechanical and/or chemical stress factors typical for a particular use of printed matter. Leading environmental stress factor include light, heat, humidity, and air pollution. Examples of chemical and mechanical stress factors are scratching, abrasion, bending, flexing, folding, tearing, and pressure as well as eventual exposure to liquids (water, solvent, sweat, oils, detergents, etc.).

In use profiles often combinations of aforementioned stress factors may be present, also including diurnal changes resulting in additional stress fatigue by periodic thermal or moisture related expansion and contraction of layers. Examples of combined stresses are outdoor weathering, wet abrasion and blocking, where the latter is caused by combined effect of pressure and moisture at ambient or elevated temperature. Display use profiles represent a set of environmental stress factors that apply for many product classes.

The actual levels of the various stress factors may span a continuous range, in which suitable “reference points” shall be defined for ease of communication. For guidance, the 95 % percentile values of environmental stress factors, such as temperature, humidity, light intensity or airborne ozone concentration levels, are regarded as reasonable worst case[27] and should therefore be chosen as meaningful reference points. One hour averages of environmental parameters are appropriate for characterizing the 95 percentile in cyclic conditions, one day (24 h) averages are suitable to characterize static conditions. See Annex G for calculation of the 95 percentile. In case of altered conditions, e.g. presence of HVAC (heating, ventilation and air-conditioning) installations in a building or (partial) protection against one of the environmental factors, appropriate other levels are defined.

NOTE In outdoor weathering, e.g., environmental stresses vary due to climate, orientation and inclination of the displayed images, but also just due to seasonal or year-to-year variations of weather. Comparison with exposure to reference climates is recommended.

4.3 Retained print quality in use profiles

Image permanence refers to both retention of certain image quality attributes as well as retention of physical integrity of the print[28]. Examples of attributes representative for real world failure of printed matter include the following changes in image quality and/or print integrity, see Annex F for examples.

a) attributes related to printed colour: colour fade, change of tone reproduction, loss of neutral balance, discoloration, etc.

b) attributes related to detail reproduction: loss of sharpness, e.g. due to (colour) bleeding, etc.

c) attributes related to print uniformity: changes in gloss, introduction of staining or mottle (as function of print density), etc.

d) failure of print layer structure including image (receiving) layer(s), coatings or laminates: cracking on micro- or macro-level, blistering, flaking off, adhesion failure, delamination, chalking, etc.

e) discoloration of the printing substrate: yellowing or carbonization ("browning”), etc.

f) physical disintegration of the printed matter: brittle failure, etc.

g) physical deformation of the print material: cockle, curl, warp, change of dimensions, etc.

h) mechanical damage of the print surface: scratches, dents, scuff marks, wear, etc.

Quantitative assessment of these various dimensions of image permanence requires instrument measurements in addition to visual assessment. Measurement of the change of an image parameter requires the measurement of the corresponding image quality parameter after and before the stability test. Methods for measurement of image quality parameters of digital prints have been described in ISO/TS 15311-1 and ISO/IEC 24790 or are under development.

Judgement of changes of the various dimensions describing initial image quality and print integrity may involve evaluation of many different image parameters. For each image parameter, endpoints may be defined that express the retention of a certain level of quality (either absolute or relative to the initial state) as quality expectation typical in the use profile.

However, an over-coupling, generic metric of visual judgement of multi-dimensional image quality by human observers, including non-linear judgement effects known as “peak picking” (i.e. observers tend to focus on the particular dimension of image quality they perceive worst) does not yet exist. Also, quality expectations depend on the individual purpose that a printed product may have within a usage class, including other aspects such as performance of benchmark materials, market share, industry standards, certification and also commercial aspects[29].

Furthermore, perception of retained image quality strongly depends on the mode of assessment, namely via single stimulus evaluation or via side-by-side comparison. In addition, the initial level of print quality plays a role in the judgement. Last but not least, viewing distance in the use situation has a direct impact of visibility of image quality degradation and artefacts, e.g. micro cracks.

NOTE ISO/TS 15311-2 applies for all press output that is typically held at a viewing distance of 30 cm to 50 cm such as publishing, transactional and stationary printing, brochures, leaflets, stationery, corporate accounts, catalogues, newspapers, magazines and books.

4.4 Measurements of colour changes

4.4.1 Colour fading

One of the most frequently discussed and reported image parameters in permanence studies is colour retention. The measurement of colour retention requires a printed test target with a defined set of test colour patches. Layout and dimensions of test patches are designed to make test targets suitable for exposure in the test chamber and colour measurements with automated chart readers. Target colour patches are typically printed including printer characterization (Colour Management System) as in actual use. Drying down or curing times typical for the printing process shall be applied and reported, as these typically differ across the various digital and analogue printing processes.

Colour retention measurement is based on comparison of colour measurements after exposure vs. before. All colour measurements shall be made in accordance with ISO 13655. The measurement conditions (M0, M1, M2 or M3) and the backing to be used (white backing, self-backing or black backing) shall be in accordance with those specified for the characterization data set being used.

Sampling of test colours in colour space is defined by the selection of colour patches in the test target. To assess colour stability of commercial prints the test target shall include the set of control strip patches specified in the corresponding series ISO 12647 (all parts) depending on the printing technology under test, including offset lithographic, letterpress, gravure, screen printing, flexographic as well as all kind of digital printing, including inkjet and electrophotography printing.

The test patches shall be arranged in a test target layout, such that the patches fit on the exposed area of the specimen holders in the tests. The size of each colour patch area shall be large enough to cover measured area plus positioning error. The appropriate size depends on the patch reading equipment used. Aperture size requirement shall comply with the geometric conditions given in ISO 5-4.

For digitally produced commercial prints, test targets with colour patches following ISO 12647-7 and ISO 12647-8, shall be used (see Annex B). An example of colour analysis after light fading is shown in Annex E.

Evaluation metrics shall be assumed to apply to the assessment of a single printed sheet with measurements after and before exposure unless otherwise specified. In case of multiple sheets, the sheet-to-sheet variability shall be accounted for in the assessment of the effective colour change in addition to the variability of consecutive colour measurements (see ISO/TS 15311-1 for details).

As a measure of colour change the mean, maximum and 95 % percentile colour difference (CIE DE2000) between the measurements of these patches before and after the test shall be calculated according to the corresponding part of ISO 12647. The 95 % percentile is obtained from an ascending sort of the results of all the patches on the target, and the 95th quantile is picked. See Annex G for analysis of targets having number of patches different from multiples of 100, where the 95 % percentile falls in between discrete positions of the histogram. Measurements shall be corrected for the contribution of measurement repeatability to overall colour difference. If the change in colour affects one set of colours significantly more this should be noted for report.

4.4.2 Colour bleeding

For testing of humidity induced colour changes by "bleeding" (diffusion of colorants) the checkerboard test target of ISO 18946 shall be used. It is important not to alter (resize, interpolate) the physical size of the checkerboard patterns, as this will influence the effect of humidity bleeding. Here, CIE ΔE76 metrics applies, for which best correlation with psychophysical judgements of image quality degradation has been obtained (see ISO 18946).

4.5 Other evaluations

For measurement of other image quality attributes (gloss, homogeneity, detail reproduction, visual assessment) the reader is referred to the requirements of the corresponding evaluation methods, e.g. as referenced in ISO 15311-1.

For non-destructive post evaluation of prints after stability testing (visual inspection and optical measurements such as colour, gloss, sharpness etc.) intermediate sampling and placing back of specimen can be considered. For destructive post evaluation (e.g. mechanical testing) a suitable number of replicates shall be provided after stability test (light, heat, humidity, ozone, weathering), which may result in a substantial amount of specimen.

A suitable example for a brittleness test of strips of printed matter is given in Reference [30]. Otherwise a tensile test may be suitable as described in ISO 527-1 and ISO 527-3.

5 Definition of use profiles based on stresses

5.1 General

As mentioned in 4.2, a particular use profile typical for a printed product and usage class is defined by a range of environmental stress factors as well as some typical mechanical/chemical stresses.

One common usage of printed products is their display. Therefore, a limited number of display use profiles is defined that are significantly different from each other. Still, the actual levels of the various stress factors in a use profile may span a continuous range, in which preferably one - or if needed a small number of - reference levels typical for that use profile are defined.

Table 1 provides a general overview of display profiles that define typical combinations of environmental stress factors, whereas generic mechanical and chemical stress factors are treated separately. The organization of ISO 21139 series follows this approach: The number block of parts 21, 22 and 23 define stress factors typical for various instances of indoor display as defined by 1.1, 1.2 and 1.3 of Table 1. Likewise, the number block of parts 31 and 32 define typical instances of outdoor display as defined by 2.1 and 2.2 of Table 1. Table 3 provides an overview of environmental stresses in display use profiles.

The parts of ISO 21139 with number block 41, 42 etc. define mechanical and chemical stresses typical for processing, conversion and handling of the printed products and/or typical for their intended usage. Depending on product and usage class various of these factors may apply as shown in Table 4 indicating their typical and eventual occurrence for the product and usage classes defined by ISO/TR 19300 (see Annex C). Some examples of product and usage classes and related stresses are shown in Annex A (Table A.1).

Table 1 — Overview of use profiles, stress factors and related test methods

Groups of stress factors	Environmental stresses						Processing and conversion stresses										Product
				Storage related stresses						Mechanical & chemical stresses (handling or functional)							test
Stress factor	Weathering[a]: light (outdoor), heat, humidity and spray	Elevated heat & humidity cycles, e.g. In enclosures [b]	Light (indoor)	Heat	Ozone	Humidity	Pressure: stack or wind	Folding	Cutting	Wear: abrasion, scratch or rub	Spill & wipe: water or other liquids [c]	Condensation	High pressure water jet[11]	Freeze/ thaw	Steam[d]	Finger-prints	Specific system test
Test method	ISO 18930	ISO 18948	ISO 18937	ISO 18936	ISO 18941	ISO 18946	ISO 18948	ISO 5626	—	ISO 18947	ISO 18935	IEC 60068-2-30	ISO 16925	IEC 60068-2-38	food context	ISO 2836	other
1. Indoor display use profiles																	
1.1 In-window display			x		x												
1.2 General indoor display (w/o partial protection)			x	x	x	x											
1.3 Indoor display on light boxes		x	x	x	x	x											
2. Outdoor display use profiles																	
2.1 Outdoor display (w/o partial protection)	x			x	x	x						x		x			
2.2 Outdoor display light boxes	x	x	x	x	x	x								x			
3. Use profiles including processing, conversion, handling and usage related stresses							x	x	x	x	x	x	x	x	x	x	x

x: Stress factor(s) included in use profile.

[a] Weathering represents a cyclic test including sequences of combined exposure to light, heat and humidity and water spray, but excluding ozone. Spectral power distribution is different for indoor and outdoor daylight exposure.

[b] Examples: print display in outdoor light boxes, transport episodes inside a closed vehicle, shipping container etc. – see D.4. Temperature increase can be based on the greenhouse effect within an enclosure that is exposed to sunlight or other illumination.

[c] Test method includes some form of wet abrasion test that may also be used with detergents; these can be used to test resistance to periodic cleaning.

[d] For some applications resistance of printed matter to micro-wave radiation may also be of interest, either in combination with steam or alone.

5.2 Daylight and its variations as source of illumination in indoor and outdoor display

(Terrestrial) daylight is a natural source of illumination for display of printed matter, both indoor and outdoor. However, intensity and spectral power distribution of the effective illumination strongly depends on the details of the display use profile (location, orientation, shading) and varies with season and atmospheric conditions. The following differentiation needs to be considered.

"Direct" daylight includes sunlight and diffuse skylight, which together define the global irradiance. Their spectral components are defined for specific atmospheric conditions and air mass, in ASTM G177 and CIE 85:1989[1)] using the SMARTS2 code. ISO 18930 provides a test method for digital prints under direct daylight in outdoor conditions, either as

— exposure to natural daylight, or as

— exposure to laboratory Xenon-arc lamps with daylight filters.

