PUBLICLY AVAILABLE SPECIFICATION

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Imaging materials — Image permanence specification of reflection photographic prints for indoor applications —

Part 1:
Test methods

Matériaux pour l'image — Spécification relative à la permanence de l'image des tirages photographiques par réflexion pour applications intérieures —

Partie 1: Méthodes d'essai

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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

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

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

A list of all parts in the ISO 18940 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

Test methods for measurement of image permanence for four important environmental stress factors for indoor use of photographs are described in the following International Standards:

— ISO 18936 for thermal stability;

— ISO 18937 (all parts) for light stability;

— ISO 18941 for ozone gas stability;

— ISO 18946 for humidity fastness.

Humidity testing according to ISO 18946 specifies high humidity test conditions to test for image fastness (resistance to colorant migration). Humidity testing according to ISO 18949 specifies low humidity test conditions, which can be observed in hot arid climates and during winter in continental climates. The importance of low humidity depends on the environmental conditions of the specific usage case. Testing according to ISO 18949 is optional.

NOTE It is acknowledged that other environmental stress factors can be present during indoor use of photographs than the four mentioned before. Examples are other atmospheric gases, including SO_2 and NO_x, the presence of which depends on local factors such as traffic, industry and heating. Mechanical stresses are also not considered here, as these are typically considered to be low in the context of indoor consumer use of photographs as compared to commercial applications (see ISO/TS 21139-1).

Each document includes variants of the test methods, test conditions and data analysis procedures to cover different purposes. For the purpose of an overall specification for indoor image permanence performance, it is necessary to specify which method, which condition and which data analysis procedure to select.

The ISO 18940 series specifies the test methods, the test conditions and details of the data analysis. The ISO 18940 series also specifies how to communicate the results obtained by these test methods.

This document specifies which test method, test conditions and data analysis procedure are selected from those listed in ISO 18936, ISO 18937 (all parts), ISO 18941, and ISO 18946.

In addition, this document also specifies the first level reporting of the results from aforementioned test methods in terms of data plots, which is the most generic reporting method. Graphical reporting addresses the needs of communication on various levels, including technical product information on datasheets, internet home pages, leaflets and posters distributed at trade shows. Graphic reporting is a key for this document, as it provides the foundation for defining end-point criteria and specifications of image permanence in other parts of this standard.

Additional parts of the ISO 18940 series are being envisaged as future work to define standardized evaluation point criteria on the one hand and typical environmental conditions on the other, so that 'typical' expectations for colour changes in the use profile 'consumer home' are taken into consideration. These additional parts acknowledge that the actual expectations, use conditions (display and/or storage, including a certain level of protection) as well as the actual environmental conditions in a specific instance of the use profile may vary.

More information on the image permanence issues of the consumer home environment can be found in ISO/TR 18942.

Imaging materials — Image permanence specification of reflection photographic prints for indoor applications —

Part 1: Test methods

1 Scope

This document specifies the test methods, the test conditions, the test target design, and the analysis procedures for the evaluation of the image permanence performance of digital photographic reflection prints. Tests based on ISO 18936, ISO 18937 (all parts), ISO 18941, and ISO 18946 characterize the thermal stability, the light stability, the ozone stability, and the humidity stability of photographic prints.

This document is applicable to any digital photographic reflection print, which includes prints created by chromogenic silver halide, inkjet, electrophotography, thermal diffusion, and others. Black and white prints composed of metallic silver are not within the scope, but monochrome prints where the printing process contains dyes are within the scope.

The document specifies the content and procedure for graphical reporting of test results as a first level data collection for basic technical communication of image permanence performance of photographic prints.

Application-specific end-points, environmental conditions and test doses (durations, intensity) are not included in this document.

