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

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

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 42, *Photography*.

Introduction

This International Standard addresses the methods and procedures for measuring the indoor light stability of reflection colour photographs.[6][8][9][18]–[23][30]

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 might not be known at the outset. Knowledge of the useful life of colour photographs is important to many users, especially since stability requirements can vary depending upon the application.

The images of most modern analog and digitally-printed colour photographs are made up of cyan, magenta, yellow, red, green, blue, orange, black, gray, 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 can form and physical degradation might 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. The quality of any chemical processing is another important factor. Post-processing treatments and, in the case of digitally generated photographs, post-production treatments, such as application of lacquers, plastic laminates, and retouching colours, also can affect the stability of colour materials.

The light stability of colour photographs is influenced primarily by the intensity of the illumination, the duration of exposure to light, the spectral distribution of the illumination, 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 plastic layers such as the pigmented polyethylene layer of RC (resin-coated) paper supports.

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 desired amount of image fading (or staining). The temperature of the sample prints and their moisture content needs to be controlled throughout the test period, and the types of light sources need to 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 might 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, which can diffuse into a photograph’s image-containing layers from the surrounding atmosphere, can be restricted in an accelerated test (dry gelatine, for example, is an excellent oxygen barrier). This can change the rate of colourant fading relative to the fading that would occur under normal display conditions. The magnitude of reciprocity failure can also be influenced by the temperature and moisture content of the test sample prints. Furthermore, light fading can 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 International Standard describes test equipment and procedures for measuring the light stability of images of colour photographic reflection prints designed for display in, for example, houses, apartments, other dwelling places, offices and commercial display, when subjected to certain illuminants at specified temperatures and relative humidities. This International Standard also addresses colour photographic reflection prints designed for display in galleries and museums.

Indoor illumination conditions described in this International Standard include a) simulated indoor daylight typical home display, b) simulated direct sunlight in-window display, c) fluorescent illumination using “cool white”, and d) other types of illumination sources, such as other fluorescent lamps, tungsten halogen, LED, OLED and metal halide lamps.

This International Standard is applicable to reflection colour prints made with colour hardcopy materials. Included are inkjet prints, thermal dye diffusion transfer (“dye-sub”) prints, liquid- and dry-toner electrophotographic prints, prints made with traditional chromogenic (“silver-halide”) photographic colour materials and, in general, all types of colour prints made with direct analog and digital print processes. The recommended evaluation methods can also be applied to black-and-white photographic prints.

This International Standard 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, will determine the useful life of a print material.

Print image stability results determined for one printer model, software settings, colourant and media combination might not be applicable to image prints produced through another printer model, software settings, colourant and media combination.

2 Normative references

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

ISO 5-3, *Photography and graphic technology — Density measurements — Part 3: Spectral conditions*

ISO 5-4, *Photography and graphic technology — Density measurements — Part 4: Geometric conditions for reflection density*

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 4892-2, *Plastics — Methods of exposure to laboratory light sources — Part 2: Xenon-arc lamps*

ISO 9370, *Plastics — Instrumental determination of radiant exposure in weathering tests — General guidance and basic test method*

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

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

ISO 18913, *Imaging materials — Permanence — Vocabulary*

ISO/TR 18931, *Imaging materials — Recommendations for humidity measurement and control*

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*

CIE S 023/E:2013, *Characterization of the Performance of Illuminance Meters and Luminance Meters*

ASTM G113, *Standard Terminology Relating to Natural and Artificial Weathering Tests of Nonmetallic Materials*

ASTM G151, *Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources*

3 Terms and definitions

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

NOTE In any case where the terms and definitions are duplicated with ISO 18913, the following terms and definitions take precedence for the use of this International Standard.

3.1
operational control point
set point for equilibrium conditions measured at one or more sensor locations in an exposure device

[SOURCE: ASTM G 113-09, 3.2]

3.2
operational fluctuations
positive and negative deviations from the setting of the sensor at the operational control set point during equilibrium conditions in a laboratory accelerated weathering device

[SOURCE: ASTM G 113-09, 3.3]

Note 1 to entry: Operational fluctuations are the result of unavoidable machine variables and do not include measurement uncertainty. Operational fluctuations apply only at the location of the control sensor and do not imply uniformity of conditions throughout the test chamber.