The so-called "UV cut-on" represents the lowest wavelength, at which the spectral power distribution of terrestrial daylight radiation introduces degradation in matter. At wavelengths below, the intensity is sufficiently reduced by the atmosphere, so that degradation cannot be observed even for long term exposure. The typical UV-cut on of natural daylight varies in the range 295 nm to 300 nm depending on season and atmospheric conditions.

"Indirect" daylight refers to exposure situations, where intensity and/or the effective UV component of direct daylight has been reduced. Typical examples of indirect daylight are:

a) daylight filtered through window glass,

b) daylight in rooms, and

c) daylight in extended shadow zones outdoors.

In case of display "self-shadowing" can simply be introduced by orientation of display essentially away from the overhead direction of the sun at noon. Blocking of direct sunlight by shading in b) and c) also avoids radiative heating of the displayed print. Since most natural and man-made materials have considerable UV absorption, the process of indirect illumination of a display dominated by reflections from its environment effectively represents "UV filtering by reflection". In all instances of indirect daylight, the effective "UV cut-on" wavelength increases in comparison to direct daylight.

Typical "window glass filtered daylight" represents indirect daylight with a spectral distribution as defined in ISO 18937. Window glass acts as UV filter with a 50 % transmission around 340 nm to 345 nm, which is representative for double glazing (6 mm total glass thickness represent e.g. 2 sheets of 3 mm thick glass sheets in double glazing). The corresponding UV cut-on is around 320 nm.

An even more indirect mode of daylight illumination is encountered for indoor display further away from a window, when large part of the window-glass filtered daylight has undergone reflection off the interior of the room before hitting the displayed print. This reflection process results in further reduction of UV component. ISO 18937 defines this "more indirect" daylight situation as "general indoor" and stipulates a filter with 50 % transmission around 370 nm to 375 nm for use with a Xenon arc light source. The corresponding UV cut-on is around 345 nm to 350 nm.

1) Under revision.

Table 2 — Variations of daylight in indoor and outdoor display use profiles

Daylight	Direct	Indirect	
		By shading	By filter
Outdoor	display to direct sunlight and diffuse skylight 100 klx to 130 klx UV cut-on at 295 nm to 300 nm radiative heating of displayed prints	display in shadow zones 1 klx to 60 klx UV cut-on at 295 nm to 310 nm no radiative heating of displayed prints	—
Indoor	—	—	in-window display 1 klx to 60 klx UV cut-on at ~320 nm radiative heating of displayed prints
	—	general indoor display in distance from windows 0,1 klx to 1 klx UV cut-on at ~345 nm to 350 nm no radiative heating of displayed prints	

Also several artificial light sources designed for building illumination can be simulated with this type of "general indoor display" filter, as most of these lamps are equipped with a UV reducing filter or have intrinsic low UV emission. Examples used in commercial context are fluorescence lamps with cover, tungsten halogen lamps, metal halide lamps with UV filter and LED.

Note: In museum display, often filtered daylight or artificial light sources filtered with a 50 % transmission wavelength of 400 nm to 420 nm is applied (see ISO 18950). The higher UV cut-on wavelength already starts to introduce a yellowish appearance.

More background information is provided in Annex D.

5.3 Use profiles for indoor display of printed matter

The following generic use profiles for indoor display are defined:

— **In-window display** is a use profile characterized by display or handling near to or in a window, where illumination is represented by indirect daylight filtered by window glass (see Table 2). Examples are showcases, in-window display or lobbies. For windows connected to buildings, typical levels for temperature, humidity and ozone have to be considered in view of building climate, i.e. whether an air control unit is in place. In-window display in a stand-alone vitrine or on a car dashboard is essentially similar, but these are characterized by larger variations of temperature and humidity due to greenhouse effect.

— **General indoor display** is a use profile for display or handling printed matter in indoor conditions with exposure to indirect daylight filtered by window glass and off-the-wall reflections (see Table 2). Also artificial illumination including UV-filtered fluorescent, LED and metal halide falls into this class. Examples are display on walls, point-of-sales prints or pop-up's. Some additional measures may be in place that protect the printed matter - at least partially - against some of the environmental stress factors including light and airborne pollutants. Examples are: printed matter stored in cabinets, drawers and storage boxes as well as framed display with some cover screen, which may act as additional UV filter (see D.1.3).

— Indoor **light box display** is a use profile characterized by a combination of front- and backside illumination, often introducing elevated temperatures due to the lamp appliance behind the print. Depending on the location of orientation of the light box relative to windows, the frontside illumination may be include indirect daylight or artificial illumination. Examples are light-boxes illuminated by fluorescent lamps or LED, with or without cover screen. In case of UV stabilized plastic screens extended UV filtering may be in place, depending on the design of the light box.

Leading environmental stress factors of concern in indoor display are:

a) Exposure to radiation: The spectral power distribution of the irradiance in the UV/VIS/NIR depends on the nature of the light source and the eventual presence of filters. The intensity is often expressed in visually weighted illuminance (lx = lm/m^2) or in integrated power per surface area [W/m^2] for a defined spectral range. Intensity is controlled by distance and orientation of the displayed print to the light source(s) with the following examples: direct and indirect daylight through window glass as well as artificial illumination by LED, fluorescent and/or metal halide lamps. In case of mixed illumination, it may be needed to determine the light source that dominates the degradation.

b) Thermal exposure: Temperature range and reference temperature should be provided.

c) Exposure to moisturized air (% RH). Range of humidity and reference value should be provided.

d) Exposure to airborne pollutants: Ozone has been selected to represent oxidative reactive gases. Indoor concentrations mainly follow outdoor levels by 10 % to 50 % of concentration depending on the rate of air exchange, unless incoming fresh air is purified by filter systems. Equipment running high voltage components or emitting UV below 280 nm may also produce ozone.

In Annex D some guidelines are given for the estimation of environmental stress factor levels.

Table 3 — Display use profiles with typical ranges of the environmental stress factors (in brackets)

Dis-play use profile	Generic description	Examples (see also Table 4)	Typical parameter range of environmental stress factors: Light: Intensity: Illuminance [lx]	Light: Intensity: UV fraction[a]	Light: Spectral power distribution	Heat	Humidity	Air pol-lution
A) Indoor display								
A1	**In-window display** with direct daylight through window glass	showcase, window display, lobby	duty cycle 12/24 3 klx (2 klx to 100 klx)	8,0 % (6,3 % – 9,7 %)	Xenon-arc with window glass filter *(ISO 18937: $\lambda_{50\,\%T}$ = 340 nm – 345 nm)*	25 °C (18 °C to 40 °C)	50 % RH (30 to 70 % RH)	indoor level
A2	a) **General indoor display** with indirect daylight through window glass or other general room illumination	Display on wall, point of sales dis-play, pop-up's	duty cycle 12/24 500 lx (150 lx to 1 000 lx)	4,1 % (2,1 % - 6,1 %)	Xenon-arc with general indoor filter *(ISO 18937: $\lambda_{50\,\%T}$ = 370 nm – 375 nm)* OR LED, fluorescent, Tung-sten Halogen, metal-halide	21 °C (18 °C to 30 °C)	50 % RH (30 to 70 % RH)	indoor level
	b) **General indoor display with some level of protection**: e.g. reduced air exchange and/or low frequency of display	Book shelf, framed display/ cover screen	duty cycle 12/24 250 lx (150 lx to 1 000 lx)	depends on screen (see Annex D)	same as in A2-a)	21 °C (18 °C to 30 °C)	50 % RH (30 to 70 % RH)	reduced indoor level
A3	**Indoor light box:** display with back illumination for indoor use (w/o cover sreen) introducing elevated temperature, still related to "room climate" with limited T/ % RH cyclingindoor light box:	Advertisement on light box, open or with cover screen	back: continuous 3 klx (1 klx to 6 klx) front: see A1 or A2	depends on design (e.g. screen, light source)	back: LED or fluorescent front: see A1, A2-a) or A2-b)	35 °C (30 °C to 45 °C)	30 % RH (20 to 50 % RH)	reduced indoor level
B) Outdoor display								
B1	a) **General outdoor display:** outdoor display in direct weather of a prototype climate (e.g. tropical, desert, Mediterranean) with specific display and mounting conditions (inclination, orientation, backing, ...)	signage and large format billboard	duty cycle 12/24 110 klx (20 klx to 135 klx)	8,2 % (7 % to 9 %)	*Xenon-arc with daylight filter: (ISO 18930: UV-cut on = 295 nm)*	cyclic,	cyclic and spray, with possibil-ity of conden-sation	outdoor level
	b) **General outdoor display with some level of protection:** e.g. in shadow or self-shadowed by orientation, and/or without direct precipitation	billboard or sig-nage under a roof or in building entrance.	duty cycle 12/24 110 klx (20 klx to 135 klx)	8,2 % (7 % to 9 %)	same as in B1 a)	cyclic	cyclic, no spray, but possibili-ty of conden-sation	outdoor level
B2	**Outdoor light box:** with back illumination for outside display, introducing green-house char-acter w. eventually large T/ % RH variations and episodes of condensation due to outside weather and construction.	backlit material in a light box with covering screen	back: continuous 3 klx (1 klx to 6 klx) front: see B-1	depends on design (e.g. screen, light source)	back: LED or fluorescent front: see B1 a) or B1 b)	cyclic	cyclic with backside spray to simulate con-densation	reduced outdoor level

[a] UV fraction is indicated as ratio of cumulative radiant energy in the range 300 nm to 400 nm versus the cumulative radiant energy in the range 300 nm to 800 nm
See Annex D for additional information.

5.4 Use profiles for outdoor display of printed matter

The following generic use profiles for outdoor display are defined.

a) **Outdoor display** is a use profile, in which environmental stress factors are referenced to a number of standard climates and for which long term average levels for irradiance and climate parameters are known. Outdoor climates span a range of environmental parameters because of latitude, proximity to surface water or open sea or altitude. Examples of reference climates include

   1) tropical,

   2) desert,

   3) mediterranean,

   4) continental, and

   5) high altitude climate.

Differentiation of the first three climates is often sufficient for performance considerations of displayed prints and typically, times-to-fade for same inclination and orientation of display may result in ratios of 1:2 to 1:4 (see information from ISO/TR 18945 in 6.2). Exposure to radiation or precipitation is typically reduced by display in direction away from the sun at noon ("self-shadowing"), by vertical display and/or by providing partial shading (e.g. open roof or near a building entrance) – see Table 2 and D.1.4. In addition, the level and type of airborne pollutants depends on proximity to emission sources (e.g. oxidative or reductive gases and/or sooth emitted from industry and traffic or elevated salt concentration near oceans). Biological stress factors to consider may be mould growth and animal droppings.

b) **Outdoor light box** display is a use profile with filtered daylight from the front side and LED or fluorescent illumination from the back. Even though the printed matter is partially protected against weather conditions by the screen, temperatures in the light box may become considerably high due to greenhouse effect. As a result, wide temperature and well as humidity cycles may occur, including episodes with condensation and/or sub-zero temperatures.

5.5 Use profiles with mechanical and chemical stress factors

For many print products, the consideration of mechanical and chemical stress factors is important.

One set of mechanical and chemical stresses is related to processing, conversion and handling of printed matter. Examples of mechanical stress are observed in the processes of feeding, printing, stacking, cutting, encapsulating, packaging, transporting, positioning, and touching with fingers etc. The observed problems are scratches, dents, scuff marks, flexing marks, tearing, abrasion, and fingerprints.

Depending on intended use, elevated levels of other stresses may be inherent to a product and usage class, including abrasion, rubbing, water immersion, spilling, wiping with chemicals or cleaning with (high pressure) water in heavy duty application including wrapping of vehicles, flooring, etc. In some use profiles including packaging of food, freeze/thaw cycles and/or exposure to water vapour may be functionally required.

During shipping and transport, the printed matter may be exposed to a wider range of temperature and humidity than for intended use. Temperature and humidity variations depend on the construction of the container used for transport as well as the outdoor climate conditions including level of solar insolation. In addition, condensation and direct exposure to precipitation may occur.

5.6 Examples of use profiles for product and usage classes

ISO/TR 19300 defines product and usage classes of commercial prints, for which Table 3 provides an overview of applicable use profiles for display as well as for physical, mechanical and chemical stresses. Some examples are discussed and applicable ISO standards are referenced.

