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Imaging materials — Methods for measuring indoor light stability of photographic prints —

Part 1: General guidance and requirements

Matériaux pour l'image — Méthodes de mesure de la stabilité de la lumière en intérieur des épreuves photographiques —

Partie 1: Lignes directrices générales et exigences

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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

This document was prepared by Technical Committee ISO/TC 42, *Photography*. This first edition of ISO 18937-1 cancels and replaces the second edition of ISO 18937:2020, which has been technically revised.

The main changes are as follows:

— This revision of the existing ISO 18937 separates the International Standard into three separate parts in a similar way to two other artificial exposure testing series, ISO 4892 (Plastics, in TC 61), and ISO 16474 (Paints and varnishes, in TC 35).

A list of all parts in the ISO 18937 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 document addresses the methods for measuring the indoor light stability of reflection prints, and transparent or translucent films, both colour and monochrome[10][18] to [23][24] to [30].Outdoor light stability is addressed in ISO 18930, with additional background referenced in ISO TR 18945.

This document focuses on general guidance, which includes aspects of the testing that applies to all of the other specific parts, including minimum performance requirements of the instruments used, details of control systems, calibration requirements, test specimen development, and reporting requirements. ISO 18937-2 focuses on exposures using xenon-arc lamps. ISO 18937-3 focuses on exposures using LED lamps. Specific testing requirements based on simulation to the defined use cases and capabilities of the instruments are included in ISO 18937-2 and ISO 18937-3 documents.

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. If display is part of the intended use, knowledge of the lightfastness level of colour photographs is important to manufacturers to improve print materials and to many users to match their display longevity expectations for any given use profile, 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, black and white or colour, 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 — Methods for measuring indoor light stability of photographic prints —

Part 1: General guidance and requirements

1 Scope

This document provides information and general guidance about the methods for measuring the indoor light stability of reflection prints, both colour and monochrome, transparent or translucent films, and photographic prints for backlit displays. This document is relevant to the selection and operation of the methods of exposure to radiation and environmental stress factors described in detail in subsequent parts. It also describes general performance requirements for devices used for exposing printed material to laboratory light sources. Information regarding performance requirements is for producers of artificial accelerated lightfastness devices.

NOTE In this document, the term "light source" refers to radiation sources that emit UV radiation, visible radiation, infrared radiation, or any combination of these types of radiation.

This document does not include test procedures for determining the effects of light exposure on the physical stability of images, supports, or binder materials. However, it is recognized that in some instances, physical degradation such as support embrittlement, image layer cracking, or delamination of an image layer from its support, rather than the stability of the image itself, determines the useful life of a print material.

Print image stability results determined for one printer model, software settings, colorant, and media combination may not be applicable to another combination.

2 Normative references

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

ISO 18913, *Imaging materials — Permanence — Vocabulary*

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 https://www.electropedia.org/

4 Principle

4.1 General

4.1.1 Specimens of the samples to be tested are exposed to laboratory light sources under controlled environmental conditions. The methods described include the requirements for the measurement of the irradiance (or illuminance) and radiation exposure in the plane of the specimen, the temperature of specified black panel sensors, the chamber air temperature, and the relative humidity.

4.1.2 The test methods in this series can be useful as stand-alone methods for comparing the stability of image materials with respect to one specific failure mode. Data from the test methods in this series can be used in stand-alone reporting of the absolute or comparative stability of image materials with respect to the specific failure mode described in this document, when reported in accordance with the reporting requirements of this document.

4.2 Significance

4.2.1 When conducting exposures in devices that use laboratory light sources, it is important to consider how well the accelerated-test conditions simulate the actual-use environment with respect to the light spectrum for the sample being tested. In addition, it is essential to consider the effects of variability in both the accelerated test and actual exposures when setting up experiments and interpreting results from those exposures.

4.2.2 Even though it is very tempting, it is invalid to assign to all materials a "general acceleration factor" relating "*x*" hours, megajoules, or klx-hours of radiant exposure in an artificial accelerated exposure to "*y*" months or years of actual exposure. Such general acceleration factors are invalid for the following reasons.

a) Acceleration factors are material-dependent and can be significantly different for each material and for different formulations of the same material in both actual-use and artificial accelerated exposures.

b) Acceleration factors calculated based on the ratio of irradiance between a laboratory light source and filtered daylight or other illuminations representative for specific indoor use profiles (even when identical passbands are used) do not take into consideration the effects of temperature, moisture, and differences in relative spectral irradiance between the laboratory light source and solar radiation.