2 Normative references

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

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

ISO 18924, *Imaging materials — Test method for Arrhenius-type predictions*

ISO 18936:2020, *Imaging materials — Processed colour photographs — Methods for measuring thermal stability*

ISO 18937-2:2023, *Imaging materials — Methods for measuring indoor light stability of photographic prints — Part 2: Xenon arc lamp exposure*

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

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

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

ISO/CIE 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

ISO/CIE 11664-4, *Colorimetry — Part 4: CIE 1976 L*a*b* colour space*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

No terms and definitions are listed in this document.

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

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

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

3.2 Abbreviations

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

4 Requirements

To be in accordance with this document, the user shall provide graphical reporting of image permanence testing associated with all four environmental stress factors required in this document, one at a time, including light, heat, ozone, and humidity. If the result of one or several stress factors is not available, it shall be reported that there is no result of that stress factor.

5 Test procedures

5.1 Test target

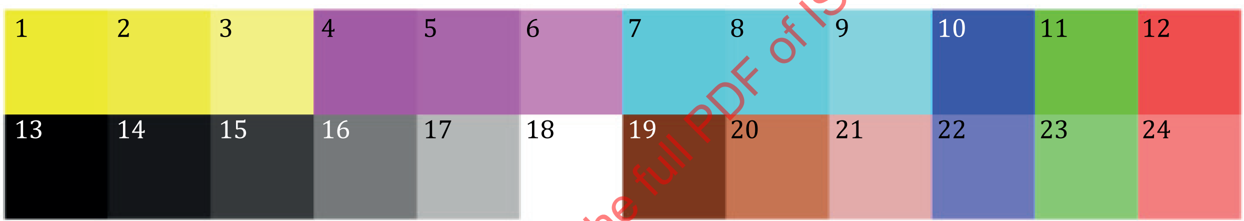
For light, ozone and thermal stability tests, the test target shall consist of the 24 patches with sRGB values defined in Table 1. The requirements for preparation, printing, handling and measurement of the test target defined in ISO 18944 apply. When preparing the test target prints, the sRGB values of Table 1 are used to construct the test patches instead of the sRGB values defined in ISO 18944:2018, 5.3.2 and Annex A. Test targets for high humidity testing are defined in ISO 18946.

An example of test target design is shown in Figure 1.

NOTE 1 This test target was created based on ISO 18944:2018, Table A.1. However, in order to reduce the test load, the number of patches was reduced from 357 to 24, and 3 brown patches were added.

Table 1 — Colour patch of the test target - RGB values of input signal in 8 bit

Number		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Name of colour patch		Dark Yellow	Medium Yellow	Light Yellow	Dark Magenta	Medium Magenta	Light Magenta	Dark Cyan	Medium Cyan	Light Cyan	Dark Blue	Dark Green	Dark Red
Digital value in 8 bit	R	255	255	255	255	255	255	32	64	128	64	64	255
	G	255	255	255	32	64	128	255	255	255	64	255	64
	B	32	64	128	255	255	255	255	255	255	255	64	64
Number		13	14	15	16	17	18	19	20	21	22	23	24
Name of colour patch		Black	Dark Grey	Medium Grey-1	Medium Grey-2	Light Grey	White	Dark brown	Medium brown	Light brown	Light Blue	Light Green	Light Red
Digital value in 8 bit	R	0	32	64	128	192	255	131	204	230	128	128	255
	G	0	32	64	128	192	255	55	115	179	128	255	128
	B	0	32	64	128	192	255	26	77	179	255	128	128



NOTE The patch numbers in the figure are only given for information as to provide a visual association with the sRGB values in Table 1 and are removed when printing.

Figure 1 — Example of the test target design

In addition to graphically reporting the measurement results from the fading of the solid patches, it is also useful to add actual photographic image prints to the fading test, to show how the appearance of the photographic image changes. Photographic images should include a variety of colours, greys and possibly skin tones. These images should also include a range of densities from shadows to highlights and tones in between, considering the primary use of the product and the relevant market.

For humidity stability test, the test target stipulated in ISO 18946 shall be used.