NOTE In the context of service life testing of identification cards defined in ISO 24789-1 and ISO 24789-2, a matrix of stresses and evaluations has been defined to simulate various application profiles of such plastic cards. ISO/TS 21139 (all parts) can be developed in such direction in a future revision.

a) **Use profiles for signage printing** are categorized into product classes for indoor and outdoor usage. In addition to one of the display use profiles, a number of stress factors related to processing, handling and shipping as well as to usage may apply. In outdoor usage, signage prints may be exposed to weather conditions including water spray/condensation, freeze/thaw and wear. Wrapping usage includes a harsh use profile eventually including, dry and wet abrasion, high pressure water jet and cleaning with detergents as encountered in automotive context, in addition to stresses from processing and handling during mounting. Floor graphics can be intended for indoor and outdoor use and the use profile represents high levels of wear (abrasion) as well as periodic cleaning (water/detergents).

b) **Use profiles for packaging printing** represent several product classes, including rigid (carton, corrugated), label and flexible. Main stress factors are episodes of indoor and/or outdoor display with additional mechanical stresses such as rubbing, freeze/thaw cycles and/or water fastness (e.g. due to precipitation, condensation). In case of flexible and label print products additional physical, mechanical and/or chemical stresses may apply, including bending, folding, freeze/thaw cycles, water fastness at ambient and high temperature, condensation of boiling water and high temperature from sterilization processes. Resistance to microwave treatment may be another requirement in food context.

c) **Use profiles for commercial production printing** cover product and usage classes of "publishing" (magazines, magazine covers and monographs, including reference books), "commercial" (catalogues, advertisement), "business forms and cards" (business forms, stationary, transactional, cards) and "newspapers". Much focus in "publishing" is on the integrity of book binding as well as curling, abrasion, stacking, scuffing and blocking, especially due to face-to-face contact of printed pages. The test method standard currently under development as ISO 18948 provides a system test for monographs such as photobooks and reference books. In commercial, rugged transport and intense short term handling needs to be considered. Business forms and cards undergo some general indoor and/or outdoor exposure with additional mechanical stresses due to some level of rugged transport and handling, including rubbing, blocking, and scratching. This also holds for newspapers.

Table 4 — Examples of potential stresses in use profiles for product and usage classes of ISO/TR 19300

Groups of stress factors		Environmental stresses						Processing and conversion stresses										Product test
					Storage related stresses						Mechanical & chemical stresses (handling, functional)							
Stress factor		**Weathering[a]: Light (outdoor), heat, humidity and spray**	**Elevated heat & humidity cycles: e.g. In enclosures[b]**	**Light (indoor)**	**Heat**	**Ozone**	**Humidity**	**Pressure: stack or wind**	**Folding**	**Cutting**	**Wear: abrasion, scratching and rubbing**	**Spill & wipe: water or other liquids[c]**	**Condensation**	**High pressure water jet[11]**	**Freeze / thaw**	**Steam[d]**	**Fingerprints**	**Specific system test**
Test method		ISO 18930	ISO 18948	ISO 18937	ISO 18936	ISO 18941	ISO 18946	ISO 18948	ISO 5626	tbd	ISO 18947	ISO 18935	IEC 60068-2-30	ISO 16925	IEC 60068-2-38	food context	ISO 2836	other
1. Signage printing																		
Indoor use	Poster		o	Table 3: A1, A2, A3				o	o	o	o	—	—	—	—	—	—	—
	POP-up		o	Table 3: A1, A2, A3				o	x	x	o	o	—	—	—	—	o	—
Outdoor use	billboard	Table 3: B1, B2	o	—	Table 3: B1, B2			o	—	o	o	o	x	—	o	—	—	—
	wrapping decoration	Table 3 B1	o	—	Table 3: B1			x	x	o	x	x	x	x	x	—	o	—
Indoor or outdoor use	flooring prints	Table 3 B1	o	Table 3: A1, A2, A3				o	o	o	x	x	o	o	o	—	—	—
2. Packaging printing																		
Packaging (carton, label)	Carton	Table 3: B1	o	Table 3: A1, A2				x	x	o	x	o	x	—	o	—	o	—
	Corrugated	Table 3: B1	o	Table 3: A1, A2				x	x	o	x	o	x	o	o	—	o	
	Label	Table 3: B1	o	Table 3: A1, A2				o	o	o	x	o	o	o	x	o	o	—
Flexible packaging	Flexible	Table 3: B1	o	Table 3: A1, A2				o	x	x	x	x	o	o	x	o	x	food compliance
3. Commercial production printing																		
Publishing	Magazines	—	o	Table 3: A1, A2				o	o	o	o	o	—	—	—	—	o	
	Magazine cover	—	o	Table 3: A1, A2				o	o	o	o	o	—	—	—	—	o	
	Monograph	—	x	Table 3: A1, A2				x	x	o	o	o	—	—	—	—	o	ISO 18948
Commercial	Catalogue	—	o	Table 3: A1, A2				x	o	o	o	o	—	—	—	—	o	
	Advertisement	—	o	Table 3: A1, A2				x	o	o	o	o	—	—	—	—	o	

Table 4 *(continued)*

Groups of stress factors		Environmental stresses						Processing and conversion stresses										Product test
					Storage related stresses						Mechanical & chemical stresses (handling, functional)							
Stress factor		**Weathering[a]: Light (outdoor), heat, humidity and spray**	**Elevated heat & humidity cycles: e.g. In enclosures[b]**	**Light (indoor)**	**Heat**	**Ozone**	**Humidity**	**Pressure: stack or wind**	**Folding**	**Cutting**	**Wear: abrasion, scratching and rubbing**	**Spill & wipe: water or other liquids[c]**	**Condensation**	**High pressure water jet[11]**	**Freeze / thaw**	**Steam[d]**	**Fingerprints**	**Specific system test**
Test method		ISO 18930	ISO 18948	ISO 18937	ISO 18936	ISO 18941	ISO 18946	ISO 18948	ISO 5626	tbd	ISO 18947	ISO 18935	IEC 60068-2-30	ISO 16925	IEC 60068-2-38	food context	ISO 2836	other
Business Form & Card	Business Form	—	o	Table 3: A1, A2				o	o	o	o	o	—	—	—	—	o	
	Transaction	—	x	Table 3: A1, A2				x	x	x	o	o	—	—	o	—	o	
	Stationery	—	x	Table 3: A1, A2				x	x	x	o	o	—	—	o	—	o	
	Card	—	o	Table 3: A1, A2				o	o	o	o	o	—	—	o	—	o	
Newspaper	Colour, B/W, Tabloid	—	o	Table 3: A1, A2				o	o	o	o	o	—	—	o	—	o	

x = stress test typically applicable for use profile.

o = stress test optionally applicable in use profile.

- = stress test typically not applicable in use profile.

[a] Weathering represents a cyclic test including sequences of combined exposure to light, heat and humidity and water spray, but excluding ozone. Spectral power distribution is different for indoor and outdoor daylight exposure.

[b] Examples: print display in outdoor light boxes, transport episodes inside a closed vehicle, shipping container etc. – see D.4. Temperature increase can be based on the greenhouse effect within an enclosure that is exposed to sunlight or other illumination.

[c] Test method includes some form of wet abrasion test that may also be used with detergents; these can be used to test resistance to periodic cleaning.

[d] For some applications resistance of printed matter to micro-wave radiation may also be of interest, either in combination with steam or alone.

6 Test methods

6.1 General

In image permanence testing, well defined exposure methods with accelerated stress levels are employed with the aim to reproduce failure modes as observed in actual use profile in shorter times than in real use, see Annex F for examples.

The approach in simulation of outdoor weathering in a laboratory test chamber is to realize a simultaneous or cyclic exposure to the leading stress factors representative for the use profile. An example is image permanence testing for outdoor display as defined in ISO 18930.

Another approach is to apply single stress factors with the other stress factors being absent or set to neutral level. An example is image permanence testing for indoor use profiles or for durability under processing and handling.

At exaggerated levels of acceleration, the assumption of reciprocity may no longer be valid or artificial failure modes occur that are not observed in actual use profile. For definition of a test protocol combining different stress factors, or for analysis of single stress factor tests, is necessary to also represent the balance of the stress factors in the actual use profile.

Furthermore, the following laboratory test methods for stability of digital prints against chemical & mechanical stresses are available.

— Abrasion stability (see ISO 18947 series on graphical and photographic prints).

— Water Resistance (see ISO 18935 on photographic prints).

— Blocking (see ISO 18948 for “photo books”).

— High pressure water jet (see ISO 16925 that specifies a test method for the assessment of the resistance of coatings to pressure water-jetting. The test method simulates the effects pressure water-jetting has on a coating [“Paints and varnishes”]).

— Fingerprint: There is no dedicated fingerprint standard for printed matter yet, but there is ISO 2836 providing methods to test the stability of prints against various agents and there are general standards checking for interaction of artificial perspiration agents with other materials, e.g. ISO 105-E04 and ISO/IEC 10373-1. In the two latter methods, the material is sandwiched and incubated between layers that are treated with the artificial perspiration agent.

— For cutting, freeze-thaw, steam and water spray /condensation, no test methods specific for printed matter have been identified yet.

6.2 Limitations of predictive testing

As prerequisite of predictive testing test results from accelerated test methods shall provide some level of correlation to observations of real world failure for a given print technology/substrate combination.

The best approach is a correlation study between accelerated and real world testing. An example is the Round Robin test, in which accelerated test results on various printing technologies based on ISO 18930 cycle A were correlated with natural weathering at difference reference sites. A summary is given by ISO/TR 18945. Standard deviations of correlation factors are rather large (40 % to 50 %) due to average over different printing technologies and post treatments. Breaking down the correlation into the various printing technology classes results in correlation factors per printing technology class and/or individual colours, and reduces the variability to typically 30 %, however within the confidence interval of $\pm 2\sigma$ most of the digital printing technologies cannot be distinguished. Investment in testing time and effort can be substantial.

The next best approach is based on comparison of cumulative dose for a single stress factor, assuming other factors are absent or excluded. Control of other stress factors is important, as influence of other stress factor may confound single factor stress tests results, with sensitivity for such interactions often depending on printing technology. The single stress factor tests developed for digital printing material have been designed as compromise between being technology agnostic and at the same time still manageable for a test lab. The following interactions have been identified.

Exclusion of light from thermal, humidity and ozone stability tests is straightforward.

Airborne ozone needs to be excluded from light, thermal and humidity stability tests. A practical low, but still measurable level for exclusion of ozone, is a relative concentration of less than 2 nl/l (= 2 10^{-9}) ozone in air. Low ozone concentrations can be achieved by continuously cleaning the air of the lab or test chamber through an ozone scrubbing elements, such as activated charcoal filters.

Light stability test (ISO 18937) results for several digital printing systems may be biased by elevated temperature and/or relative humidity and the presence of ozone. Means to maintain limited specimen temperatures in a xenon test chamber include the choice of low irradiance levels for test (30 klx to 50 klx), the use of IR filters and/or the chilled chamber air. For suitable settings for Xenon test chambers see ISO 18937. Measurement of specimen temperature is recommended for verification of specimen temperature.

Results from thermal stability test (ISO 18936) for Arrhenius analysis (ISO 18924) may depend on humidity and the presence of ozone.

Results from humidity induced bleeding tests (ISO 18946) may be influenced by elevated temperature due to thermal activation of moisture transport and reactions and the presence of ozone.

Ozone stability test (ISO 18941) may be confounded by different levels of humidity and temperature, which directly influence the transport (ozone diffusion) and reaction processes. Control of turbulent air flow is important to avoid ozone depletion at the surface of the specimen, which could occur in case of laminar flow.

The comparison of cumulative doses is based on the assumption of reciprocity; i.e. same degradation occurs when testing at a high level of the stress factor in shorter time as long as the same dose (intensity × time) is applied. In addition to the assumption of reciprocity, it is also assumed that a constant exposure under laboratory test conditions will produce the same amount of degradation as an intermittent exposure condition, i.e. a diurnal cycle, with the same amount of cumulative exposure (“intensity × time”).