NOTE Acceleration factors determined for a specific formulation of a material may be valid, but only if they are based on data from a sufficient number of tests in the end-use environment and artificial accelerated exposures so that results used to relate times to failure in each exposure can be analysed using statistical methods.

4.2.3 There are a number of factors that may decrease the degree of correlation between accelerated tests using laboratory light sources and exposures in end-use conditions:

a) differences in the relative spectral irradiance of the laboratory light source and that representative for the indoor use case;

b) irradiance/illuminance levels higher than those experienced in actual-use conditions;

c) exposure cycles that use continuous exposure to radiation from a laboratory light source without any dark periods;

d) specimen temperatures different than those in actual conditions;

e) exposure conditions that produce unrealistic temperature differences between light- and dark-coloured specimens;

f) unrealistic levels of moisture in the accelerated test compared with actual-use conditions.

4.3 Use of accelerated tests with laboratory light sources

4.3.1 Results from artificial accelerated exposures conducted in accordance with any of the parts of this document are best used to compare the relative performance of materials. Comparisons between materials when tested in different exposure devices must consider variables inherent to the design of those devices. Results can be expressed by comparing the exposure time or radiant exposure necessary to reduce the level of a characteristic property to some specified level. A common application of this is a test conducted to establish that the level of quality of different batches does not vary from that of a control of known performance.

4.3.2 It is strongly recommended that at least one control be exposed with each test for the purpose of comparing the performance of the test materials to that of the control.

NOTE A control would be a material of similar composition and construction to the test material. An example would be when a formulation different from one currently being manufactured for commercial use is being evaluated. In this case, the control would be the material made with the original, or current, formulation.

4.3.3 In some specification tests, properties of test specimens are evaluated after a specific exposure time or radiant exposure using a test cycle with a prescribed set of conditions. Results from any accelerated exposure test conducted in accordance with any of the parts of this document should not be used to make a "pass/fail" decision for materials, based on the level of a specific property after a specific exposure time or radiant exposure, unless the combined reproducibility of the effects of a particular exposure cycle and property measurement method has been established.

4.4 Other limitations

4.4.1 Conversion of data obtained from these methods for the purpose of making public statements regarding product life should be in accordance with the applicable documents for specification of print life.

4.4.2 No accelerated laboratory exposure test can be specified as a total simulation of actual use conditions. Results obtained from 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. Even if results from a specific exposure test conducted in accordance with any of the parts of this document are found to be useful for comparing the relative durability of materials exposed in a particular environment, it cannot be assumed that they will be useful for determining the relative durability of the same materials in a different environment.

4.4.3 Print image stability results from the test methods in those documents, 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, colorant, and media combination should not be applied to another printer model, software settings, colorant, and media combination.

4.5 Safety cautions

In light stability tests, a high irradiance level is used, often with significant UV content. Special care should 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 Requirements for laboratory exposure devices

5.1 Irradiance

5.1.1 Laboratory light sources are used to provide irradiance for the test specimens. In ISO 18937-2, a xenon-arc lamp for use with dedicated optical UV filters is specified and in ISO 18937-3 an LED lamp is specified.

5.1.2 The exposure device should provide holders or space appropriate for placement of specimens and any designated sensing devices in positions that allow uniform irradiance from the radiation source.

5.1.3 Exposure devices should be designed such that the irradiance at any location in the area used for specimen exposures is at least 80 % of the maximum irradiance measured in this area. Procedures for measuring irradiance uniformity by the device manufacturers are given in Annex B.

NOTE The irradiance (illuminance) uniformity in exposure devices depends on several factors, such as the configuration of the lamp with respect to the exposed samples. In addition, irradiance uniformity can be affected by the type of specimen and the number of specimens being exposed.

5.1.4 If the minimum irradiance at any position in the specimen exposure area is between 80 % and 90 % of the maximum irradiance, specimens should be periodically repositioned to reduce the variability in radiant exposure. The repositioning procedure and schedule should be agreed upon by all interested parties.

NOTE There are several possible procedures, including random positioning of replicate specimens, that can be used to reduce the variability in exposure stresses experienced by specimens during exposure. Consult the device manufacturer for guidance.