NOTE 2 For humidity stability tests, a test target with not only solid-fill colour patches, but also patches with fine patterns of interleaved colour squares for checks for blur or migration of colorants are needed, and so the test target described in ISO 18946 is used.

5.2 Light stability test

The test procedure for "general indoor display" stipulated in ISO 18937-2:2023, 7.2, shall be used. The light intensity shall be equal to or larger than 50 klx and equal to or smaller than 80 klx. The irradiance shall be controlled by illuminance (lx), or by irradiance (W/m^2) at 420 nm. When irradiance is controlled at 420 nm, the illuminance [lx] shall be measured before and after the test, and the average illuminance value shall be used for data processing.

NOTE This document applies the general indoor condition that uses L37 or SC37 filter to block out shorter UV irradiation. The half cut wavelength of L37 and SC37 is about 370 nm. This condition corresponds to the light spectrum of a typical home. The in-window-display condition stipulated in ISO 18937-2:2023, 7.3, which uses a window glass filter, does not apply.

It is recommended to check the reciprocity failure as detailed in ISO 18937-1. If this is not possible, it shall be reported that the reciprocity failure is not checked.

5.3 Ozone gas stability test

The test procedure stipulated in ISO 18941 shall be used. The standard environmental condition, i.e. temperature of 23 °C and relative humidity of 50 %RH, shall be selected. As an addition, 80 %RH condition may be used.

The ozone concentration shall be 1,0 ppm[1)].

5.4 Thermal stability test

For thermal testing, the test procedure with constant relative humidity at 50 %RH and with the free-hanging method shall be used, as stipulated in ISO 18936:2020, 7.2.4. The 70 %RH condition may be applied as additional option.

NOTE High humidity simulates the condition of storage places in regions of the world where the climate includes semitropical or tropical conditions.

5.5 Humidity fastness test in high humidity condition

The test procedure of Method B (Multiple humidity conditions) stipulated in ISO 18946 shall be used.

It is recommended starting with higher humidity and stepping down to lower humidity to reduce the number of tests. If a print passes the test at a certain humidity condition, there is no need to do the tests at lower humidity levels.

6 Measurement

For measurement, spectral colorimetry shall be used.

The colour of the samples, which include all the colour patches defined in 5.1, shall be measured before and after each exposure based on ISO 11664-1 and ISO 11664-4.

The measurement condition of M1 described in ISO 13655 shall be applied. The other details shall be in accordance with ISO 18944.

NOTE Measurement condition M1 requires the illumination during measurement to closely match the CIE illuminant D50, which includes UV components and makes it possible to evaluate the aging impact from the degradation of optical brightening agents.

Density measurement can be used in addition according to ISO 5 (all parts).

7 Data processing and graph creation

7.1 Data processing

The measured data should be aggregated in a table. An example of the table is shown in Table 2.

The definition of each symbol is as follows:

Q: Patch number (Q = 1, 2, 3, ..., 23, 24) shown in Figure 1;

t_j: Exposure time up to the j^{th} sampling (j = 1, 2, 3, ..., n when sampled n times;

$L^*_{Q,j}$: L^* value of colour patch Q at the sampling point j (j = 0, 1, 2, 3, ..., n when sampled n times);

1) 1 ppm (1×10^{-6}) = 1,0 µl/l.

$a^*_{Q,j}$: a^* value of colour patch Q at the sampling point j (j = 0, 1, 2, 3, ..., n when sampled n times);

$b^*_{Q,j}$: b^* value of colour patch Q at the sampling point j (j = 0, 1, 2, 3, ..., n when sampled n times);

Here, "j = 0" means "before exposure".