Validity of reciprocity is the basis for accelerated testing of stability against light and ozone and should preferably be checked for a printing technology under test. In its basic form, the term “reciprocity factor” is defined as $R_f = \Delta D_{LI}/\Delta D_{HI}$ where ΔD_{LI} is the change measured at a low intensity exposure condition and ΔD_{HI} is the change measured under a high intensity exposure condition[7][25][26].

Sensitivity to primary and secondary stress factors as well as reciprocity may have to be considered for a particular printing system, when image permanence performance is reported for a use profile that spans a wide range(s) of stress factors.

6.3 Dependence of image permanence test results of printing technology

The susceptibility of the printed image to the environmental as well as to the chemical/mechanical factors mentioned before depends on the interplay of all system components, including:

— colorant (type of formulation of dye/pigment in a carrier/matrix including binders, surfactants, dispersants and other additives as well as type and setting of curing, e.g. heat or radiation);

— substrate (coated/uncoated rigid or flexible material with a particular formulation and/or surface energy);

— printer (with certain settings for dpi, making use of binary/multi-level printing, single-pass/multi-pass [uni- or bi-directional] printing as well amount of colorant deposition (as defined by printer calibration and software settings);

— pre-and post-treatments (inline as well as of offline) are applied in order to increase the resistance of the printed image including (primer, fusing, curing, annealing, application of varnishes or laminates and/or UV-curable overcoats).

Furthermore, the level of acceleration actually achieved by a test method may depend on the printing technology under test, i.e. test results (see Annex E) may not be technology agnostic. Examples are given in ISO/TR 18945 (RR outdoor weathering) as discussed in 6.2.

Material test methods that have been developed by other industries, e.g. ISO 4892-2, ISO 105-B series, ISO 16474-2, have occasionally been used for digitally printed matter, too, especially if digital printing has entered the respective application field. However, test parameters have been defined to simulate typical failure modes of plastics, textiles, paints and varnishes etc., but not digital prints. As a result, those test methods are likely to produce larger variations in test results with both, false positives and false negatives.

Communication of image durability performance is thus only meaningful in view of well-defined use profiles and for a well-defined printing system.

7 Reporting of changes

7.1 Reporting at fixed load

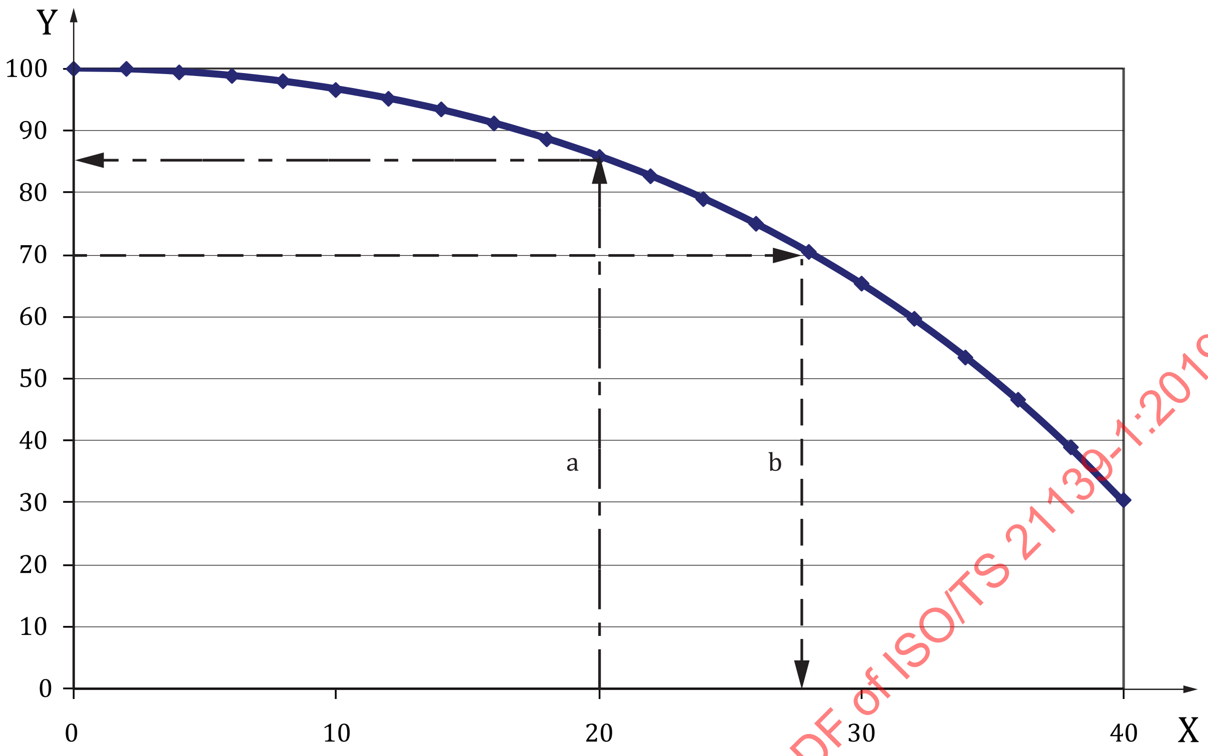
In a first approach fixed cumulative loads of all stress factors representative for the use profile are applied, but without reference to any endpoints or acceptance criteria. Then, changes of image parameters (such as colour) or retention of properties (such as tensile strength) after exposure to a reference fixed load are reported. See also path of test with fixed load, footnote a in Figure 1.

Fixed loads shall be chosen to be representative for the use profile and in balance to each other. One approach to specify representative loads is based on the calculation of an "average-dose-for-the-anticipated-time-of-use ", or to determine a "typical worst case" for the reference use profile, for which definition of the 95 % tile of each stress factor is recommended.

NOTE Suitable sampling of stress factor values for calculation of the 95 % tile depend on the rate of changes of the stress factors and the response time of the material to changes of these stresses, e.g. time constants for water uptake, thermal equilibrium, ozone diffusion, etc.

Degradation kinetics, however, do not always linearly follow the load. By collection of intermediate results in addition to the full fixed load, the actual change of properties as function of load can be plotted. Based on these graphs, the dose until a certain level of property change can be readily obtained by interpolation. In the communication of results, the meaning of the chosen fixed load needs to be explained and the actual range of stress loads typical for the use profile needs to be addressed. Even though fixed load may be expressed as "dose equivalent to *X* years", the degradation may not perfectly represent the level of image permanence after "*X* years" in real world due to limitations of accelerated testing and dependence of results on printing technology.

Fixed load testing is related to a fixed test duration, which facilitates organization and commissioning of such testing at independent test laboratories.



Key

X cumulative load (dose × time)

Y retained property

a Test with fixed load.

b Test until certain change.

Figure 1 — Schematics of test with fixed load and test until certain change

7.2 Reporting until certain change is reached

In another approach, one continues the exposure to each of the stress factors until a certain level of change is measured. See also path of test until certain change, footnote b in Figure 1. That levels needs to be chosen such that any observed change in image parameters is significant against noise of the image parameter analysis (variations of measurement and exposure). That level of change may preferably be chosen to represent a limit of fitness-for-use or endpoint. Then, the cumulative dose of stress to reach that endpoint is reported.

Depending on the envisaged use, endpoints can be chosen to for example represent just noticeable changes or acceptable changes as pass/fail criterion. Judgement of levels depend on whether a single- or double stimulus comparison is applied. User should be aware, that not all tolerance metrics for perceived differences provide perfectly equidistant scales, so that individual endpoints per colour may have to be considered.

NOTE Level of equidistance within the colour distance metrics CIE ΔE76 is ~1:6 across CIE $L^*a^*b^*$ colour space, whereas CIE DE94 or CIE DE2000 perform ~1:2 to 1:3.

In communication of results, it is again tempting to ratio the cumulative dose to reach the endpoint with the year equivalent doses for given use profile and then to communicate "years of longevity". Due to limitations of accelerated testing and dependence of results of accelerated tests on printing technology such translations into real years can be rather misleading, due to aforementioned limitations of accelerated testing and including reciprocity failure. False expectations about the certainty of the results are also caused by lack of measures of uncertainty in the communication (or if such measure is 'hidden' in lengthy, technical language).

In case of this test approach, final duration of the test depends on the stability of the instance of the print technology under test. Sampling schemes may thus become more sophisticated and test durations more difficult to plan.

7.3 Blue wool scale and visual grey scale reporting

Several industries are used to express light stability in terms of “Blue Wool Scale (BWS)” as defined in the ISO 105-B series.

NOTE The ISO 105-A series defines the Blue Wool Scale, a series of 8 blue dyed patches on wool representing an approximate logarithmic scale of light stability: each level is approximately twice as stable as the previous level, with level 1 marking “fugitive” to level 8 “exceptional”.

The main use of BWS is essentially comparable to the function of a dosimeter: An exposure to the level of “BWS x” (x = 1-8) represents an equivalent dose that introduces a visual contrast change of patch x of the BWS target. Discoloration of the BWS patches is analysed by comparison with the contrast level of the visual greyscale ruler (VGR), with “articulate” visual contrast level 3 used for detection of BWS 1 to BWS 6 and “just noticeable” visual contrast level 4 for detection of BWS 7 and BWS 8. Since different visual detection criteria are employed, the BWS scale appears to perform non-continuous between BWS 6 and BWS 7.

Colour changes expressed in CIED ΔL^*, Δa^* and Δb^* can be translated in visual greyscale ratings according to ISO 105-A04.

The BWS is exposed together with the specimen under test, however it is noteworthy, that ISO 105-B04 requires the BWS card to be protected by Quartz glass against direct wetting by water spray (that is also present in ISO 18930).

Discoloration of the specimen after exposure can be measured in various ways. Originally each specimen is partially covered during exposure to allow contrast assessment during intermediate sampling. Contrast change of the specimen is visually assessed by comparison with the VGR. Alternatively, instrument measurements with subsequent translation into VGR contrast can also be employed (ISO 105-A04).

The visual greyscale rule measurement is based on a two stimulus comparison. The observer task requires to compare the perceived contrast upon discoloration of the specimen (potentially having any colour) with the neutral reference contrast of the grey target contrast cards of the VGR.

BWS rating is not recommended for colour stability measurements of prints: radiometers and instrument measurements are readily available, so that the use of the original analysis protocol of the ISO 105-B is no longer justified, especially for non-textile specimen.

— State-of-the art Xenon test apparatus has calibrated, electronic UV dosimeters that measure cumulative UV doses direct and with much smaller uncertainty than BWS cards.

— In addition, the response of BWS cards to the combined stress factors light, temperature and humidity is not the same as for the various printing technologies, which may introduce additional bias to the interpretation of results[31].

— The observer task introduces extra variations during visual contrast assessment. These variations occur twice, namely with evaluation of the BWS grade and evaluation of the discoloration of the specimen.

— Visual assessment is impractical for the many different colour patches typical for digital printing. BWS rating adds significantly to the uncertainty of light fading exposure and analysis.

BWS ratings are still very common in various industries, in which also digital printing is being used. Therefore, it might be desirable to also express colour fastness of digital prints in BWS ratings. For that purpose, one may refer to typical dose levels characteristic for the various spectral power distributions of light stability and weathering test conditions representative for the usage case (see Table 3). When including BWS specimen in those test cycles, users should be aware that BWS ratings are highly susceptible to the level of relative humidity during the test (see ISO 105-B02).

7.4 Communication of results

From a fitness-for-use perspective a set of endpoints and/or loads of stress factors may be derived to define performances classes of prints. For example, this could be used to map changes of image parameters for a selection of print attributes and well defined stress factor doses into a performance system. Such mapping should consider a balance of stress factor levels typical for the use profile of interest and also allow different levels of image parameter changes, as expectation levels may be different.

