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Imaging materials — Photographic reflection prints — Methods for measuring indoor light stability

Matériaux pour l'image — Tirages photographiques par réflexion — Méthodes de mesure de la stabilité de la lumière en intérieur

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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*.

This second edition cancels and replaces the first edition (ISO 18937:2014), which has been technically revised. The main changes compared to the previous edition are as follows:

— Removal of non-xenon light sources;

— Removal of non-essential verbiage to improve method clarity;

— Inclusion of annex on actual sample temperature measurements during exposure;

— Inclusion of continuous phase test for in-window display conditions.

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 document addresses the methods and procedures for measuring the indoor light stability of photographic reflection prints[3]–[5][11]–[16][20].

The length of time that such photographs are to be kept can vary from a few days to many hundreds of years and the importance of image stability can be correspondingly small or great. Often the ultimate use of a particular photograph may not be known at the outset. Knowledge of the lightfastness level of colour photographs is important to manufacturers to improve print materials and to many users, especially since stability requirements may vary depending upon the application.

The images of most modern analogue and digitally-printed colour photographs are made up of cyan, magenta, yellow, red, green, blue, orange, black, grey, white or other colourants. Colour photographic images typically fade during storage and display; they will usually also change in colour balance because the various image colourants seldom fade at the same rate. In addition, a yellowish (or occasionally other colour) stain may form and physical degradation may occur, such as embrittlement and cracking of the support and image layers. The rate of fading and staining can vary appreciably and is governed principally by the intrinsic stability of the colour photographic material and by the conditions under which the photograph is stored and displayed. For silver halide prints, the quality of any chemical processing is another important factor. Post processing treatments and post-production treatments, such as application of lacquers, plastic laminates, and retouching colours, also may affect the stability of colour materials.

The light stability of colour photographs is influenced primarily by the intensity of the radiation/light source, the duration of exposure to light, the relative spectral irradiance of the light source, and the ambient temperature and humidity conditions. However, the normally slower dark fading and staining reactions also proceed during display periods and will contribute to the total change in image quality. Ultraviolet radiation is particularly harmful to some types of colour photographs and can cause rapid fading as well as degradation of the underlying substrate. Information about the light stability of colour photographs can be obtained from accelerated light stability tests. These require special test units equipped with high-intensity light sources in which test strips can be exposed for days, weeks, months, or even years, to produce the required amount of image fading (or staining). The temperature and moisture content of the specimen prints should be directly or indirectly controlled throughout the test period, and the types of light sources should be chosen to yield data that can be correlated satisfactorily with those obtained under conditions of normal use.

Accelerated light stability tests for predicting the behaviour of photographic colour images under normal display conditions may be complicated by “reciprocity failure." When applied to light-induced fading and staining of colour images, reciprocity failure refers to the failure of a colourant to fade, or to form stain, equally when irradiated with high-intensity versus low-intensity light, even though the total light exposure (intensity × time) is kept constant through appropriate adjustments in exposure duration. The extent of colourant fading and stain formation can be greater or smaller under accelerated conditions, depending on the photochemical reactions involved in the colourant degradation, on the kind of colourant dispersion, on the nature of the binder material, and on other variables. For example, the supply of oxygen that can diffuse into a photograph’s image-containing layers from the surrounding atmosphere may be restricted in an accelerated test (dry gelatine, for example, is an excellent oxygen barrier). This may change the rate of colourant fading relative to the fading that would occur under normal display conditions. The magnitude of reciprocity failure may also be influenced by the temperature and moisture content of the test specimen prints. Furthermore, light fading may be influenced by the pattern of irradiation — continuous versus intermittent — as well as by light/dark cycling rates (see Annex A).

Imaging materials — Photographic reflection prints — Methods for measuring indoor light stability

1 Scope

This document describes test equipment and procedures for measuring the light stability of colour photographic reflection prints designed for display, when subjected to a filtered xenon-arc light source simulating daylight through windows at specified temperatures and relative humidity.

This document is applicable to photographic reflection prints, made with analogue and digital print processes. The recommended test methods can be applied to both colour and black-and-white photographic prints.

This test method assesses colour and density change.

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 2471, *Paper and board — Determination of opacity (paper backing) — Diffuse reflectance method*

ISO 4892-1, *Plastics — Methods of exposure to laboratory light sources — Part 1: General guidance*

ISO 18913, *Imaging materials — Permanence — Vocabulary*

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*

3 Terms and definitions

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

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

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

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

4 Requirements and limitations

This document specifies a set of recommended test methods with associated requirements for permitted reporting. Data from these tests shall not be used to make life expectancy claims, such as time-based print lifetime claims, either comparative or absolute. Conversion of data obtained from these methods for the purpose of making public statements regarding product life shall be in accordance with the applicable documents for specification of print life.