Table 2 — Example of blank table for colour data, L^*, a^*, b^*

Colour patch Q	Fresh (before exposure)			Exposed for t_1			Exposed for t_j (j = 2, 3, ..., n − 1)			Exposed for t_n		
	$L^*_{Q,0}$	$a^*_{Q,0}$	$b^*_{Q,0}$	$L^*_{Q,1}$	$a^*_{Q,1}$	$b^*_{Q,1}$	$L^*_{Q,j}$	$a^*_{Q,j}$	$b^*_{Q,j}$	$L^*_{Q,n}$	$a^*_{Q,n}$	$b^*_{Q,n}$
1	$L^*_{1,0}$	$a^*_{1,0}$	$b^*_{1,0}$	$L^*_{1,1}$	$a^*_{1,1}$	$b^*_{1,1}$	$L^*_{1,j}$	$a^*_{1,j}$	$b^*_{1,j}$	$L^*_{1,n}$	$a^*_{1,n}$	$b^*_{1,n}$
2	$L^*_{2,0}$	$a^*_{2,0}$	$b^*_{2,0}$	$L^*_{2,1}$	$a^*_{2,1}$	$b^*_{2,1}$	$L^*_{2,j}$	$a^*_{2,j}$	$b^*_{2,j}$	$L^*_{2,n}$	$a^*_{2,n}$	$b^*_{2,n}$
3	$L^*_{3,0}$	$a^*_{3,0}$	$b^*_{3,0}$	$L^*_{3,1}$	$a^*_{3,1}$	$b^*_{3,1}$	$L^*_{3,j}$	$a^*_{3,j}$	$b^*_{3,j}$	$L^*_{3,n}$	$a^*_{3,n}$	$b^*_{3,n}$
↓												
23	$L^*_{23,0}$	$a^*_{23,0}$	$b^*_{23,0}$	$L^*_{23,1}$	$a^*_{23,1}$	$b^*_{23,1}$	$L^*_{23,j}$	$a^*_{23,j}$	$b^*_{23,j}$	$L^*_{23,n}$	$a^*_{23,n}$	$b^*_{23,n}$
24	$L^*_{24,0}$	$a^*_{24,0}$	$b^*_{24,0}$	$L^*_{24,1}$	$a^*_{24,1}$	$b^*_{24,1}$	$L^*_{24,j}$	$a^*_{24,j}$	$b^*_{24,j}$	$L^*_{24,n}$	$a^*_{24,n}$	$b^*_{24,n}$

7.2 Calculation of colour difference

For each patch, the colour difference between the unexposed sample and the exposed sample shall be calculated. The colour difference ΔE^*_{ab} stipulated in ISO/CIE 11664-4 shall be applied[6][7].

The colour difference ΔE^*_{ab} of the colour patch Q (Q = 1, 2, ..., 24) at the exposure point t_j relative to the unexposed is denoted as $\Delta E^*_{Q,j}$, and shall be calculated by Formula (1).

$$\Delta E^*_{Q,j} = \sqrt{(L^*_{Q,j} - L^*_{Q,0})^2 + (a^*_{Q,j} - a^*_{Q,0})^2 + (b^*_{Q,j} - b^*_{Q,0})^2} \tag{1}$$

The average of $\Delta E^*_{Q,j}$ of all 24 patches (Q = 1, 2, ... 24) at the exposure point t_j is denoted as $\Delta E^*_{\text{ave},j}$, and shall be calculated by Formula (2).

$$\Delta E^*_{ave,j} = \frac{\sum_{Q=1}^{24} \Delta E^*_{Q,j}}{24} = \frac{\Delta E^*_{1,j} + \Delta E^*_{2,j} + \Delta E^*_{3,j} + \cdots + \Delta E^*_{23,j} + \Delta E^*_{24,j}}{24} \tag{2}$$

The calculated values for $\Delta E^*_{Q,j}$ and $\Delta E^*_{\text{ave},j}$ shall be tabulated as shown in Table 3.