Graphs showing the change or retention of initial property as function of cumulative stress dose or exposure time can be useful as generic communication of permanence performance for printing products intended for use in different usage classes, representing either different acceptability endpoints or cumulative test dose requirements. In those graphs, reference dose levels and/or endpoints shall be marked accordingly. Plots need to provide cumulative results in reference to the colour patches and metrics required by the reporting section of the appropriate standards from the ISO 12647 for the print technology under test. For digital printing, ISO 12647-7 and ISO 12647-8 require reporting of max and 95 % tile for a given Delta E00 criterion.

Binning classification such as A, B, C, … or 1, 2, 3, … [with or without 'unit-symbols' such as 'stars'] is criticised because of in-built mis-ranking of "border-cases". Intermediate bins [e.g. 'A-B', '5-6'] or quasi continuous numerical binning [e.g. '4.9, 5.0, 5.1, …'] may overcome this limitation to large extent. Still the question arises, whether performance of print permanence is better expressed in linear or logarithmic terms to match user expectations. In that context, also significance of data (experimental uncertainty) as well the variability of performance that is representative for the span in the use profile have to be considered.

Binning classification also cannot overcome the limitations of accelerated testing and dependence of results of accelerated testing on printing technology.

As mentioned before, it is also tempting to translate prediction of lifetime in real time units, e.g. based on a ratio of the cumulative test dose to the year average dose for either light or ozone exposure as mentioned in 7.1.

a) The dose equivalent time for light exposure is calculated as the ratio of the total light exposure dose to reach specific change in image parameter versus the reference light intensity on the displayed prints for given use profile per time unit, e.g. per year.

b) The dose equivalent time for ozone exposure is calculated as the ratio of the total ozone exposure dose to reach specific change in image parameter versus the reference ozone concentration at the location of the displayed prints for given use profile per time unit, e.g. per year.

Those ratios have only the meaning of a dose equivalent time and may indicate an order of time to reach the endpoint under consideration, but do not represent a print-life simulation as discussed before:

— uncertainties in accelerated testing (reciprocity failure, single factor testing or testing at different balance of factors as compared to use profile);

— span of actual stress levels in the use profile.

Even though tempting, such an approach is likely to nourish unrealistic expectations about the accuracy of such lifetime prediction for an individual user. Language in communication shall therefore make clear, that longevity in actual use may differ from extrapolated results from accelerated testing, even though the choice of image permanence test conditions in this series of use profile test conditions helps to keep those unpredicted variations at the lowest level currently possible. Published "year ratings"[32] have to be regarded as "years in standardized test conditions" and therefore do not necessarily match with years in actual use. This is often a matter of dispute if communication is not detailed enough in that respect.

8 How to define a permanence/durability test suite for a use profile

8.1 General

This clause defines step-by-step the elements required for standardization of the image permanence characterization in view of a specific use profile based on the concepts and background explained in sections before. These elements provide the document structure of any of the parts of this series ISO 21139.

8.2 Define use profile

The leading stress parameters characteristic of the use profile shall be defined and tabulated, considering environmental and mechanical/chemical stresses. Also, optional stress factors shall be mentioned and their consideration shall be explained. The span of each of the stress factors shall be described, acknowledging differences by region (e.g. due to building constructions) or by other criteria applicable. Within this span one (or few) reference points representative for the use profile shall be defined and characterized within the range of parameters observed. Especially, the 95 % percentile shall be mentioned as reasonable worst case. Also, describe realisations of (partial) protection against environmental and other stresses typical for use profile, if applicable.

A measure of an average year load (for light and ozone) shall be provided and typical extreme levels (min/max) of humidity and temperature in the use profile shall be marked.

For the other stress factors cumulative stress doses shall be defined that are representative for the envisaged lifetime cycle of printed matter in the use profile. A suitable measure for mechanical test is a number of repetitions of an elementary treatment (with well-defined test parameters and well defined test geometry, see 8.3). Doses as fixed loads of testing shall be defined. Eventually, several levels of fixed doses are suitable to represent short or extended use.

Data shall be collected to define changes in image parameters that represent fitness-for-use. This can typically go beyond colour fading and include other image parameters related to appearance and/or physical integrity of the printed matter. It shall be identified, whether the range of user expectations in use profile is rather homogenous or whether user expectation in use profile may vary considerably depending on intended purpose of the printed matter. Consider collecting and providing endpoints for (eventually multiple levels of) fitness-of-use, if such endpoint data are available based on use profile experience and market response.

8.3 Select test methods and procedure

For all leading and additional stress factors, appropriate test methods are identified from the stress factor and test method matrix in Table 1. If suitable for specific application, additional tests can be considered.

Specific test parameters in laboratory tests shall be defined in order to achieve controlled level of acceleration. Stress levels shall be chosen in combination with test duration to represent a suitable balance of leading stress factors that represent failure modes observed in use. Consider limiting different settings of test parameters across use profiles as far as possible in order to manage complexity of testing. This allows users to feed results of tests for one particular stress factor into various use profiles and to manage practicality of testing.

A suitable mode of testing shall be selected, namely fixed load testing or a testing until some endpoint, and fixed loads and endpoints shall be defined, respectively.

A layout of test targets shall be defined that allows for investigating changes of envisaged image parameters during the test (see ISO/TS 15311-1). For colour retention measurement, the test patches shall be selected according to the requirements of the series ISO 12647 (all parts), which defines test patches for calibration and verification of analogue and digital printing systems as well as the statistics and metrics for analysis of colour differences. The test patches shall be arranged in a suitable test target layout, such that the patches fit on the exposed area of any specimen holders used in the tests. The size of each colour patch area shall be large enough to cover measured area plus positioning error. The appropriate size depends on the patch reading equipment used and has typically square format. Aperture size requirement shall comply with the geometric conditions in ISO 5-4. For gloss measurements the patch size requirements depend on the apparatus and gloss angle under inspection and has typically rectangular format.

For example, test target layout according to requirements of ISO 12647-7 and ISO 12647-8 are shown in Annex B. Also, preparation of test targets on the printing system shall be defined, including drying down times for differentiation of short term stabilization and long term permanence. Differences in the preparation of test targets on analogue and digital print systems need to be acknowledged.

8.4 Measurement and analysis of test results

Collect measurements of the required image parameters as post evaluation of stress exposure based on the data analysis and statistics that define metrics of the image parameter under question. See ISO/TS 15311-1 with reference to test target definition according to ISO 12647 (all parts).

Evaluate and report changes in image parameters for fixed load at the reference points. Alternatively, report the cumulative doses to reach the endpoint, provided endpoints as measure for fitness-of-use are available.

In case of graphical report of attribute changes as a function of stress load, mark the reference and the min/max of the parameter ranges in case of the single factor stress.

8.5 Communication of image permanence results

Report changes of image parameters for fixed load or cumulative dose to reach defined test endpoints for all test methods and image parameters required. Optional test results may be added.

If appropriate, test results may be set into perspective by comparison to year equivalent dose, but without introduction of over-simplifying year translation. Remind user that the reported data that results from accelerated tests may not perfectly match degradation in actual use because of limitations of accelerated testing. Therefore, include the statement that “calculated dose equivalent time of exposure” are indicative only and will likely differ from actual user experience in use profile. Strictly speaking, such dose equivalent times only have the meaning of “years-in-standardized-test-conditions”, intended for relative comparison of image permanence performance of products under these standardized test conditions.

Annex A
(informative)

Examples of indoor display use profiles

Table A.1 — Examples of display use profiles and typical stress factors

Group of stress factors			Environmental stress				Processing & conversion stresses			
				Storage related stress						Mechanical + chemical stresses (handling or functional)
Examples			Stress factor							
			Light	Heat	Humidity	Air pollution	Pressure	Folding	Cutting	1. Wear Water jet 2. Spill and wipe 5. Freeze/thaw 3. Condensation 6. Steam 4. High pressure 7. Fingerprints
In-window display	Facing outdoor	**Shop window (building integrated with HVAC)** e.g. show window of department store other products (such as clothes) are exhibited in the same window. heat resistivity of these products is typically less than for printed matter. 		T and % RH typically are controlled by HVAC system to exclude condensation (>15 °C) and to avoid heat damage to other materials (<40 °C.)		controlled by outside air exchange rate of HVAC installation	—	—	—	(7)[a]
		Shop front (backside open to sales floor) see before 					—	—	—	(7)[a]

Table A.1 *(continued)*

Group of stress factors				Environmental stress				Processing & conversion stresses			
					Storage related stress						Mechanical + chemical stresses (handling or functional)
Examples				Stress factor							
				Light	Heat	Humid-ity	Air pollu-tion	Pres-sure	Fold-ing	Cut-ting	1. Wear 2. Spill and wipe 3. Condensation 4. High pressure Water jet 5. Freeze/thaw 6. Steam 7. Fingerprints
In-win-dow dis-play	**Facing out-door**	**Shop front (building in-tegrated without HVAC)** e.g. display of accessories for phones exhibited products shall have high heat resistance.		depending on building construction: dominated by direct, diffuse or indirect dalig fht through window glass (see Table 1) at levels of 6 klx, 3 klx or 1 klx.	*T*/% RH are typically not controlled: for direct sunlight "green-house" may introduce high tempera-ture episodes with % RH levels goverend by moderate dewpoint (lim-ited moisture exchange due to window sealings)		not con-trolled. reduced indoor level due to marginal air exchange rate.	—	—	—	(7)[a]
		Independent showcase window (closed, no HVAC) typically posters are exhibited					reduced indoor level due to marginal air exchange rate.	—	—	—	(7)[a]

Table A.1 *(continued)*

Group of stress factors			Environmental stress				Processing & conversion stresses			
				Storage related stress						Mechanical + chemical stresses (handling or functional)
Examples			Stress factor							
			Light	Heat	Humidity	Air pollution	Pressure	Folding	Cutting	1. Wear Water jet 2. Spill and wipe 5. Freeze/thaw 3. Condensation 6. Steam 4. High pressure 7. Fingerprints
In-window display	**Facing in-door**	**Shop front (building integrated without HVAC)** e.g. show windows of shopping mall	fluorescent light, LED, metal halide, tungsten halogen: 750 lx to 2 000 lx for highlighted matter or 300 lx to 500 lx for general display (conditions as in passage, lounge, etc.)	*T* and % RH typically are controlled by HVAC system		Controlled by HVAC	—	—	—	(7)[a]
		Shop front (open to sales floor)					—	—	—	(7)[a]
		Shop front (building integrated without HVAC)		*T* and % RH depending on building climate; no "greenhouse effect".		Not controlled. reduced indoor level	—	—	—	(7)[a]
		Independent frame e.g. poster of film etc.					—	—	—	(7)[a]

Table A.1 *(continued)*

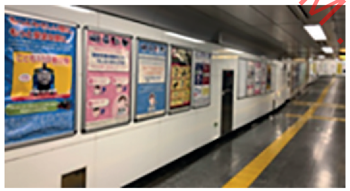
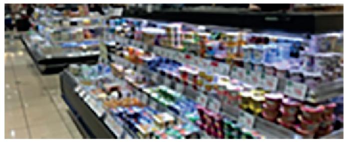
Group of stress factors			Environmental stress				Processing & conversion stresses			
				Storage related stress						Mechanical + chemical stresses (handling or functional)
Examples			Stress factor							
			Light	Heat	Humid-ity	Air pollu-tion	Pres-sure	Fold-ing	Cut-ting	1. Wear Water jet 2. Spill and wipe 5. Freeze/thaw 3. Condensation 6. Steam 4. High pressure 7. Fingerprints
General in-door dis-play	**Paste to wall, pillar, etc, directly (without frame)** e.g. poster		fluorescent light, LED, metal halide, tungsten halogen: 750 lx to 2 000 lx for highlighted matter or 300 lx to 500 lx for general display	*T* and % RH may be controlled by air conditioning system or not.		depends on rate of air exchange: low level, if controlled by HVAC	(x)[b]	x	x	1 (0,2 – 0,5 N/cm²), (7)[a]
General in-door dis-play	**Store shelf** e.g. price tag, POP, packaging		fluorescent light, LED, metal halide, tungsten halogen: 500 lx to 2 000 lx for highlighted matter	*T* and % RH typically are controlled by air conditioning system		depends on rate of air exchange: low level, if controlled by HVAC	x	x	—	1, 7
				refrigerator or freezer		controlled	x	x	—	1, 2, 3, 5, 6,7
	Office, home, factory etc. (horizontal use) e.g. flyer, leaflet, brochure, direct mail, (instruction) manual, magazine, catalogue, report, invitation, etc.		fluorescent light, LED, etc. (300 lx to 750 lx)	controlled by air conditioner		controlled by air con-ditioner	x	x	x	1 (<0,6 N/cm²), 2, 3, 7
	Office, home, factory etc. (vertical use) e.g. poster, calendar, etc.		fluorescent light, LED, etc. (100 lx to 500 lx)				—	x	x	1, 7