The test methods in this document may be useful as stand-alone test methods for the absolute or comparative stability of image materials with respect to colour fading or measurement of physical properties. Caution shall be used when comparing test results for different materials. Comparisons shall be limited to test cases using test apparatus with matching specifications and matching test conditions.

No accelerated laboratory exposure test can be specified as a total simulation of actual use conditions. Results obtained from these laboratory accelerated exposures can be considered as representative of actual use exposures only when the correlation has been established for the specific materials being tested and when the type of degradation is the same. The relative durability of materials in actual use conditions can be very different in different locations because of differences in radiant energy (both in spectral irradiance and intensity), relative humidity, temperature, pollutants such as ozone, and other factors.

Print image stability results from this test method, especially in terms of the amount of acceleration and/or correlation to end-use service life, that are determined for one printer model, software settings, colourant, and media combination should not be applicable to another printer model, software settings, colourant, and media combination.

5 Test methods — General

5.1 Safety cautions

In light stability tests, a high irradiance level is used, often with significant UV content. Special care shall be taken to avoid eye injury or skin erythema. Precautions should be taken to ensure that the light source cannot inadvertently be viewed without suitable eye and skin protection.

5.2 Light source and filters

This document references the use of a filtered xenon-arc light source (daylight behind window glass) as described in ISO 4892-2 for accelerated tests with the intention of reproducing as closely as possible different end-use lighting conditions[17][18]. In addition, special filtering of the xenon-arc lamp is used (which is not referenced in ISO 4892-2) to achieve the lighting conditions applicable to this method.

5.3 Humidity control

The relative humidity of the air circulating the test chamber shall be controlled. The location of sensors used for measuring humidity shall be as specified in ISO 4892-1.

5.4 Temperature control

Uninsulated black metal panels are used to indirectly control specimen temperature. The black panel shall be constructed in accordance with ISO 4892-1 and mounted at the specimen exposure plane. The uninsulated black panel shall be controlled.

Chamber (ambient) temperature shall be controlled. The sensor shall be shielded from light and mounted near the exposure zone.

Most lightfastness apparatus use ambient laboratory air to control chamber air temperature. Therefore, laboratory conditions shall be maintained such that the apparatus can control temperature effectively. Air refrigeration units may be required to maintain the chamber air temperature depending on the laboratory air temperature.

NOTE The ± tolerances given for testing set points are the allowable fluctuations of the parameter about the given value under equilibrium conditions. This does not mean that the apparatus set point value can be varied by ± the amount indicated from the given value, just that the measured value may. These ± tolerances are also not intended as requirements for chamber uniformity.

5.5 Air quality in the test environment

Some types of print materials can be highly sensitive to degradation caused by ozone or other airborne pollutants. Therefore, the test facility where print specimens are made, dried, exposed, and measured, shall be ozone free (<2 nl/l average over any 24-h period) for ozone sensitive samples, as determined in accordance with ISO 18941. A material that is not sensitive to ozone shall have demonstrated no measurable D_{min} or printed patch colour change at ambient ozone exposure levels and measurement condition temperature and humidity.

NOTE 1 nl/l = 1 ppb (1×10^{-9}). Although the notation "ppb" (parts per billion) is widely used in the measurement and reporting of trace amounts of pollutants in the atmosphere, it is not used in International Standards because it is language-dependent.

Either active or passive ozone monitoring can be used. Active monitoring includes real-time measuring and logging of ozone levels in the test facility. Passive monitoring measures long-term cumulative ozone levels yielding a final verification that pollutant levels were at or below acceptable levels during the test. Active monitoring is preferred as passive monitoring cannot indicate whether test conditions were valid until the test is completed.

If necessary, the apparatus can be fitted with an appropriate filter in the incoming chamber air stream to reduce the ozone concentration levels, or ozone can be scrubbed in the laboratory air by appropriate filters.

NOTE 2 The susceptibility of specimens to a given level of airborne pollutants in the air of the test environment (laboratory) can be qualitatively assessed by exposure of replicate specimens to the condition of high air flow in a darkened section of the test environment (with the same air quality), running parallel to the intended test described in this document. If "no measurable change" is obtained as a result of this additional exposure test, the material is regarded as "not susceptible to airborne pollutants" for the duration of the test and for the given test environment. This approach represents a fail-safe test for each imaging material of interest that integrates the effects of ozone and all other potentially harmful pollutants that could be present in the laboratory atmosphere.

5.6 Duration of exposures

The duration of exposures shall be determined with the following considerations:

a) Total exposure required, for example:

   1) Total exposure expected in the usage;

   2) Total exposure required for the warranty;

   3) Total exposure stipulated as endpoint criteria in the applicable International Standards for specification of print life, when such a specification document is available.

b) Total exposure that will cause an aim change, for example:

   1) Total exposure that will cause expected change;

   2) Total exposure that will reach endpoint criteria specified in the applicable International Standards for specification of print life.

c) Total exposure required to cause a change to be reliably detected beyond the noise of the system, particularly for highly stable systems. A reliable change is considered detected when the test result has progressed beyond the noise of the test system.