3.3
operational uniformity
range around the operational control point for measured parameters within the intended exposure area within the limits of the intended operational range

[SOURCE: ASTM G 113-09, 3.6]

Note 1 to entry: Operational uniformity evaluates the measured parameters throughout the volume of a test chamber so that regions of the test chamber volume can be determined to comply within the required stated limits of the measured parameter operating aim.

3.4
uncertainty of measurement
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could be reasonably attributed to the measurement

Note 1 to entry: The parameter might be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated confidence level.

Note 2 to entry: Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. The other components, which can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

Note 3 to entry: It is understood that the result of the measurement is the best estimate of the value of the measurement, and that all components of uncertainty, including those arising from systematic effects, such as components associated with corrections and reference standards, contribute to the dispersion.

[SOURCE: ASTM G 113 and ISO Guide 98-3:2008, 2.2.3]

4 Requirements

This International Standard 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 International Standards for specification of print life.

The test methods in this International Standard may be useful as stand-alone test methods for comparison of the stability of image materials with respect to one specific failure mode. Data from the test methods of this International Standard may be used in stand-alone reporting of the absolute or comparative stability of image materials with respect to the specific failure mode dealt with in this International Standard, when reported in compliance with the reporting requirements of this International Standard. Caution shall be used when comparing test results for different materials. Comparisons shall be limited to test cases using equipment with matching specifications and matching test conditions.

The test procedures contained within this standard allow for the use of a variety of light source and filter combinations. Test results obtained using different test conditions, such as different light sources and filters, shall not be compared. Materials under test can be expected to behave quite differently as a result of different relative spectral power distributions of the flux incident on the specimen.

5 Test methods — General

5.1 Safety precautions

In light stability tests, high intensity illumination 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 Acceleration and reciprocity issues

The sample prints to be tested are exposed to laboratory light sources under controlled environmental conditions.

Commonly employed accelerated methods of testing light stability, for both photographic digital hardcopy materials and for traditional analog photographic materials, are based on the concept that increasing the light intensity should produce a proportional increase in the photochemical reactions that occur during typical viewing or display conditions, without introducing any undesirable side effects.

However, because of “reciprocity failures” that might be present in high-intensity accelerated light fading tests with imaging materials, this assumption may not always apply (i.e. a material might fade, change colour balance, or stain a different amount when exposed to high-intensity illumination for a short period than it does when exposed to lower-intensity illumination for a longer period, even though the spectral distribution, the total light exposure [intensity × time], the temperature, and the relative humidity are the same in both cases.)[12]–[17][24]

In general, the closer accelerated test conditions are to actual use conditions, the more meaningful the test results become.

For further discussion of approaches to evaluating reciprocity behaviour in the light-induced fading, changes in colour balance, and stain formation in imaging materials, see Annex A.

5.3 Catalytic fade issues

Catalytic fade is the process by which a given colourant can fade faster (or slower) when in contact with another colourant as a result of an image area containing more than just one of the colourants. It can also occur when other components in the imaging system act as catalysts. Because this process often involves photocatalysis, it can show a dependency on the nature of the light source as well as the light absorption characteristics of the additional colourant, UV absorbing materials, intentionally-added radical quenchers and other components.[31]

Because of these complex interactions, catalytic fade and the resulting nonlinearities can confound predictions of colour fading rates for real-world images.

5.4 Light intensity control

The light intensity shall be maintained and controlled throughout testing with an operational fluctuation within ± 7 % of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±4 % of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h.

5.5 Spectral power distribution

This International Standard references the use of different light sources for accelerated tests with the intention of reproducing as closely as possible different end-use lighting conditions.[25][26] However, no accelerated laboratory exposure test can be specified as a total simulation of actual use conditions. Results obtained from these laboratory accelerated exposures may be considered as representative of actual use exposures only when the degree of 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 spectra power distribution and intensity), relative humidity, temperature, pollutants, such as ozone, and other factors.