Table 3 — Example of blank table for colour differences, $\Delta E^*_{Q,j}$ and $\Delta E^*_{\text{ave},j}$

Colour patch Q	Colour difference generated up to exposure time t_j		
	t_1	t_j (j = 2, 3, ..., n - 1)	t_n
	$\Delta E^*_{Q,1}$	$\Delta E^*_{Q,j}$	$\Delta E^*_{Q,n}$
1	$\Delta E^*_{1,1}$	$\Delta E^*_{1,j}$	$\Delta E^*_{1,n}$
2	$\Delta E^*_{2,1}$	$\Delta E^*_{2,j}$	$\Delta E^*_{2,n}$
3	$\Delta E^*_{3,1}$	$\Delta E^*_{3,j}$	$\Delta E^*_{3,n}$
↓	↓	↓	↓
23	$\Delta E^*_{23,1}$	$\Delta E^*_{23,j}$	$\Delta E^*_{23,n}$
24	$\Delta E^*_{24,1}$	$\Delta E^*_{24,j}$	$\Delta E^*_{24,n}$
Average of all 24 patches	$\Delta E^*_{\text{ave},1}$	$\Delta E^*_{\text{ave},j}$	$\Delta E^*_{\text{ave},n}$

As an addition, the largest and next largest $\Delta E^*_{Q,j}$ in exposure time t_j are extracted from Table 3. The average $\Delta E^*_{Q,j}$ of the largest and next largest shall be calculated. It is denoted as $\Delta E^*_{\text{wor},j}$.

For a more detailed analysis, the difference in L^*, C^* and Hue between the unexposed sample and the exposed sample should also be calculated. It shall be done at least for the patches of grey and brown tones. This analysis is important because the tolerance varies depending on the direction of hue and the level of saturation (chroma)[9].

NOTE It is acknowledged that the ΔE_{ab} metric does not fully account for the different perception of colour differences at different levels of brightness and saturation. For example, for similar visually perceived colour differences of yellow, magenta and cyan, the measured ΔE_{ab} values are typically 2 to 3 times larger for yellow, because of its different position in CIELAB colour space with much larger values for L^* and C^* compared to magenta and cyan. Nevertheless, the average ΔE_{ab} metrics provides a good correlation with visual performance and the alternative ΔE_{00} metric, which is designed for tolerancing of small colour differences and limited to ΔE < 5, whereas often larger colour differences are evaluated in colour fading experiments. Therefore, ΔE_{ab} has been chosen over ΔE_{00}, see ISO/CIE 11664-6.

7.3 Graph reporting

7.3.1 General

The resulting values are plotted on a graph. The advantages of a graphical report are as follows:

a) Graphs of colour changes over time represent a generic visualization of discoloration under the given test conditions, even when the evaluation point and the assumed environmental conditions in the final application are not yet determined.

b) The test results can be used according to the purpose. A graph of changes over time can be used to either derive the amount of exposure at which a certain amount of change has occurred, or to determine the size of the change after a certain amount of exposure.

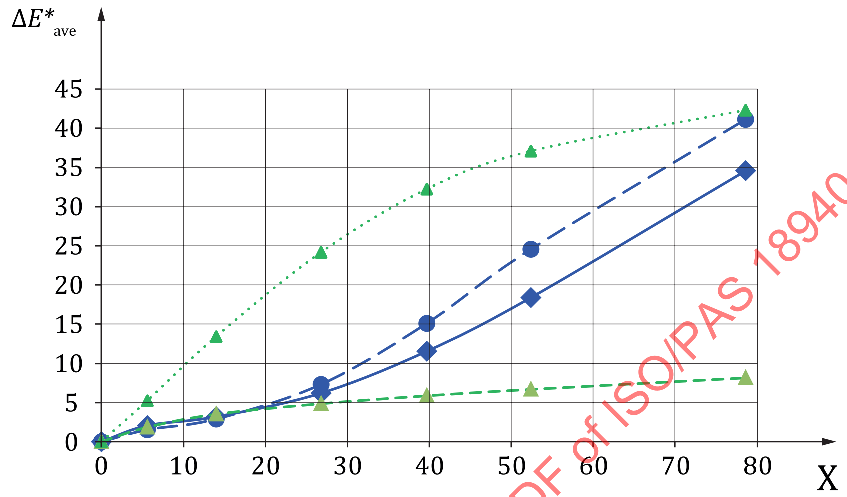
c) A graph better visualizes the trend of a colour change, for example whether the rate of fading is constant, whether the fading rate slows down in the course of the exposure, or whether the fading rate changes at some pivotal point.

d) The variability of the measurement results can be shown and the reliability of the data can be confirmed by observing the variation of the plotted points.