This test method does not include test endpoints to establish test duration.

6 Light source conditions

6.1 Light source measurements

The filtered xenon-arc light source shall be measured at the specimen plane in terms of radiation source intensity as described in ISO 4892-1.

NOTE Measurement of illuminance or irradiance is used as an integral part of the control system in light test equipment. The control system can then compensate for reduced UV transmission due to solarisation of the lamp and filters.

6.2 Light exposure equipment

Xenon-arc radiant exposure apparatus that can achieve the test conditions and the tolerances stipulated in Clause 5 shall be used. Any configuration of xenon-arc lamp exposure apparatus can be used, provided it can achieve the required test conditions and the tolerances.

6.3 Specifications for optical filters

6.3.1 General

The spectral irradiance of the test light source can be modified by the use of optical filters in order to simulate a particular usage condition. To control the specimen surface temperature at the desired aim value, IR filters may be employed to reduce infrared energy above 800 nm.

NOTE Ultraviolet radiation is considerably more harmful to some types of printed matter than it is to others and, therefore, variations in the level (and spectral irradiance) of the ultraviolet radiation in the light source will affect some materials more than others.

6.3.2 Filter specifications for simulating general indoor display conditions

This filter system shall consist of window-glass filters with spectral irradiance in accordance with Table 3 and an additional UV cut-off filter with a half-cut wavelength (λ at T = 50 %) of 370 nm to 375 nm. The resulting spectral irradiance shall be in accordance with Table 1. The intent of this filter is to simulate an indoor exposure further away from a window, when a large part of the window-glass filtered daylight has undergone reflection off the interior of the room before hitting the displayed print.

Examples of the standard UV cut-off filter and their corresponding spectral transmission characteristics are shown in Table B.1 and Table B.2.

NOTE Examples of an acceptable UV cut-off filter are L-37 (Hoya Co.) and SC-37 (Fujifilm Co.).

In order to maintain conformance, the filter shall be cleaned or replaced per OEM instructions.

6.3.3 Filter specifications for simulating in-window display conditions

This filter system shall consist of window glass filters with spectral irradiance in accordance with Table 3. The intent of this filter is to simulate terrestrial daylight transmitted through standard architectural window glass.

In order to maintain conformity, the filter shall be cleaned or replaced per OEM instructions.

6.3.4 Use of an IR-reducing filter

An IR-reducing filter can be used with the filter systems specified in 6.3.2 or 6.3.3 as needed to meet the black panel temperature and chamber air temperature requirements.

6.3.5 Filter configuration

The optical filters shall be placed at any position between the light source and the specimens to achieve the required spectral irradiance conditions. The filters can be placed near the light source or near the specimens, but the air gap between the specimens and the filter shall be at least 2 mm with an unobstructed airflow between the filter and the specimens.

6.4 Verification of chamber fade uniformity

Chamber fade uniformity assessment is required to qualify the initial illuminance or irradiance, specimen mounting, air flow configuration, and filter placement configuration with the light stability test conditions (including lamp and filter spectral irradiance, light intensity, air quality, temperature and humidity levels). See Annex C for specific information about this procedure.

The chamber fade uniformity between any two locations in the exposure plane used for specimen exposure, as indicated by percent optical density change, shall be at least 80 %.

$$U_{CF} = \frac{C_{SOC}}{C_{LOC}} \times 100$$

where

U_{CF} is the chamber fade uniformity (CFU);

C_{SOC} is the the smallest optical density change (SOC);

C_{LOC} is the the largest optical density change (LOC).

For chamber fade uniformity testing, the following requirements apply.

Design the specimen and equipment configuration that will be used in the light stability testing before evaluating chamber fade uniformity. Each aspect of the specimen and equipment configuration including number of specimens, size of specimens, placement of specimens, specimen holders, light intensity, filtration, whether air refrigeration is used, relative humidity of the environment, and chamber airflow shall be specified in the design and fixed before beginning the chamber fade uniformity verification.

7 Light source specifications

7.1 Simulated general indoor display

7.1.1 Application

This test is intended to simulate common use conditions found in houses, apartments and other dwelling places where indirect lighting due to filtering (through window glass) and shading is often the principal illumination causing displayed photographs to fade. A UV-filtered xenon-arc lamp is found to provide a reasonable match to indirect, window-filtered daylight[11][21][22]. The specimen temperature is dominated by ambient conditions.

7.1.2 Filtered xenon-arc configuration to simulate general indoor display conditions

The xenon-arc lamp shall be configured with a UV filter specified in 6.3.2 and may be used with or without a standard IR filter (the IR filter can be used if it is necessary to attain the black panel temperature).