Table A.1 *(continued)*

Group of stress factors			Environmental stress				Processing & conversion stresses			
				Storage related stress						Mechanical + chemical stresses (handling or functional)
Examples			Stress factor							
			Light	Heat	Humidity	Air pollution	Pressure	Folding	Cutting	1. Wear 2. Spill and wipe 3. Condensation 4. High pressure Water jet 5. Freeze/thaw 6. Steam 7. Fingerprints
Light box in-door	**Independent frame with back light** Signage print (on transmissive or transflective substrates) E.g. Poster, pop, (sign & display)		[ambient light/ front] fluorescent light, LED, etc. (300 lx to 750 lx) [back light] fluorescent light, LED, etc. (300 cd/m² to 800 cd/m²)	not controlled. (temperature 5 °C to 60 °C, measured value in Tokyo)		not necessary (no space between prints and flame)	(x)[c]	—	—	(7)[a]
Light box out-door	**Independent frame with back light** Signage print (on transmissive or transflective substrates) Ex) poster, pop, (sign & display)		[ambient light/ front] window glass filtered daylight (6 000 lx) [back light] fluorescent light, LED, etc. (3 000 lx to 5 000 lx)	not controlled. (temperature 5 °C to 60 °C, measured value in Tokyo)		not necessary (no space between prints and flame)	(x)[c]	—	—	(7)[a]

[a] Fingerprints may adhere when displaying printed products.

[b] A person may lean on printed matter.

[c] Pressure required for mounting.

stresses in (..) can be avoided by handling instructions.

Annex B
(informative)

Test Targets

Test targets applicable for measurement of colour stability of commercial prints are based on control strips defined in the ISO 12647 series for the corresponding analogue and digital printing technologies under evaluation. For digital prints, the parts ISO 12647-7 and ISO 12647-8 apply.

Test patches have to be prepared in suitable layout to meet the dimensions of sample holders in test chambers as well as the requirements for automatic chart readers, providing a minimum patch size in view of measurement aperture and positioning accuracy.

Examples of publically available layouts are e.g. control strips provided by Fogra and IdeAlliance.

B.1 Fogra Media Wedge

https://www.fogra.org/en/fogra-products/control-devices/

(see links titled 'Info sheet Media Wedge Standard' and 'Info sheet Media Wedge LFP')

https://www.fogra.org/index.php?menuid=35&downloadid=213&reporeid=0

https://www.fogra.org/index.php?menuid=35&downloadid=526&reporeid=0

NOTE Copy link into browser if hyperlinks do not open the expected page.

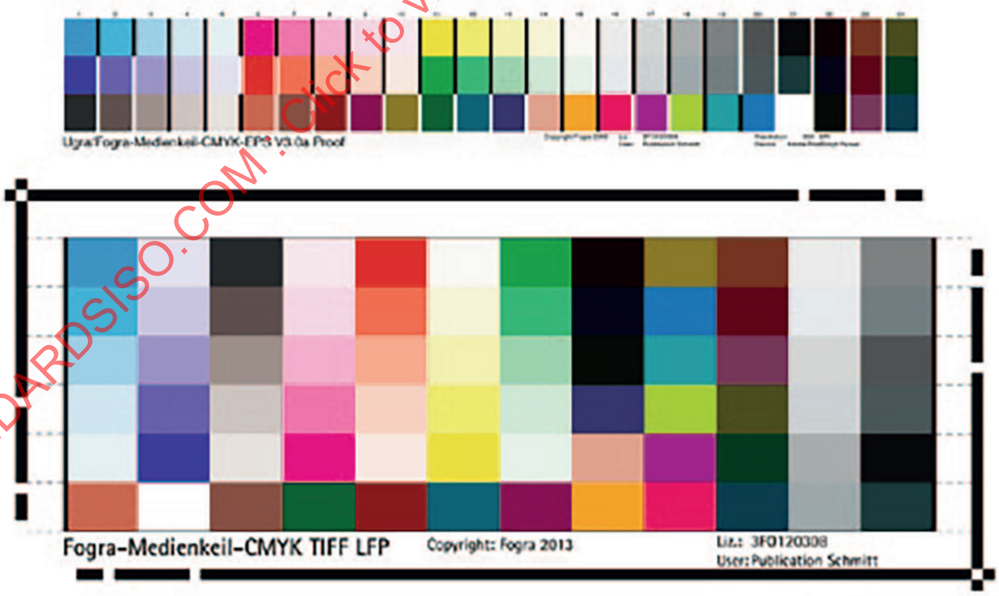


Figure B.1 — Fogra Media Wedge

B.2 Idealliance control strip

http://connect.idealliance.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=0b540849-4e64-0867-f121-2c9b2406e165&forceDialog=0

NOTE Copy link into browser if hyperlinks do not open the expected page. This link opens a .zip file and response can depend on the browser used.

Annex C
(informative)

Product classes defined by ISO/TR 19300

Table C.1 — Product and usage classes as defined in ISO/TR 19300:2015, Table 2

Category	Use case	Sub case	Example of product	Typical printing process[a]
Commercial production printing	Publishing	Magazines	Monthly magazine	Gravure or offset
			Weekly magazine	Offset
				Offset Letterpress
		Monograph	Picture/photo book	Offset
			Comic, paperback, textbook, directory	Offset
		Magazine cover	Monthly/weekly magazine (cover)	Offset
Commercial production printing	Commercial	Catalogue	Catalogue of product or services	Offset or Gravure
		Advertisement	Flyer, pamphlet, leaflet	Offset or Gravure
			Direct marketing	Offset
			Free Magazine	Offset
		Others	Manual	Offset
	Business Form and Card	Business Form	Slip, Carbon copy	Offset
		Transaction	Transaction for cell-phone	Offset
		Stationery	Notebook, envelope business card, post card	Offset letterpress
		Card	Magnetic stripe card, IC card	Offset screen
	Newspaper	Colour, black and white, tabloid	Daily newspaper	Web offset (cold set)
Signage printing	Indoor use	Poster	Poster	Inkjet Offset
		POP-up	Banner, tapestry, textile	Inkjet offset screen
	Outdoor use	Billboard	Billboard	Inkjet screen
		Wrapping decoration	Wrapping decoration, but	Inkjet screen
Packaging	Packaging (Carton, Label)	Carton	Beverage carton, Cardboard container, box	Offset
		Corrugated	Corrugated box	Offset flexo
		Label	Label Sticker	Flexo
	Flexible packaging	Flexible	Snack pouch, retort pouch	Gravure flexo

[a] Digital technology is not stated because it could be used in every production shown in the table.

Annex D
(informative)

Estimation of stress levels

D.1 Indoor light

D.1.1 General

If available, illumination levels are measured with a lux-meter with cosine characteristics.

NOTE There are several apps for modern smartphones available (including the terms "light meter, lux meter"), which may provide an estimate of the illumination level. The in-built light sensor (i.e. one of the in-built cameras) does however not provide a cosine corrected but a more directional characteristics of the optical probe. One may point the sensor in various directions to estimate an average. The camera function can help to control the choice of representative probing directions.

Lux levels however, do not provide information about spectral power distribution, but represent a visually weighted measure of light intensity (based on weighting function V_λ or CIE $\bar{Y}$).

The UV content of the actual illumination is not characterized by lux, but needs to be measured with a suitable spectroradiometer or estimated based on the nature of the source of illumination and any eventual optical filters in between light source and print on display as explained below.

D.1.2 UV content of light sources

UV content of light sources may vary considerably, when normalized to same illuminance level (see example in Figure D.1 with 100 klx representing bright natural daylight).

The following ranking with respect to UV content holds approximately (from highest UV to lowest UV). The UV content is expressed as the ratio of radiant energy in the UV range 300 nm to 400 nm versus to the radiant energy in the range 300 nm to 800 nm.

natural daylight (~8,2 % UV)

> daylight through window glass (~8,0 % UV)

> metal halide (~5,1 % UV)

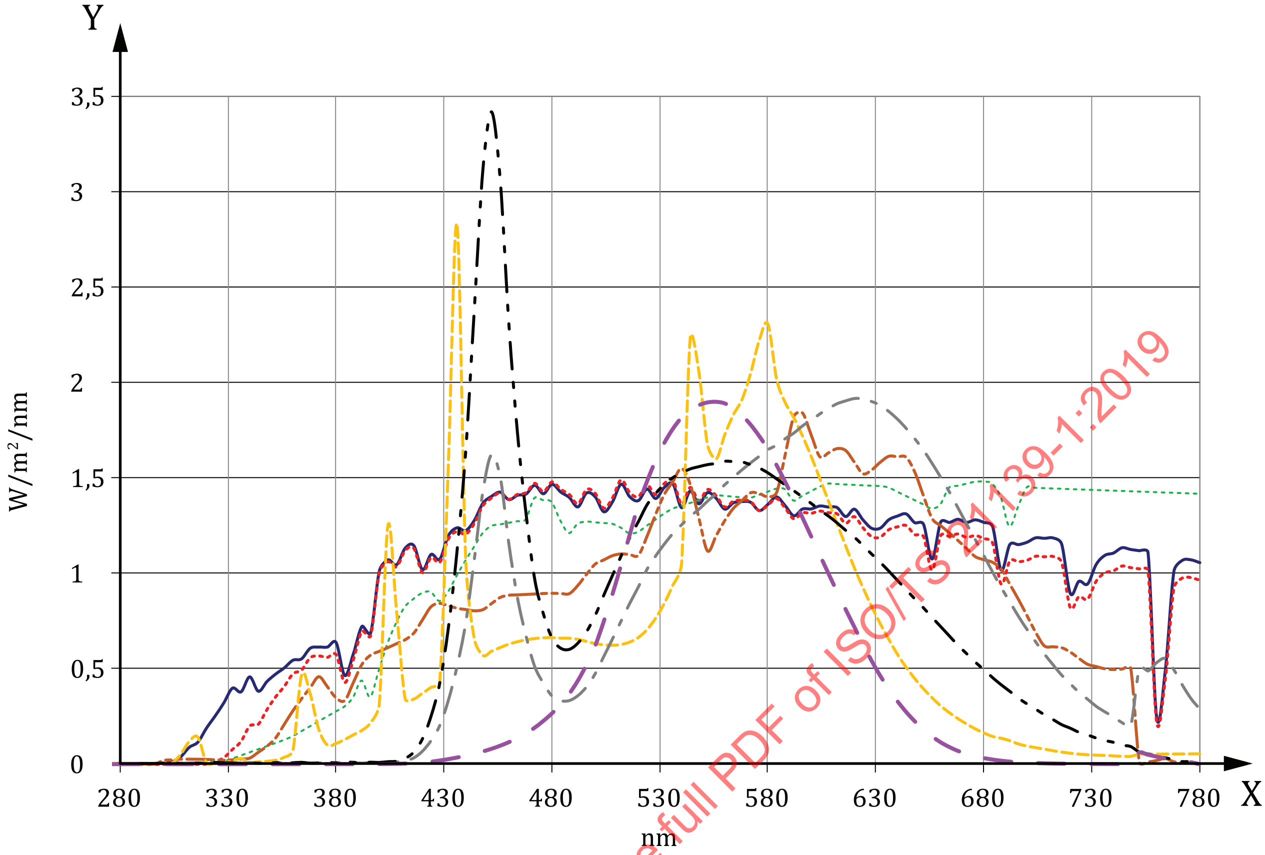
> general indoor (~4,1 % UV)

≅ > fluorescent (~3,5 % UV)

> LED (~ 0,1 % UV)

This ranking does not account for individual sensitivity of colorants for photolytic degradation, the so-called action spectrum. Also variations between actual types of metal halide, fluorescent and LED lamps need to be considered.