Light sources referenced in this International Standard include filtered xenon-arc, fluorescent, tungsten halogen, LED or OLED (and others). Each of these can be useful to simulate the various existing lighting conditions found in different environments. It shall be recognized that these different light sources emit different spectral power distributions (SPDs). The combination of different SPDs from these light sources and associated material sensitivities will significantly impact test results. As a result, test results of replicate sample prints using different light sources shall not be compared to each other.

It is essential to consider the effects of variability in accelerated tests when conducting exposure experiments and when interpreting the results from these tests. Sources of variability include sample-to-sample, measurement instrument repeatability/reproducibility, and exposure zone uniformity. It is recommended the user expose replicate sample prints to understand and mitigate the variability of exposures.

5.6 Humidity control

5.6.1 Humidity control calibration

The test chamber relative humidity control shall be calibrated for measurement accuracy and control by using a chilled mirror hygrometer or other type of measurement device calibrated and traceable to a national standards bureau suitably responsible for certifying reference weights and measures. The calibration shall include the full temperature and relative humidity ranges that are to be used in the ensuing test processes. A check of the calibration shall be performed when there is any indication of sensor failure. Ongoing use of redundant sensors is recommended so that sensor integrity can be ascertained. Details of humidity calibration and control methods are described in ISO/TR 18931.

5.6.2 Humidity control

The preferred relative humidity of the air circulating the test chamber shall be 50 % relative humidity (RH). Other levels may be used, such as 30 % and 70 %, where such levels reflect actual product use conditions. In all cases the relative humidity test conditions shall be reported.[29]

NOTE 1 The relative humidity of the sample surface is essentially controlled at the aim value; however, it is not practicable to measure the humidity of the air of the sample surface. It is estimated that the relative humidity difference between the sample surface and the circulating air is not significant, even if the temperature of the sample surface is higher than that of circulating air, according to estimation supposing that the chemical potential of water molecules are equal at the sample surface and the circulating air at the equilibrium state. Water chemical potential of vapour is an increasing function of the partial vapour pressure. On the other hand, it is a decreasing function of temperature at a constant pressure, due to the fact that the derivative of the chemical potential is equal to a negative value (i.e. molar entropy with the opposite sign). Therefore it is qualitatively clear that the increase in the water chemical potential in the blowing air as caused by the decreased air temperature compared to the sample temperature can be compensated by the lower relative humidity of the circulating air. To get numerical predictions, one can utilize the tabulated values of thermophysical properties of water available from NIST.[27]

The specified aim of the relative humidity of the air shall be established for the air temperature of the bulk air in the region of the sample. One approach is to locate the sensor in the region of the sample, however the sensor shall not be directly in the light. Alternatively, based on the temperature offset between the air temperature in the region of the sample and the air temperature next to the humidity sensor, calculate the control percentage RH to achieve the required aim percentage RH at the sample.

NOTE 2 In rotating rack chamber designs, the humidity sensor can be placed behind samples and near the temperature sensor. In flat panel chambers, a small shade can be used in front of the sensor to block the light while not hindering the airflow.

The relative humidity shall be maintained and controlled throughout testing with an operational fluctuation within ± 6 %RH of aim during test periods when the light is on and ± 3 %RH of aim during test periods when the light is off. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ± 2 %RH of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h. Operational uniformity of the equipment at the test conditions shall be evaluated prior to test start and shall be within ± 6 %RH of aim during test periods when the light is on and ± 3 %RH of aim during test periods when the light is off, at a constant air temperature. Regions of the test chamber shall be selected for use to comply with the required operational uniformity conditions. If the running average of the operational fluctuation does not meet the requirement it shall be documented and explained.

5.7 Temperature control

The sample aim temperature shall be within the range of 25°C to 30°C and shall be controlled by configuring the light exposure equipment and its environment to achieve the appropriate black panel temperature (BPT) (uninsulated) or white panel temperature (WPT) according to the procedure described below. The air temperature shall be maintained no lower than 5,0°C below sample temperature. These temperature conditions shall be maintained and controlled throughout testing with an operational fluctuation within ± 2,0°C of aim, and with not more than 3 % of temperature measurements in any 24-h period to exceed this operational fluctuation limit. For the sample temperature as represented by the calibrated BPT (uninsulated) or WPT, the 24-h running average of the operational fluctuation, sampled at least once every 15 min, shall be within ± 1,0°C of the aim value. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h. Operational uniformity of the equipment at the test conditions shall be evaluated prior to test start and shall be within ± 5,0°C of aim during test periods when the light is on and ±2,0°C of the aim value during periods when the light is off. Regions of the test chamber shall be selected such that they comply with the required operational uniformity conditions. If the running average of the operational fluctuation does not meet these requirements, it shall be documented and explained.