Optical filters shall be positioned according to 6.3.5.

7.1.3 Spectral irradiance

The spectral irradiance shall conform to the tolerances in Table 1.

Table 1 provides the relative spectral irradiance in the given bandpass, expressed as a percentage of the total irradiance between 300 nm and 800 nm.

Table 1 — Relative spectral irradiance for filtered xenon-arc lamp for simulated general indoor display

Spectral bandpass λ (wavelength) nm	Relative spectral irradiance %
310 ≤ λ < 340	0,0 to 0,1
340 ≤ λ < 370	0,1 to 1,0

Table 1 *(continued)*

Spectral bandpass λ (wavelength) nm	Relative spectral irradiance %
370 ≤ λ < 400	2 to 5
400 ≤ λ < 430	4 to 8
430 ≤ λ < 800	86 to 93

7.1.4 Radiation intensity, temperature, and humidity

The following set points given in Table 2 shall be used, with acceptable deviations based on the data provided in Annex D.

Table 2 — Set values for simulated general indoor display

Parameter	Set value
Illuminance at the specimen plane (klx)	≤80
Black panel temperature (uninsulated) (°C)	25 to 35
Chamber air temperature (°C)	21 to 27
Relative humidity (% RH)	50

The tolerance of the operational fluctuation of the temperature shall be less than ±2 °C, and the tolerance of the operational fluctuation of the relative humidity shall be less than ±10 % RH.

The radiation intensity, black panel temperature, and chamber air temperature range of set points in the above table are intended to result in a photographic print exposed under these conditions to be indirectly controlled at a temperature between (25 to 30) °C. The construction and absorption properties of the black panel will result in temperatures (3 to 8) °C higher than the photographic prints exposed, as shown by the data in Annex D.

NOTE 1 Annex D provides a table of temperature measurement data of a grey (0,75 OD) target sample with a variety of illuminance and chamber temperature settings, as well as with/without IR-attenuating filters. Combinations of these variables can be used based on guidance from this table in order to achieve the targeted sample temperature of (25 to 30) °C.

NOTE 2 Radiation intensity can be measured in irradiance units in place of the stated illuminance units. When testing with the L-37 or SC-37 filter, irradiance shall be controlled at 300 nm to 400 nm or 420 nm. Contact the radiant exposure apparatus manufacturer to obtain appropriate conversions from illuminance to irradiance.

An IR-reducing filter can be used if the uninsulated black panel temperature and/or chamber temperature cannot be controlled at the set points listed.

7.2 Simulated in-window display

7.2.1 Application

This test is intended to simulate terrestrial daylight transmitted through standard architectural window glass. A typical example of such display can be found when images are displayed in store windows, facing toward the outdoors, so that they may be viewed by people outside of the store[11][19].

Two testing conditions are noted. 7.2.4.1 describes a test that includes higher temperatures caused by strong radiative heating, and light/dark cycling to promote stress fatigue. The cycling simulates episodes with elevated temperature differences between colours and between the imaging layer and support, as well as episodes of elevated specimen temperature with reduced moisture content (hot light phase) and remoistening (cool dark phase). 7.2.4.2 describes a continuous light test at lower temperatures to simulate limited radiative heating, such as show windows in an air-conditioned air space, with sun shade or orientation away from the equator. The continuous light simulates limited stress fatigue as compared to the cyclic test conditions.

7.2.2 Filtered xenon-arc configuration to simulate in-window display conditions

The xenon-arc lamp shall be configured with a window-glass filter specified in 6.3.3 and may be used with or without a standard IR filter (the IR filter can be used if it is necessary to attain the black panel temperature).

Optical filters shall be positioned according to 6.3.5.

7.2.3 Spectral irradiance

The spectral irradiance shall conform to the tolerances in Table 3.

Table 3 gives the relative spectral irradiance in the given bandpass, expressed as a percentage of the total irradiance between 300 nm and 800 nm.

Table 3 — Relative spectral irradiance for filtered xenon-arc lamp for in-window display

Spectral bandpass λ (wavelength) nm	**Relative spectral irradiance** %
$300 \leq \lambda < 340$	0,5 to 1,2
$340 \leq \lambda < 370$	2,8 to 3,5
$370 \leq \lambda < 400$	3 to 5
$400 \leq \lambda < 430$	4 to 7
$430 \leq \lambda < 800$	83 to 88

7.2.4 Radiation intensity, temperature and humidity

Two test cycles are listed: a light/dark cycling test[11][19] and a continuous light test.

7.2.4.1 Light/dark cycling

The conditions for the light cycle and dark cycle are shown in Table 4.

The following set points shall be used.