NOTE Exposure to high levels of UV, visible or infrared radiation may harm your eye or skin. Take appropriate measures to limit exposure to avoid health risks.



Key

X wavelength, in nm

Y spectral power, in W/m²/nm

natural daylight (ASTM G173)

daylight through window glass (calc. from ASTM G173 with European window glass from ISO 18937)

average consumer home illumination[33][34]

metal halide

fluorescent (CIE F6)

LED (CCT 3 000 K)

LED (CCT 6 500 K)

photopic luminosity function (V_λ)

Figure D.1 — Spectral power distributions of illuminants visually normalized (V_λ) to 100 klx

D.1.3 UV cut-on wavelength of optical-filters

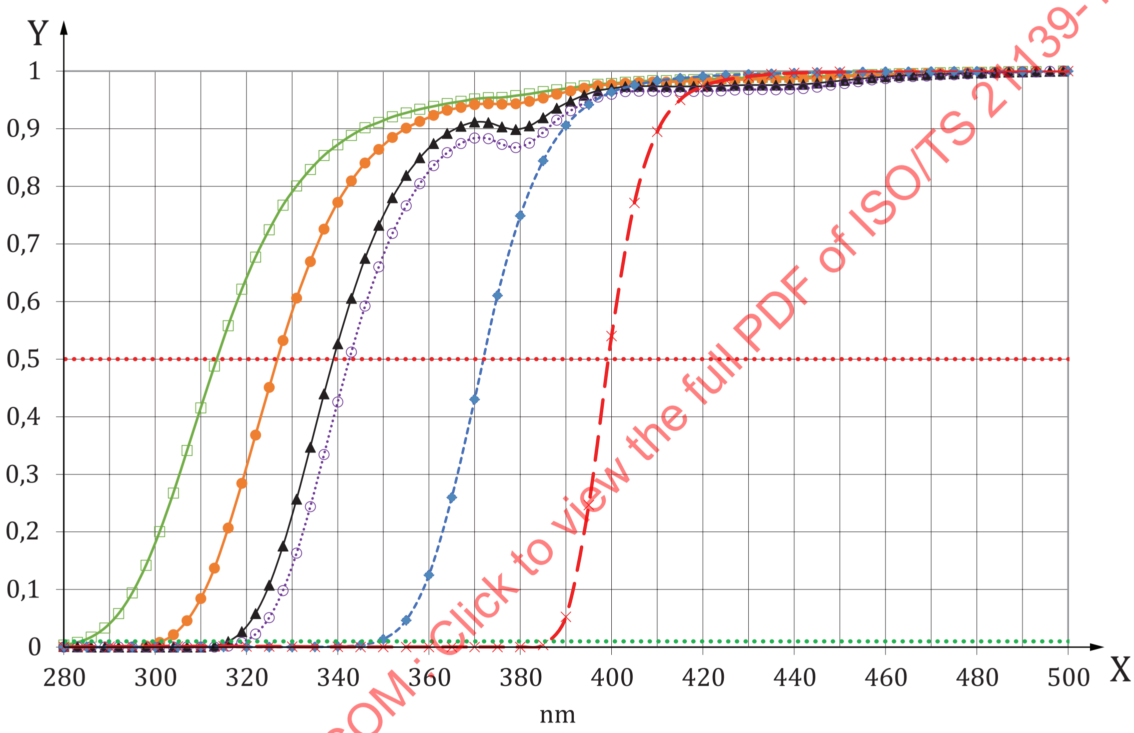
In indoor illumination by indirect daylight, the natural daylight spectrum is typically filtered by window glass and/or reflections from UV absorbing material in the environment of the display (see 5.2). Users should be aware, that window glass specified in Europe and Northern America have different optical transmission due to differences in raw material composition and manufacturing processes (e.g. sodalime, float glass). The degree of UV filtering is often expressed as “UV cut-on” approximately representing the lowest wavelength of the spectral power distribution of the radiation, for which degradation is observed. At wavelengths below, the intensity is too low to cause damage even for extended exposure times.

For UV transmission filters, the filter material as well the total filter thickness determines the UV cut-on wavelength. In modern building windows, typically double or triple glazing is used for thermal insulation and/or sound protection, representing 2 or 3 sheets of 3 mm to 4 mm thick window glass.

Every doubling of the overall thickness of window glass increases the UV cut-by ~10 nm (see example of European Window glass in Figure D.2). Note that for optical filters, also the wavelength for 50 % transmission is often used to characterize the UV filter effect.

L37 and SC37 (see Figure D.2) are filters to simulate indirect daylight in general indoor illumination with UV content reduced by both, window glass filtering and off-wall reflections (see Table 1 and ISO 18937).

In case of indoor illumination with artificial light sources including fluorescent, metal halide and tungsten halogen lamps, often lamp covers are used that may be constructed from glass or various sorts of plastics, including PMMA and polycarbonate. Due to various formulations of the latter, one can only estimate a UV cut-on, which probably situated in between window glass 4,5 mm and UV stabilized polycarbonate in Figure D.2. As a result of such filters in place, the UV emission of covered fluorescent and metal halide lamps is reduced to large extent (compare Figure D.1)



Key

X wavelength, in nm

Y transmittance

window glass 0,55 mm

window glass 1,5 mm

window glass 4,5 mm

window glass 6 mm

SC37

polycarbonate

50 % transmission

“UV cut-on” (1 %)

Figure D.2 — Transmission of optical filter materials including European window glass

D.1.4 Comparative illumination levels

The following comparative illumination situations can be considered as comparative guidance, if no measurement instrument is available[35][36].

NOTE Illuminance (lux) defines the luminous flux (lm/m^2) incident on a surface and has the unit symbol lx.

Table D.1 — Typical illumination levels indoor and outdoor

Illumination level lx	Observed condition
130 000	Direct sunlight from clear sky at noon (perpendicular on display)
10 000 to 25 000	Full diffuse daylight (open sky, no direct sun)
1 000	Overcast day
750	Supermarkets, workshops, office landscapes
500	Normal work station space, training rooms, kitchens, sports activity space
200	Internal corridors, support spaces, stairwells, auditoria
100	Very dark overcast day
50 to 450	Home environment

D.2 Ozone levels

Information over outdoor ozone levels is available via federal agencies that monitor air pollution in many countries. At typical levels of ventilation, indoor levels of ozone follow those outside with ~30 %. This ratio may depend on the actual construction of ventilation, e.g. by HVAC installation.

Ozone test strips may be suitable to monitor actual ozone concentration. Also, ozone sensors for continuous monitoring are commercially available.

D.2.1 Comparative ozone levels

Table D.2 — Ozone concentrations and their effects

Ozone concentration in air nl/l	Observed condition
2	Lowest concentrations of ozone that can be measured with fair accuracy. For purpose of test methods ISO 18930 (weathering), ISO 18936 (heat), ISO 18937 (light), ISO 18941 (ozone) and ISO 18946 (humidity), air up to this level of ozone is defined as "ozone free".
3 to 10	The threshold of odour perception by the average person in clean air. Readily detectable by most normal persons (50 % confidence level).
20	Threshold of odour perception in laboratory environment, 90 % confidence level.
1 to 125	Typical ozone concentrations found in the natural atmosphere. These levels of concentration vary with altitude, atmospheric conditions and local
50	Maximum ozone concentration produced by electronic air cleaners and similar residential devices according to the proposed amendment of the Federal Food, Drug and Cosmetic Act.
100	Maximum allowable limit for industrial, public, or occupied spaces in England, Japan, France, the Netherlands and Germany (8 hours per day, 6 days a week).
NOTE Exposure to high levels of ozone may harm your eyes or lung. Take appropriate measures to limit exposure to avoid health risks.	

Table D.2 *(continued)*

Ozone concentration in air nl/l	Observed condition
300	Approximate threshold for nasal and throat irritation. Also the ozone level at which some species of plant life began to show signs of ozone effects. Foliage injury appears as dark stipples, light flecks, dead patches and general discoloration. The stomata (pores) of adult leaves are the first areas to show signs of damage.
NOTE Exposure to high levels of ozone may harm your eyes or lung. Take appropriate measures to limit exposure to avoid health risks.	

D.3 Indoor temperature and relative humidity

Commercial measurement devices and loggers with suitable precision for indoor temperature and relative humidity are readily available.

D.4 Outdoor climate

Year average data for environmental stress factors in prototype climates are available via federal agencies and various other organizations, including weathering test service providers and guidance for photovoltaic installation.

D.5 Climate during transport (container and car)

Examples of temperature and humidity variations in transport situations are given below for transport in a sea-container[37][38] as well as temperature variations in a vehicle parked in open air with direct sunlight (air, cabin and boot [= trunk])[39].