7.3.2 Light stability

The $\Delta E^*_{ave,j}$, which is average of $\Delta E^*_{Q,j}$ of all 24 patches (Q = 1, 2, ... 24) at the exposure point t_j, shall be plotted against the cumulative exposure as shown in Figure 2. The cumulative exposure is the product of exposure intensity in lux [lx] and exposure duration in hour [h], and expressed in megalux hour [Mlx-h].

The range of the X-axis, which is the cumulative exposure, should be (0 to 80) Mlx-h.



Key

X light exposure (Mlx-h)

type A (current)

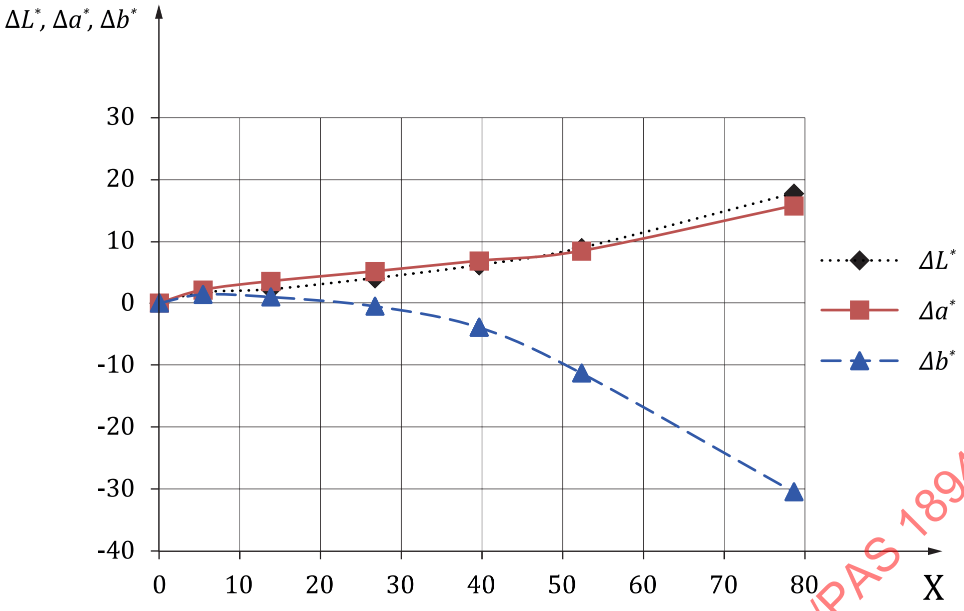
type B (new)

type C (see Reference [6])

type D (see Reference [7])

Figure 2 — Example of graph of ΔE^*_{ave} versus light exposure (Mlx-h) of 4 kinds of photographic prints

The changes in L^*, a^*, and b^* of the exposed samples versus the unexposed samples should also be plotted against the cumulative exposure for the patches arbitrarily selected for the purpose, as shown in Figure 3.