Table 4 — Set values for light/dark cycling conditions for simulated in-window display

Parameter	Light phase	Dark phase
Illuminance at the specimen plane (klx)	≤100	N/A
Phase duration (hours)	3,8	1,0
Black panel temperature (uninsulated) (°C)	63	N/A
Chamber air temperature (°C)	40	25
Relative humidity (% RH)	40	(80)

The tolerance of the operational fluctuation of the temperature shall be less than ±2 °C, and the tolerance of the operational fluctuation of the relative humidity shall be less than ±10 % RH.

7.2.4.2 Continuous light

The conditions for the continuous light test are shown in Table 5. If a reciprocity behaviour test is conducted, lower radiant intensity, e.g. 10 % of nominal condition, shall be used (details are described in Annex A).

Table 5 — Set values for continuous conditions for simulated in-window display

Parameter	Conditions
Illuminance at the specimen plane (klx)	50 to 80
Black panel temperature (uninsulated) (°C)	35
Chamber air temperature (°C)	25
Relative humidity (% RH)	50

NOTE Radiant intensity can be measured in irradiance units in place of the stated illuminance units. Contact the radiant exposure apparatus manufacturer to obtain appropriate conversions from illuminance to irradiance.

The tolerance of the operational fluctuation of the temperature shall be less than ±2 °C, and the tolerance of the operational fluctuation of the relative humidity shall be less than ±10 % RH.

8 Specimen preparation

8.1 Specimens

8.1.1 Use of replicates and reference specimens

At least two replicate prints are required for each test case. Replicates shall be located for testing in different regions of the test chamber volume.

Reference specimens are recommended to be included in every exposure test to track consistency of the test procedures as well as unintended changes of test conditions, see Reference [5].

It is recommended that reflection prints be backed with a non-reactive and non-yellowing white material such as 100 % cotton cellulose mount board (100 % "rag" board) or metal (e.g., white-painted aluminum or stainless steel plate) to ensure dimensional stability. If a backing material is used, it shall be reported[1].

8.1.2 Setting of dummy specimens for the open space

All specimen positions shall be filled with specimens — or with dummy specimens which are equivalent in average density or reflectance to the actual test specimens.

8.1.3 Test target design and format

For general testing purposes, users of this document are free to choose whatever test images, target, patches and starting densities they feel are appropriate for their testing needs. An example of such a target is included in ISO 18944 with requirements and recommendations for specimen preparation. Applicable International Standards for specification of print life may require the use of specific standard targets. Other recommendations for specimen preparation are contained in ISO 18909. Image prints may also be used. When specific starting densities are desired or required, there may not be a step on a properly designed and printed test target that is of exactly the desired density. Interpolation between two neighbouring density patches can be used to predict the values for the exact desired starting density. See ISO 18944 for details on interpolation between two neighbouring density patches. Other designs and formatting may be used for physical property testing.

8.2 Conditioning the prints after printing

Aqueous and solvent inkjet prints, and prints of any type that require curing/stabilization/dry-down shall be conditioned until the curing process is finished. If the duration of curing is unknown, prints should be conditioned for two weeks after printing, in an environment with a temperature of (23 ± 2) °C, with a relative humidity of (50 ± 5) %. The print conditioning environment shall be ozone-free (≤2 nl/l average concentration over any 24 h period) for ozone-sensitive target prints, as determined in accordance with ISO 18941. During the conditioning period the prints shall be maintained with unrestricted airflow. Prints of any types that do not require curing/stabilization/dry-down shall be held for 24 h. Measurements shall be conducted after conditioning or print hold.

9 Test report

9.1 General reporting requirements

Reporting based solely on this test method shall be restricted to reporting the specific light stability test result for the specific system tested. Users are cautioned that results from this test method apply only to the specific system tested. For example, in inkjet systems, a specific ink used with a specific paper may have very different results from another. Test reporting shall include this disclaimer.

The results of these tests are typically reported as the amount of densitometric or colorimetric change observed for a given cumulative exposure, or cumulative exposure to reach the observed densitometric or colorimetric change.

This test method does not contain endpoint criteria, and therefore, the measurement results of this test method shall not be used independently to estimate or predict any aspect of print image life.

The test has not been designed to cause physical deterioration of the print, but any visual observations of print quality degradation, such as loss of sharpness, and physical deterioration, such as curl, cockle, cracking, or delamination, that occurred during the test shall also be reported.

Depending on evaluation context, results from physical test methods, including brittleness and layer adhesion, and chemical analytical results (e.g. FTIR) can be reported. The report of test results shall include the following:

a) A reference to this document, i.e., ISO 18937:2020.

b) Details of specimen prints, if known. For digital output specimen prints, this shall include:

   — the printer model, printer driver version, printer driver settings, printer front panel settings, the name of the host application used in generating the print, the cartridge configuration, and the colour controls selected in that application;

   — the colourant (ink, toner, donor, ribbon, etc.);

— the paper used (manufacturer's name and model number), and any other necessary information, such that the print file can be reproduced by another user of this document.