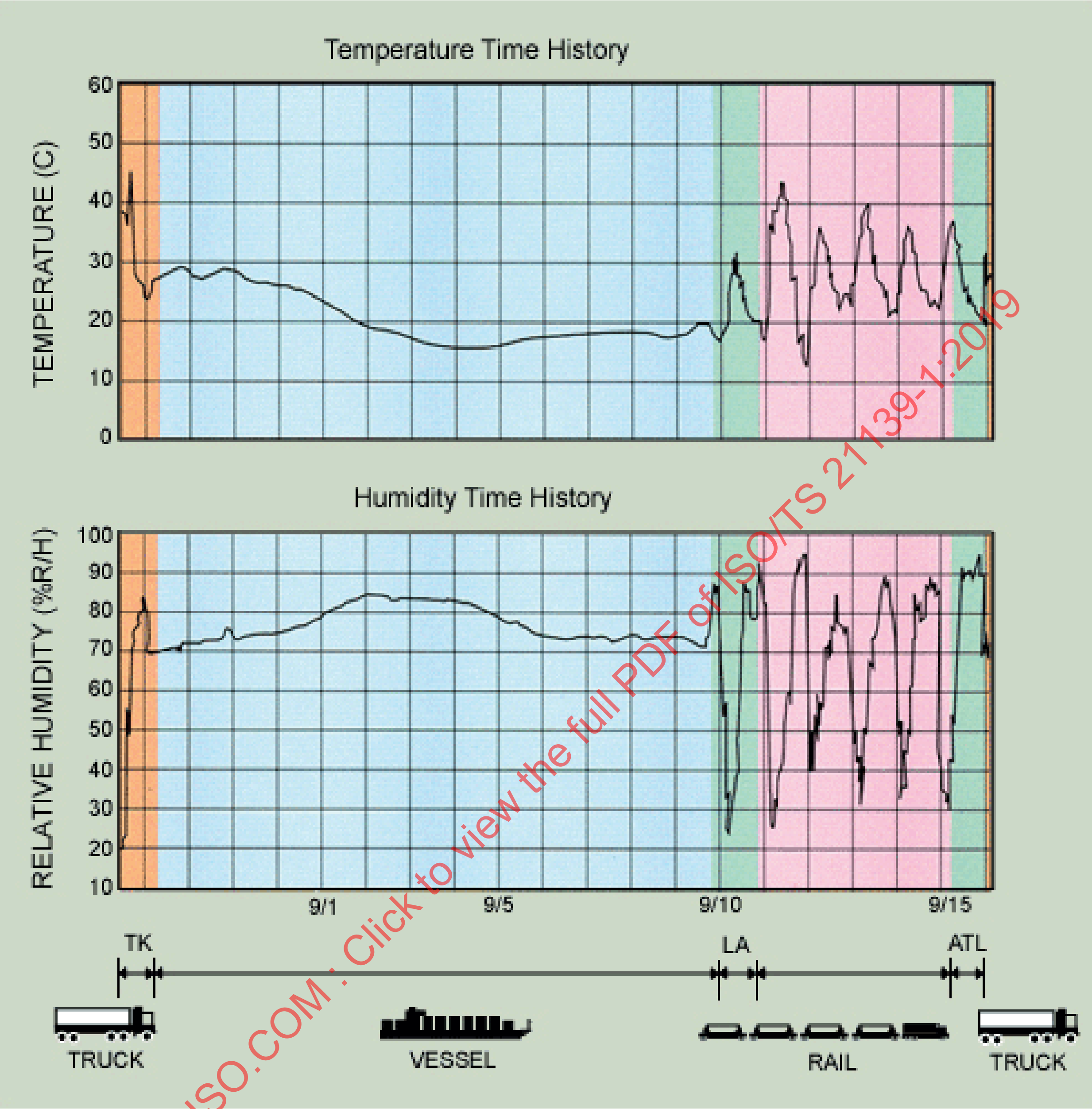
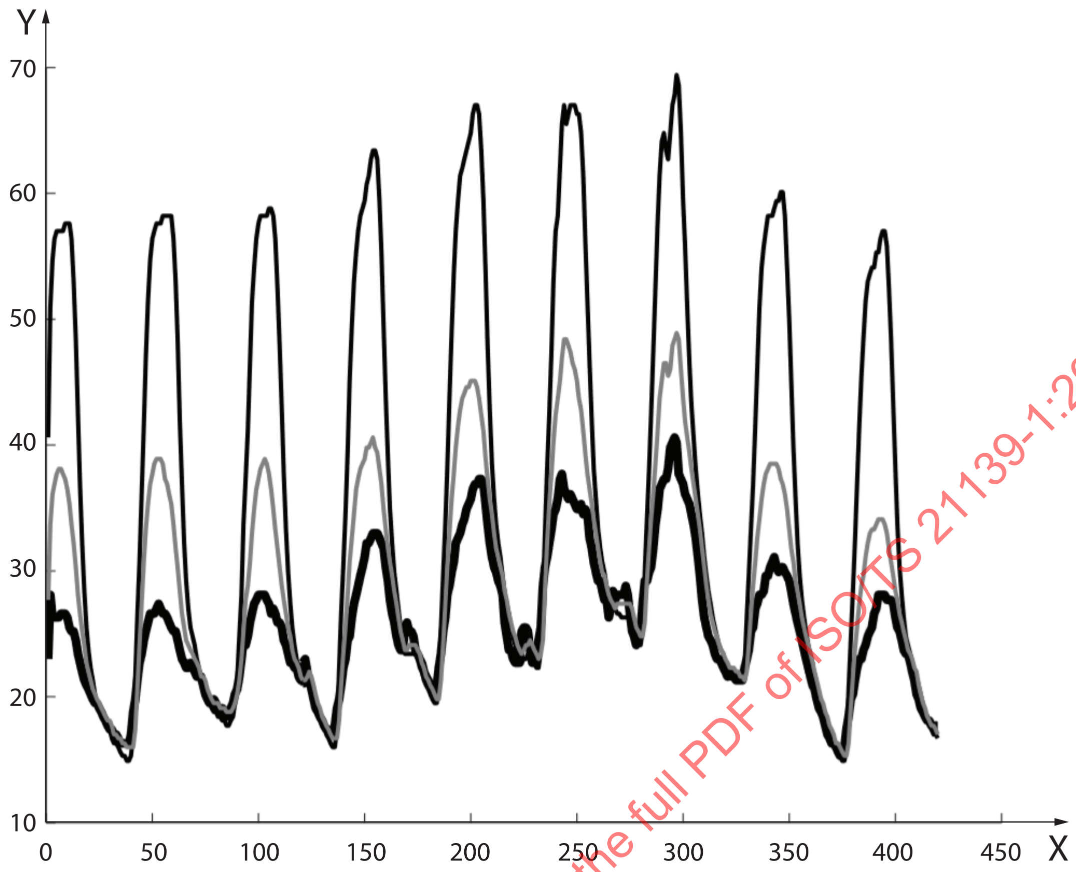


Figure D.3 — Temperature and humidity variations during container transport[38]



Key

X daytime

Y temperature

air temperature

cabin temperature

boot temperature

Figure D.4 — Temperature variations in a parked vehicle[39]

Annex E
(informative)

Example of test results

E.1 Outline

An example of test results based on the test method described in this document is shown here. A total of 6 prints for commercial application were tested. The colour coordinates of the samples were measured before and after exposure to different amounts of light. The colour differences, ΔE_{00}, were calculated for each set of fresh and faded samples. The total quantity of light exposure required to reach the specific image quality parameter, i.e. $\Delta E_{00} = 5$, for each sample was also calculated. In parallel, two professional observers conducted visual assessments of the faded colour patches by comparing them with their corresponding initial ones. The correlations between the visual assessments (human perception) and the image permanence estimated as the total exposure to the image quality parameter calculated using the colour difference data were then evaluated[40][41][42][43].

E.2 Light exposure test

E.2.1 Samples

A total of 6 prints for commercial application were tested. The details are shown in Table E.1.

Table E.1 — Example test prints in light exposure test

	Printing technology	Media	over coat, lamination
1)	Offset lithography print – oil based	Coated paper	No
2)	Electrophotography – liquid toner	Coated paper	No
3)	Electrophotography – dry toner	Coated paper	No
4)	Electrophotography – dry toner	Coated paper	No
5)	Inkjet –pigment based aqueous ink	Coated paper	No
6)	Inkjet – pigment based aqueous ink	Coated paper	No

E.2.2 Test procedures

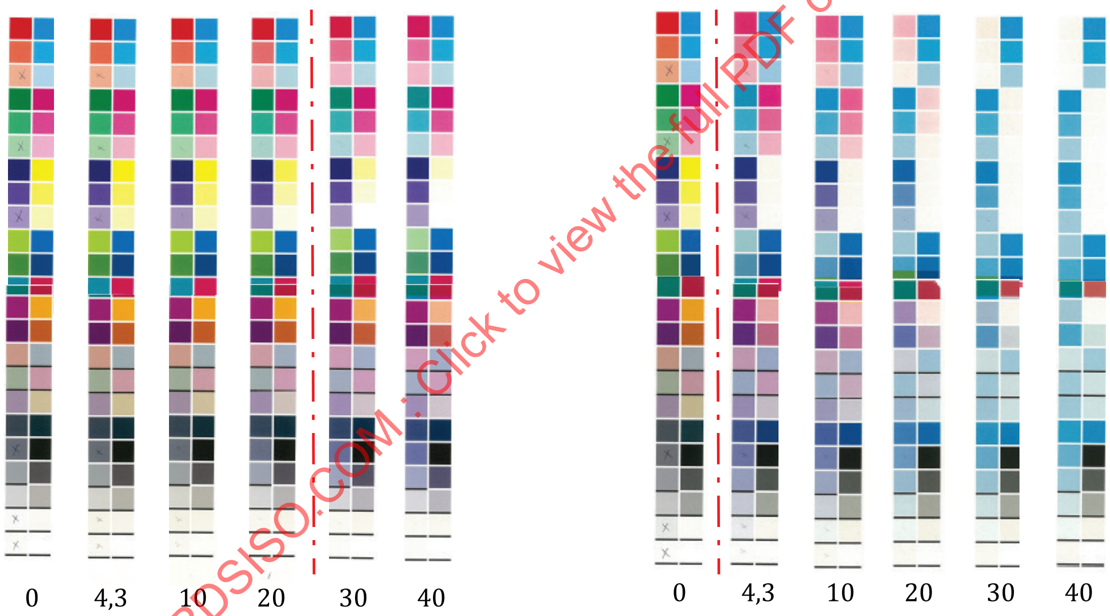
The test procedures described in clause ISO/TS 21139-21 “in-window display” were used. For the test chart, the image of the test charts is shown in Figure E.1. The input signals of each patch are described in ISO 12647-7. The measurements were carried out based on the methods described in Clause 5.

Figure E.1 — Image of the printed test pattern

E.2.3 Test results

The examples of scanned images of the initial and the faded patches of each sample are shown in Figure E.2.

The averages of the ΔE_{00} of 48 patches at each light exposure of each sample are show in Figure E.3.



a) Light exposure of sample A in Mlx·h

b) Light exposure of sample B in Mlx·h

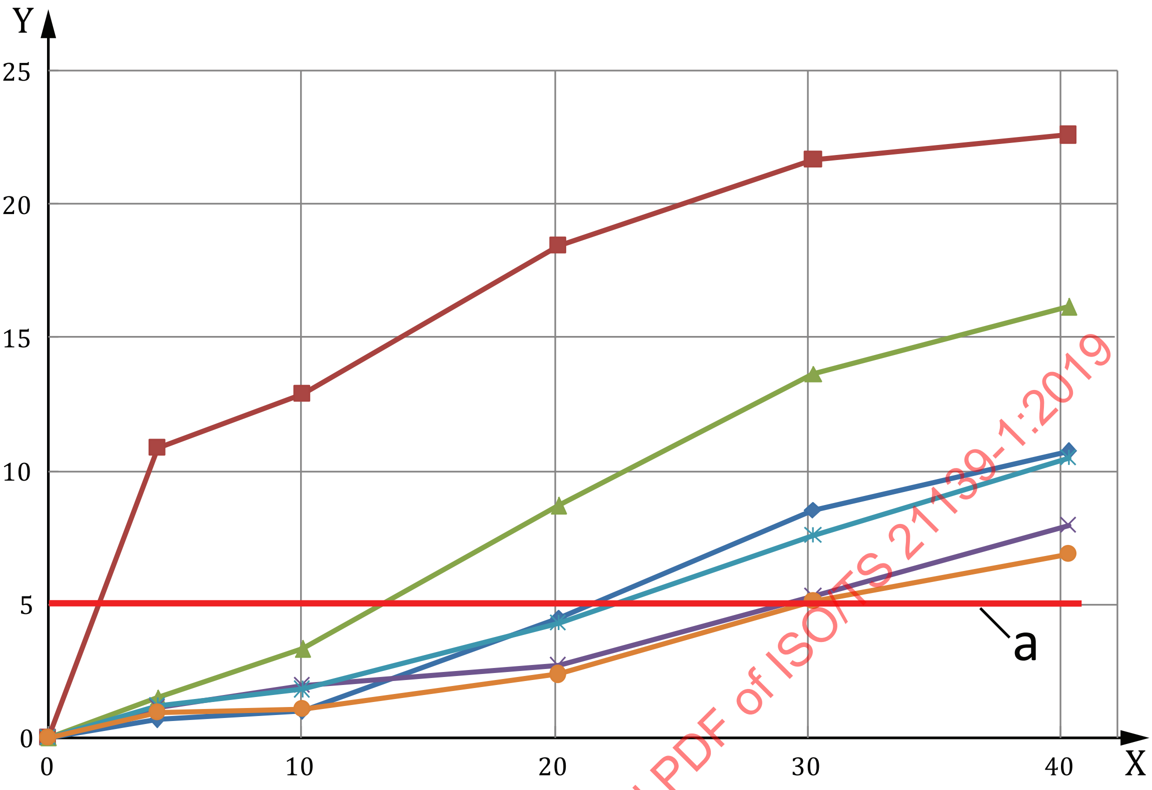
NOTE The red dotted lines indicate the positions related to the image quality parameter described in E.3.1.

Figure E.2 — Examples of faded images

E.3 Evaluation

E.3.1 Image quality parameter

As the image quality parameter ΔE_{00} = 5 was applied. The total light exposure (Mlx·h) to the image quality parameter was determined from the graph as shown in Figure E.3.



Key

X light exposure (Mlx·h)

Y average ΔE_{00}

A

B

C

D

E

F

a Image quality parameter ΔE_{00} = 5.

Figure E.3 — Example of test results

E.3.2 Visual assessment

Visual assessments of the fading of the 48 patches were carried out as described in Reference [40].

E.3.3 Correspondence of measurements to the visual assessments

The value of the total light exposure to the image quality parameter and the score of the visual assessments are plotted in Figure E.4. It shows that the measured values based on the above mentioned procedures correspond well to the visual impression. It is also concluded that chromaticity measurement and the image quality parameter criteria of CIE DE2000 ΔE_{00} = 5 are the good approach for evaluation of image permanence.

E.3.4 Evaluation of colour stability

The colour stability of each sample can be derived from Figure E.3 as shown in Table E.2.