Key

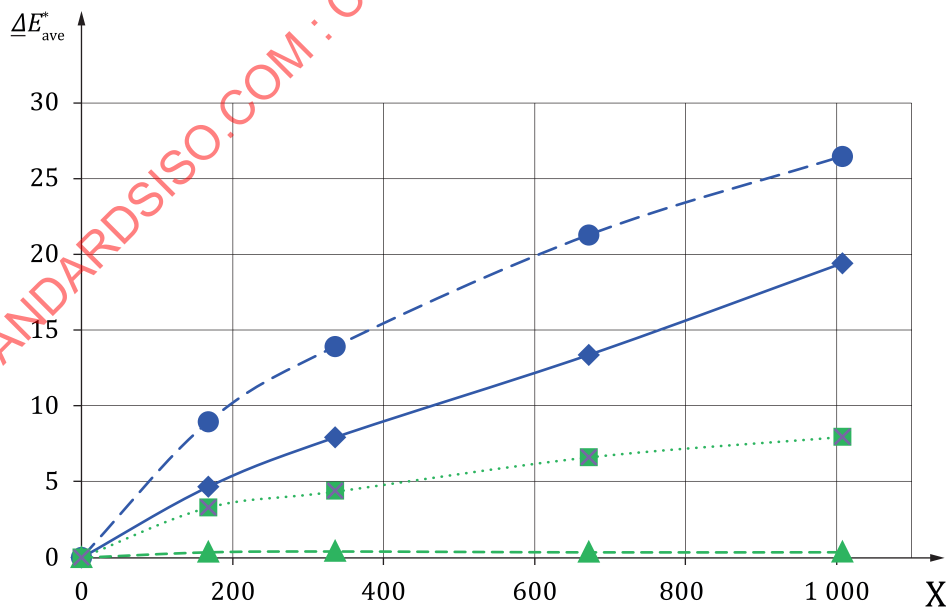
X light exposure (Mlx-h)

Figure 3 — Example of graph of the changes in L^*, a^*, and b^* versus light exposure (Mlx-h)

7.3.3 Ozone gas stability

The $\Delta E^*_{\text{ave},j}$, which is average of $\Delta E^*_{Q,j}$ of all 24 patches (Q = 1, 2, ... 24) at the exposure point t_j, shall be plotted against the cumulative exposure as shown in Figure 4. The cumulative exposure is the product of ozone gas concentration in microlitres per litre (ppm) and exposure duration in hours [h], and expressed in ppm hour [ppm-h].

The range of the X-axis, which is the cumulative exposure, should be (0 to 1 000) ppm-h.



Key

X ozone exposure (ppm-h)

— ● — type A (current)

type B (new)

type C (see Reference [6])

type D (see Reference [7])

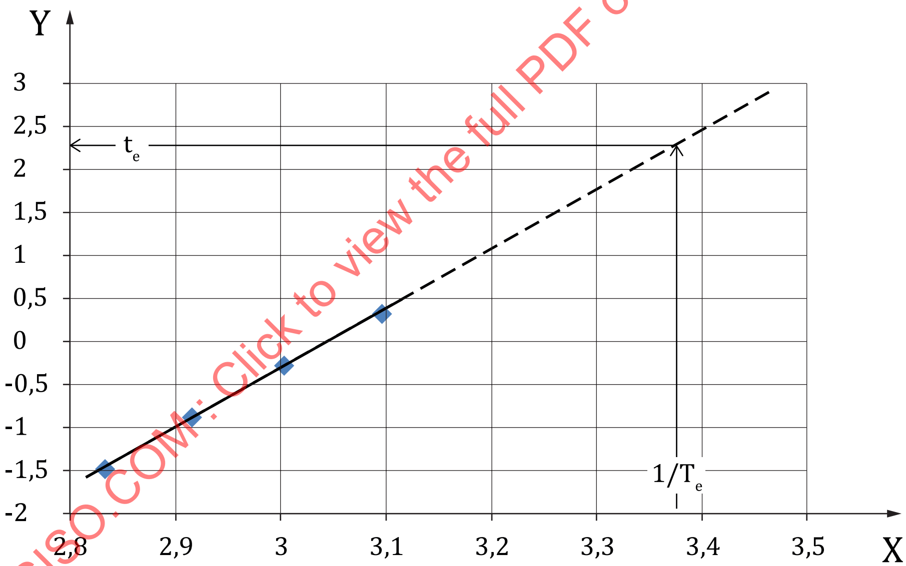
Figure 4 — Example of graph of ΔE^*_{ave} versus ozone gas exposure (ppm-h) of 4 kinds of photographic prints

7.3.4 Thermal stability

For data processing of the thermal test data, the Arrhenius analysis stipulated in ISO 18924 shall be applied.