For silver-halide based specimen prints, the processing conditions (i.e. chemicals, procedures) shall be reported.

In all cases any post-processing treatments that may have been applied to the prints shall be reported.

c) Test target design, including the target patch encoding values of the patches selected for monitoring in the test, and the corresponding initial densities (i.e. 1,0) of the neutral and colour patches; the number of replicate test specimen prints included in the test.

d) The test method (the light source and filter system) and test conditions (light intensity, uninsulated black panel temperature, chamber air temperature, relative humidity). If the actual test conditions deviate from the nominal conditions specified in this document then an explanation shall be provided.

e) Whether or not a backing material was used behind the specimen print in the test (if a backing material was used, specify its characteristics).

f) Duration of the test.

g) Measurement environment and specimen holding conditions, temperature, relative humidity, ozone, and illuminance or irradiance levels, fluctuations, and uniformity, if they differ from the stipulated conditions.

h) The backing used during measurement or the material opacity according to ISO 2471.

NOTE When reporting for comparison, test reporting is valid only when the test conditions have produced a fade signal (loss or gain) that can be statistically separated from test noise. For other test purposes, reporting the results from tests conducted for a cumulative exposure or test condition that does not produce a separable fade signal can be useful.

Annex A
(informative)

Evaluation of light stability reciprocity behaviour

A.1 General

Depending on the nature of the specific products to be tested, an assumption of reciprocal behaviour, or adherence to the reciprocity law, may not be valid. This is especially important if the user is going to make predictions of performance at ambient light levels based on accelerated test results obtained at the higher light levels. In which case, the user shall track the behaviour of light degradation at high intensities versus lower intensities, in order to validate the predictions of performance at ambient light levels. The reciprocity law was originally proposed in 1862 by Bunsen and Roscoe. It states that the response (e.g., change in density) of a light-sensitive system is proportional to the total energy received and is independent of the rate at which the energy is supplied[8], where the total energy (or cumulative exposure) is the product of intensity (illuminance or irradiance) and time. In many photographic systems this is true. However, in some traditional photographic systems, several non-traditional digital output systems, and under some extreme exposure conditions, the change in density is not independent of the rate at which the energy is supplied[9][10]. This is said to be reciprocity law failure.

If predictions of performance are to be made based on tests at very high light levels, it is recommended that a check for adherence to the reciprocity law be performed. To do so, it is recommended that light stability tests be conducted at two or more intensities to a common cumulative exposure. As is the case with the other light fade tests contained in this document, it is critical that these tests be carried out under environmental conditions of temperature, humidity, and air quality such that there is no substantial contribution of these factors to the observed amount of change. For example, if a specimen print is known to fade in response to low levels of ambient ozone, then the results of a test run at lower intensity for longer periods of time would be confounded by the larger contribution to the observed fade caused by the longer exposure to ambient ozone[16].

A reciprocity factor is defined as the ratio of the change in density at the low intensity to the change in density at the high intensity with both intensities run to a common cumulative exposure, as provided by the equation below:

$$R_{\text{f}} = \Delta D_{\text{low intensity}} / \Delta D_{\text{high intensity}}$$

For a specified cumulative exposure.

Reciprocity factors greater than one and less than one have been observed in imaging systems[12][23], which can result in under, and over prediction of the colourant loss. Because reciprocity factors both greater and less than one have been observed in imaging systems, it is important that reciprocity tests be run for each imaging system in question.

If reciprocity failure is noted, it is recommended that tests be run to check for confounding factors. As mentioned above, apparent reciprocity could be introduced as a result of uncontrolled environmental factors not related to light fade, unexpected test equipment variability, or both[12][23].

If reciprocity failure is still noted after double-checking for confounding factors, then any comparisons or predictions with respect to light fade should be based solely on the lower intensity condition. Using the condition that is closer to the ambient condition reduces the impact of reciprocity failure, if any, and is statistically superior, as it requires a smaller extrapolation of the data[6][7].

NOTE It is very important to correctly assess the impact of intensity versus time of exposure when calculating and applying reciprocity factors. To do so, carry out both the high and low intensity tests to a common cumulative exposure and compare the observed colour fade under both conditions in order to calculate the reciprocity factor. In contrast, running the test to the same level of observed colour fade and comparing the different amounts of cumulative exposure can result in an incorrect and variable factor when the colour fade follows other than a linear function.

A.2 Practical test method of reciprocity characteristics

When evaluating reciprocity, use a high-intensity test and a low intensity test with the radiation level of the lower intensity test set to 1/10 or less than the high intensity test. The lower intensity tests will require proportionally longer test times. To help reduce the time required for a reciprocity evaluation, it may be useful to use relatively small amounts of density losses and colour balance changes (e.g. 5 % or 10 %)[6][7].