5.1.5 If the irradiance at any position in the area used for specimen exposure is at least 90 % of the maximum irradiance, it is not necessary to use periodic repositioning of the specimens during exposure to ensure uniform radiant exposure. While periodic repositioning of the specimens is not necessary in this case, it is nevertheless good practice in order to assure that the variability in exposure stresses experienced during the exposure period is kept to the minimum.

NOTE 1 Depending on the specific sensitivity of the material to the exposure stress factors, periodic repositioning of the specimens is good practice to minimize variability of material degradation in replicate specimens. Minimizing variability in exposure stress levels is especially important when the test involves relative comparison of prints made with different printing methods or with different colourant/substrate material combinations.

NOTE 2 Random placement of replicate specimens is also good practice to reduce the effect of any variability in the conditions within the exposure area.

5.1.6 Follow the device manufacturer's instructions for lamp and filter replacement and for any pre-ageing of lamps and/or filters.

5.1.7 General

5.1.7.1 A radiometer for measuring irradiance in a specific wavelength range or a narrow passband that complies with the requirements outlined in ISO 9370 should be used to measure the irradiance, E, or spectral irradiance, E_λ, and the radiant exposure, H, or spectral radiant exposure, H_λ, in the plane of the specimen surface.

5.1.7.2 Alternatively, a radiometer for measuring illuminance that has a spectral response corresponding to the photopic standard luminous efficiency $V(\lambda)$, which is identical to the colour-matching function $y(\lambda)$ specified in ISO 11664-1 should be used to measure the irradiance (illuminance).

In this case, the irradiance (illuminance) is reported in lux and the radiant exposure is reported in lux·hours.

5.1.7.3 The radiometer should be mounted so that it receives the same radiation as the specimen surface. If it is not positioned in the specimen plane, it should have a sufficiently wide field of view and be calibrated for irradiance at the specimen distance. The radiometer should be calibrated using a light source filter combination of the same type that will be used for testing or an appropriate spectral mismatch factor has been taken into account, especially for passband radiometers. The calibration should be checked in accordance with the radiation measuring instrument manufacturer's instructions. A full calibration of the radiometer that is traceable to a recognized radiometric standards body should be conducted at least once per year. More frequent calibrations are recommended.

NOTE 1 ASTM G130[11] provides specific guidance on the calibration of radiometers using spectroradiometers. This method can be used to calibrate the instrument radiometer(s).

NOTE 2 See ISO 9370 for definitions of field and reference radiometers.

NOTE 3 The definition of passbands is found in ISO 9370.

5.1.7.4 When measured, the irradiance in the wavelength range agreed upon by all interested parties should be reported. Some types of device provide sensor(s) for measuring irradiance in a specific wavelength range (e.g. 300 nm to 400 nm or 300 nm to 800 nm), in a narrow passband that is centred around a single wavelength (e.g. 340 nm or 420 nm), or for measuring illuminance (lux).

5.2 Temperature

5.2.1 The surface temperature of exposed materials depends primarily on the amount of radiation absorbed, the thermal emissivity of the specimen at the specimen surface temperature, the amount of thermal conduction within the specimen and the amount of heat transmission between the specimen and the air or between the specimen and the specimen holder. The rate of air flow over the specimen and its sample holders influences the total amount of heat continuously extracted from the specimen (see also 5.3.5 and 5.6.3 for other effects of chamber air flow). Since it is not practical to monitor the surface temperature of individual test specimens, a specified black-panel sensor is used to measure and control the temperature of a representative specimen surface under given exposure conditions. The black surface of the black panel sensor should be measured, controlled, and mounted within the specimen exposure area so that it is in the same plane and orientation and receives the same radiation and experiences the same cooling conditions as a flat test panel surface.

5.2.2 An uninsulated black-panel thermometer should be used as a reference temperature sensor. These panels consist of a plane (flat) metal plate that is resistant to corrosion. Typical dimensions are about 150 mm long, 70 mm wide, and 1 mm thick, but these dimensions may vary depending on the type of exposure apparatus used. The surface of this plate that faces the radiation source should be coated with a black layer which has good resistance to ageing. The coated black plate should reflect no more than 10 % of all incident radiation from the light source, up to 2 500 nm. A thermally sensitive element should be firmly attached to the centre of the exposed surface. This thermally sensitive element can be a black-coated bimetallic dial sensor, a resistance-based sensor, a thermistor or a thermocouple. The back side of the metal panel should be open to the atmosphere.