The Arrhenius analysis shall process the data for each patch one at a time, instead of using the average ΔE^* values for the 24 colour patches. Since modern photographic print materials rarely show changes under thermal exposure, the data of the patches showing the significant changes shall be plotted for Arrhenius analysis.

An example of Arrhenius plot is shown in Figure 5. From the extrapolation of the plot towards lower temperature and longer test times, the extrapolated time to reach the predetermined change can be derived for a target temperature that is defined by the use profile.



Key

X reciprocal of temperature (1/K × 1 000)

Y time in years (log scale)

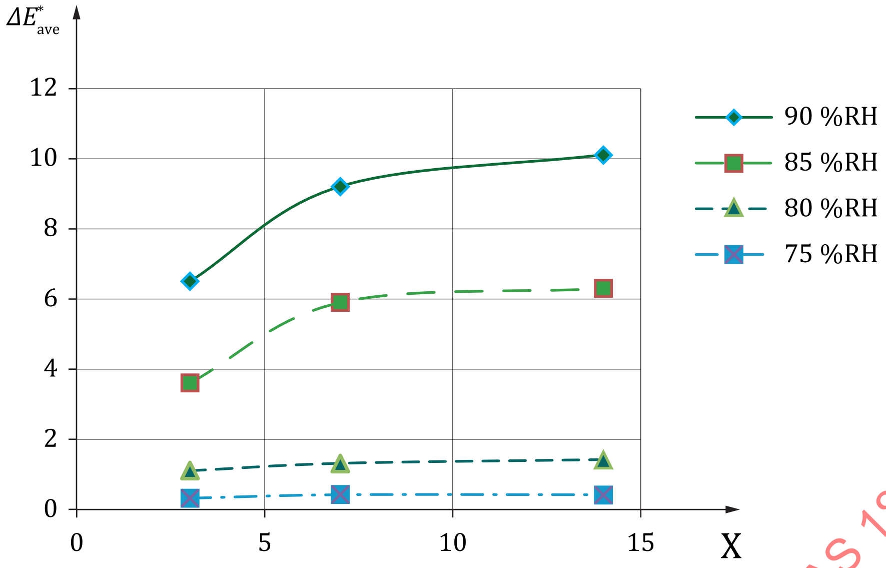
T_e target temperature [K]

t_e extrapolated time to predetermined change

Figure 5 — Example of graph of Arrhenius plot (Time in years to reach ΔE^*_{max} = 5 at each temperature)

7.3.5 Humidity fastness in high humidity conditions

The average colour difference, $\Delta E^*_{ab,ave}$, of the 84 patches of the checkerboard test pattern defined in ISO 18946 shall be plotted against the duration of humidity exposures for at least 3 humidity conditions as shown in Figure 6.



Key

X humidity exposure (days)

Figure 6 — Example of graph of humidity test

8 Reporting

8.1 Internal recording

The following should be recorded internally, for example in the laboratory notebook.

a) Reference:

Reference to this document, i.e. ISO/PAS 18940-1:2023.

b) Printing system:

1) Printer: model name, manufacturing number, manufacturing date.

2) Printer settings: e.g. driver or RIP settings, software version, and any other relevant settings: e.g. calibration settings, colour management settings, media related settings, screen settings.

3) Materials (media and ink/toner/ribbon or chemicals, others): product name, manufacturing number, manufacturing date.

c) Printing procedures:

1) Date and time, place, name of the operator.

2) Environmental conditions (temperature, relative humidity, etc.) during the printing and during the conditioning and storage of test specimens.

3) Test target (any deviation from Figure 1).

d) Measurements:

1) Date and time (time from printing to measurement, time from environmental stress test to measurement), place, name of the operator.

2) Measurement device, e.g. product type, geometry, UV cut filter, and other settings.