Annex B
(informative)

Relative spectral transmittance of filters

Table B.1 — Relative spectral transmittance of L-37 filter

Wavelength nm	Transmittance %	Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
300	0,0	470	90,4	640	90,7
305	0,0	475	90,5	645	90,7
310	0,0	480	90,4	650	90,8
315	0,0	485	90,6	655	90,8
320	0,0	490	90,5	660	90,8
325	0,0	495	90,5	665	90,8
330	0,0	500	90,7	670	90,7
335	0,0	505	90,5	675	90,9
340	0,0	510	90,6	680	91,0
345	0,0	515	90,5	685	90,9
350	0,0	520	90,5	690	91,0
355	1,0	525	90,5	695	91,2
360	6,6	530	90,6	700	91,0
365	20,7	535	90,6	705	91,0
370	37,0	540	90,6	710	91,0
375	52,6	545	90,6	715	91,1
380	63,6	550	90,7	720	91,0
385	72,0	555	90,6	725	91,2
390	77,4	560	90,6	730	91,1
395	81,4	565	90,7	735	91,2
400	84,1	570	90,6	740	91,1
405	86,0	575	90,7	745	91,1
410	87,1	580	90,7	750	91,4
415	88,2	585	90,5	755	91,1
420	88,7	590	90,6	760	91,3
425	89,2	595	90,7	765	91,2
430	89,5	600	90,5	770	91,3
435	89,7	605	90,5	775	91,5
440	89,9	610	90,7	780	91,1
445	90,1	615	90,7	785	91,0
450	90,1	620	90,6	790	91,5
455	90,1	625	90,7	795	91,3
460	90,4	630	90,7	800	91,2
465	90,3	635	90,8		

Table B.2 — Relative spectral transmittance of SC-37 filter

Wavelength nm	Transmittance %	Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
300	0,0	470	92,1	640	92,3
305	0,0	475	92,1	645	92,3
310	0,0	480	92,1	650	92,4
315	0,0	485	92,2	655	92,5
320	0,0	490	92,2	660	92,4
325	0,0	495	92,2	665	92,5
330	0,0	500	92,3	670	92,4
335	0,1	505	92,2	675	92,5
340	0,1	510	92,2	680	92,6
345	0,4	515	92,2	685	92,5
350	1,5	520	92,2	690	92,5
355	5,0	525	92,2	695	92,7
360	12,7	530	92,3	700	92,5
365	26,7	535	92,3	705	92,5
370	42,5	540	92,2	710	92,6
375	58,8	545	92,3	715	92,6
380	70,5	550	92,2	720	92,6
385	79,0	555	92,2	725	92,7
390	84,3	560	92,3	730	92,6
395	87,5	565	92,3	735	92,8
400	89,3	570	92,3	740	92,7
405	90,4	575	92,4	745	92,8
410	90,8	580	92,2	750	92,7
415	91,3	585	92,2	755	92,5
420	91,5	590	92,4	760	92,6
425	91,7	595	92,2	765	92,8
430	91,7	600	92,2	770	92,7
435	91,9	605	92,3	775	93,2
440	91,8	610	92,3	780	92,5
445	91,9	615	92,3	785	92,5
450	91,9	620	92,2	790	93,1
455	92,0	625	92,4	795	92,9
460	92,0	630	92,3	800	92,7
465	92,0	635	92,4		

Annex C
(informative)

Example of chamber uniformity verification method

The chamber fade uniformity target and the patches in the target shall be the same size as the planned light stability test target and shall contain at least one column of equal value (0,75 % ± 0,05 %) OD (optical print density) patches for each primary colourant of the print systems under test. See the example of chamber fade uniformity target given in Figure C.1.

If the test includes media types that are sensitive to air contamination such as ozone, and temperature and humidity variation, the chamber fade uniformity specimens shall be produced with media that have a similar sensitivity to those factors. A combination of silver halide photo media and dye inkjet on porous photo media can satisfy this requirement. The media types selected shall each be distributed throughout the chamber.

In a chamber with stationary specimens, print materials shall be evenly distributed throughout the exposure zone. In a chamber design in which specimens rotate through the same space, such as a rotating rack style, the print materials shall be distributed such that there are at least three replicates per print material per rotational tier planned for use in the light fade test. For example, two print materials would require 18 total specimens for a three-tier rotating rack style chamber.

The chamber fade uniformity fade exposure cycle shall be conducted in a manner consistent with the planned light stability testing, continuing until reaching an average of (30 % ± 10 %) OD fade in one or more of the primary cyan, magenta, and yellow colourants for each of the two test materials. Measure and compute primary colourant average fade percent for the specimens of each media type at sufficient frequency to ensure capturing the (30 % ± 10 %) OD average fade values for at least one primary for each media. Record and retain specimen location and patch within specimen location with each data record, for use in determining chamber fade uniformity improvements.