5.2.3 The temperature indicated by the black-panel thermometer depends on the irradiance produced by the laboratory light source and the temperature and speed of the air moving in the exposure chamber. Black-panel temperatures generally correspond to those for dark coatings on metal panels without thermal insulation on the rear side.

5.2.4 At low irradiance/illuminance levels, the difference between the temperature indicated by a black-panel thermometer and the real specimen temperature may be small. When radiation sources that emit very little infrared radiation are used, there will generally be only very small differences

in the temperatures indicated by the two types of black panel or between light- and dark-coloured specimens.

5.2.5 Chamber air temperature should be measured and controlled. The temperature-sensing element should be shielded from the radiation source. The chamber air temperature measured at this position may not be the same as the chamber air temperature near the surface of the exposed specimens.

5.2.6 Calibrate the temperature sensors used to measure the black panel thermometer and chamber air temperature in accordance with the sensor manufacturer's instructions at least annually.

5.3 Humidity

5.3.1 Devices operated in accordance with any of the parts of this document may have means for providing relative humidity control of the chamber air.

5.3.2 If humidity is provided and controlled, the purity of the water used is important. Without proper treatment to remove cations, anions, organics and silica, exposed specimens will develop spots or stains that do not occur in actual-use exposures. The conductivity of the water used should be less than 5 µS/cm. Testing the water for silica content or organic impurities is also highly recommended.

5.3.3 If specimens are found to have deposits or stains after exposure, the water purity should be checked to determine whether it meets the purity requirements specified in 5.3.2.

5.3.4 All components of the humidification unit should be fabricated from a material that does not contaminate the water with materials that could absorb UV radiation or form unrealistic deposits on test specimens.

5.3.5 If humidity control is required, sensors used to measure humidity should be placed within the chamber air-flow and shielded from direct radiation. Humidity sensors should be calibrated at least annually in accordance with the exposure device manufacturer's instructions.

5.4 Maximum allowable deviations

See Table 1 for maximum allowable deviations from the set points for all controllable parameters.

5.5 Other requirements for the exposure device

5.5.1 Although various designs of exposure device are used in practice, each device should meet the following requirements:

a) Any device intended to simulate the effects of light and dark cycles should have an electronic controller or mechanical device to programme periods with or without radiation.

b) Any device that provides periods during which the exposure conditions are different have means to time each period. The length of each exposure period should be controlled to within ±10 % of the shortest period used. It is desirable to use timers that are as accurate and have as high a repeatability as possible. Optionally, a means to record the length of each test period may also be provided.

5.6 Air quality in the test environment

5.6.1 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, should be ozone free (<2 nl/l average over any 24 h period) for ozone sensitive samples, as determined according to ISO 18941. A material that is not sensitive to ozone should have demonstrated

no measurable D_{min} or printed patch colour change at ambient ozone exposure levels and measurement condition temperature and humidity.

NOTE 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.

5.6.2 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.

5.6.3 If necessary, the apparatus can be fitted with an appropriate filter in the incoming chamber air stream to reduce the ozone concentration levels.

NOTE 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.

6 Test specimens

6.1 Form, shape and preparation

The methods used for the preparation of test specimens can have a significant impact on their apparent durability. Therefore, the method used for specimen preparation should be agreed upon by the interested parties. Label test and control specimens using markings that will not become illegible during the exposure and will not affect the measurement of the desired properties. Do not touch the exposed surfaces of specimens or the optical components of the device with the bare skin because this is likely to transfer oils that may act as UV absorbers or contain contaminants that affect degradation.

6.2 Specimen selection, preparation, mounting, and conditioning

6.2.1 Sufficient replicates of each control and each test material being evaluated are necessary in order to allow statistical evaluation of the results. Unless otherwise specified, use a minimum of two replicates for all test and control materials. Replicates should be located for testing in different regions of the test chamber volume. When material properties are measured using destructive tests, a separate set of specimens is needed for each exposure period.

6.2.2 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 ASTM G156[12] for more information on the definition and use of reference specimens as a means to monitor consistency of conditions in an exposure test.

6.2.3 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 should be reported[6]. Note that use of a backing will reduce the efficiency of backside cooling and therefore increase specimen temperature.

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

6.2.5 For general testing purposes, users of this document are free to choose whatever target, patches and starting densities they feel are appropriate for their testing needs. An example of such a target is included in ISO 18944, along with requirements and recommendations for specimen preparation. Applicable document(s) for specification of print life may require the use of specific targets. Other recommendations for specimen preparation are contained in ISO 18909 and ISO 21139-1. Image prints may also be used. When specific starting densities are desired or required, there cannot be a step on a printed test target that corresponds to the exact 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.

6.2.6 Aqueous and solvent inkjet prints, and prints of any type that require curing/stabilization/dry-down should be conditioned until curing 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 (RH) of (50 ± 5) %. The print conditioning environment should 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 should be maintained with unrestricted airflow. Prints of any types that do not require curing/stabilization/dry-down should be held for at least 24 h. Measurements should be conducted after conditioning or print hold.

7 Test conditions and procedure

7.1 Allowable deviations from the set points

The conditions and procedures for the artificial accelerated exposure depend upon the particular method selected. Refer directly to the appropriate part of ISO 18937. For each exposure test, specific set points for important parameters such as irradiance, temperature and humidity are used. Typically, their parameters are measured and controlled at a single position within the test chamber that is known as the control point. Table 1 lists the maximum allowable deviation from the set point when the exposure device is operating at equilibrium conditions. The 24 h running average of the operational fluctuation, sampled at least every 15 min, should be within the range noted in the below table for each parameter. The running average should not include the test condition transition time which occurs when the test condition is initiated. This transition time should be at most 1 h.

Table 1 — Maximum allowable deviation from exposure condition set points

Set-point parameter	Maximum allowable deviation from the set point at equilibrium	Maximum 24 h deviation from the set point
Irradiance or Illuminance	7 % of set point	4 %
Black-panel temperature	±3 °C	±1 °C
Chamber air temperature	±2 °C	±0,5 °C
Relative humidity	±6 %	±2 %
NOTE A single-point measurement does not mean conditions throughout the exposure chamber are the same. The maximum allowable deviation refers to the operational fluctuation around the set point. It also does not mean two tests run in similar exposure devices will produce the same results.		

7.2 Duration of exposure

The duration of exposures should 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, and

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, and

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.

Intermediate evaluations are recommended in order to better understand varying rates or trends of change of different materials under exposure.

8 Test report

8.1 General reporting requirements

Reporting based solely on this test method should 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 media may have very different results from another. Test reporting should include this disclaimer.

The results of these tests are 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. Data are commonly reported in graph form, with exposure level as the X-axis and densitometric or colorimetric change as the Y-axis. The light source-specific methods do not contain endpoint criteria, and therefore, the measurement results of this test method should not be used independently to estimate or predict any aspect of print image life.

The tests have 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 should 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.

8.2 Light stability reporting requirements

The report of test results should include the following:

a) A reference to this document, i.e. ISO 18937-1:2023;

b) Details of specimen prints, if known. For digital output specimen prints, this should 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 colorant (ink, toner, donor, ribbon, etc.), and

— the media used (manufacturer's name and product name), 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) should also be reported.

In all cases any post-processing treatments that may have been applied to the prints should 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, if necessary) 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 should 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 the evaluation measurement or the material opacity of the backing according to ISO 2471.

i) the amount of densitometric or colorimetric change and cumulative exposure to reach the observed densitometric or colorimetric change

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, it is advisable to 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[15], 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[16][17]. 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[23].

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 Formula (A.1):

$$R_f = \Delta\rho_{\text{low intensity}} / \Delta\rho_{\text{high intensity}} \quad \text{(A.1)}$$

For a specified cumulative exposure.

Reciprocity factors greater than one and less than one have been observed in imaging systems[17][18], which can result in under, and over prediction of the colorant 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[19][30].

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[13][14].

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 may 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 %)[13][14].

Annex B
(informative)

Example of chamber uniformity verification method

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

If the test includes media types that are sensitive to air contamination such as ozone, and temperature and humidity variation, produce chamber fade uniformity specimens 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. Distribute media types selected throughout the chamber.

In a chamber with stationary specimens, distribute print materials evenly throughout the exposure zone. In a chamber design in which specimens rotate through the same space, such as a rotating rack style, distribute print materials 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 3-tier rotating rack style chamber.

Conduct the chamber fade uniformity exposure cycle 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 colorants for each of the two test materials. Measure and compute primary colorant 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.

Calculate the chamber fade uniformity using the fade data of all of the patches in each primary colorant patch set, for each print material, that achieves 30 % ± 10% OD average fade. Note that the uniformity of the colorants 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, do not include the cyan patch set for that print material in the uniformity calculation (until further testing of these specimens causes a 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 % (16/25). 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. Use a patch that complies 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