Calculation of the chamber fade uniformity shall use the fade data of all of the patches in each primary colourant patch set, for each print material that achieves (30 % ± 10 %) OD average fade. Note that the uniformity of the colourants that do not complete to at least an average 30 % OD fade need not be calculated. For example, if all cyan patches of a print material in the test measure between (14 % to 24 %) OD fade with an average of 17 % OD fade, then the cyan patch set for that print material shall not be included in the uniformity calculation [until further testing of these specimens causes them to reach (30 % ± 10 %) OD average fade]. However, if, for example, the magenta patches on that print material do achieve 23 % OD average fade, then further fading of the cyan patches is not necessary. If the magenta patches measured between (16 % to 25 %) OD fade, then the calculated uniformity is 64 %. Moreover, if the yellow patches on that print material measured 33 % OD average fade, then fade uniformity would also be calculated using the full set of yellow patches on that print material.

Based on the measured results, adjust the specimen area, specimen mounting, specimen rearrangement plan, air flow system, and filter placement to achieve the required chamber fade uniformity, while maintaining all test conditions. Periodic specimen rearrangement may be included to manage fade uniformity. This may include rotation about the exposure zone in flat-bed configurations, moving specimens from tier-to-tier in multi-tier rotating rack configurations, or inverting specimens for single and multi-tier rotating rack configurations.

One method to improve uniformity without changing equipment is simply to reduce the utilized specimen holder light exposure area by reducing the area used by the test specimen print within the specimen holder. For example, eliminate patches near the edges of the bracket or reduce patch size. The patch size shall comply with the required patch size relationship to the planned measurement instrument aperture, as stated in ISO 18944. Continuing with the example above in which the magenta uniformity was calculated to be 64%, if eliminating the outer most patches of the specimen area results in a range of (22 % to 25 %) OD fade, then the uniformity is improved to 88 %.

NOTE 1 Internal chamber reflection can contribute to fade non-uniformity.

NOTE 2 Fast-fade print materials can be used to decrease the time required for the fade uniformity assessment procedure.

NOTE 3 In rack configurations with the filter close to the specimen, airflow configurations that control and direct airflow over the specimens can exhibit excellent uniformity. A small air gap can be effective for maintaining specimen uniformity in configurations with air forced through the specimen filter gap. On the other hand, in configurations that do not control and direct airflow over the specimen, increasing the specimen filter spacing to allow a larger air gap can be effective.

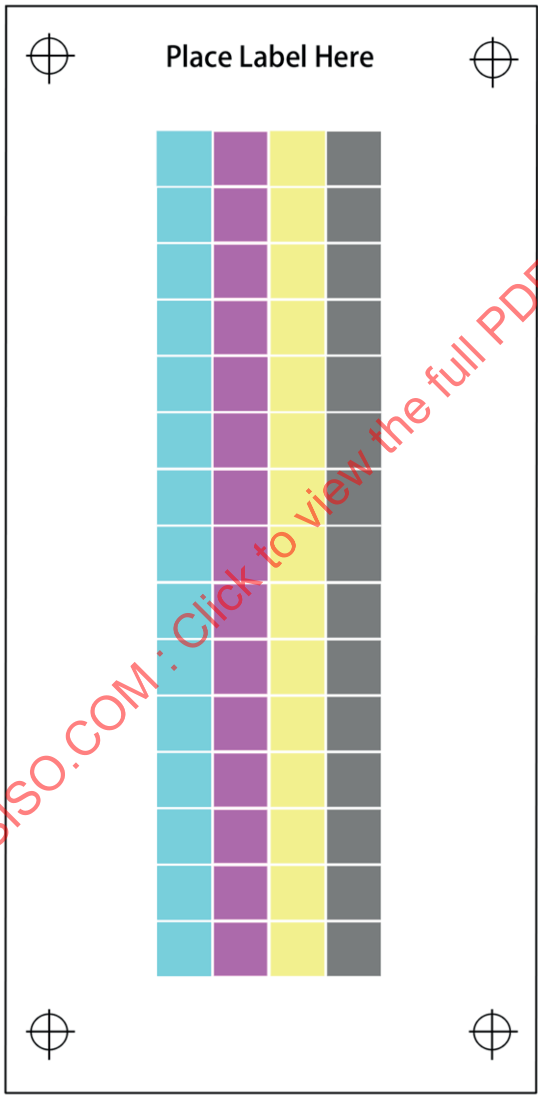

Figure C.1 — Example of chamber fade uniformity test target

The chamber fade uniformity test target patches can be modified as appropriate for the bracket in use and the patch size can be adapted.