NOTE Considerations for the actual choice of the test temperature are dependent on the non-accelerated use case and the capability of the equipment as follows: 25°C might be closer to the non-accelerated use case. However, some test equipment might not be able to meet the temperature and humidity operational requirements at temperatures below 30°C.

BPT (uninsulated) and WPT, whichever is used, shall be constructed in accordance with ISO 4892-1 and ASTM G151, as follows:

- The WPT or BPT (uninsulated) should be mounted on a support within the sample print's exposure area so that it receives the same radiation and experiences the same cooling conditions on all sides as do the test samples.
- The sensor accuracy shall be better than or equal to ±1,0°C throughout the measuring range. The sensor shall be small enough to attach to the panel and shall have a known response throughout the expected temperature range.
- In the case of a black panel, the top (exposed) surface of the panel shall absorb 90 % or greater at all wavelengths from 300 nm to 2500 nm.
- In the case of a white panel, the top (exposed) surface of the panel shall exhibit reflectance of 90 % or greater at all wavelengths between 300 nm and 1 000 nm and 60 % or greater at all wavelengths between 1000 nm and 2500 nm.

The control value of the BPT (uninsulated) or the WPT shall be determined prior to actual use (see Annex C for the temperature calibration procedure) in order to control the sample temperature at the selected sample temperature aim. The actual sample patch temperatures depend on the print materials, the colourant materials and each patch's colour, in addition to the equipment environmental conditions.

For the purpose of calibrating the BPT (uninsulated) or WPT to the sample temperature for use in a light fade test, the average sample temperature shall be the average temperature of a set of 0,75 status A or status T density neutral patches from a set of samples that are printed with print materials and colourant materials representative of the materials that will be tested.

The following temperature calibration procedure shall be used, prior to conducting a light fade test, to determine the control value of the BPT (uninsulated) or WPT, whichever is used, and to verify that sample temperature and air temperature meet the requirements of this International Standard. Additional guidance for sample temperature calibration, calculation, and control is provided in Annex C.

a) Printed temperature calibration test samples that each contain one or more neutral patches with status A or status T density, as appropriate for the material under test, of 0,75 ± 0,10 status A or status T shall be prepared. The neutral patches shall be large enough for the precise temperature measurement; for example 20 mm × 20 mm. A number of temperature calibration test samples shall be printed so that the temperature calibration test samples can be distributed over the volume of the light fade test chamber. When more than one type of print material is planned to be light fade tested, the printed temperature calibration test sample set should include a representative variety of such samples.

   NOTE 1 If the neutral patches of the temperature calibration test samples contain carbon black, the difference in temperature between such neutral patches and other colour patches can be accentuated, with the carbon black being warmer.

b) Temperature calibration test samples shall be placed in the light fade test chamber in accordance with the planned manner of placement to be used in light fade testing. As necessary to approximate the planned distribution of light fade sample materials over the volume of the light fade test chamber, the sample positions not occupied by printed temperature calibration test samples shall be populated with a representative range of materials normally tested.

c) The equipment and its environment shall be configured in an initial configuration according to the planned light fade test process. This may include setting up to achieve a preset BPT (uninsulated) or WPT. The light fade test equipment shall be operated in accordance with the planned light fade test process to expose the temperature calibration test samples.

   NOTE 2 The light exposure equipment is configured and operated in the same manner that will be used for the intended light fade tests. The test unit is warmed up and operationally stabilized according to the manufacturer's recommendations.

d) For the equipment and environment configuration, the temperatures of the one or more 0,75 ± 0,10 status A or status T density patches on each of the samples used for calibration shall be measured under the actual planned light fade test conditions using a flat thin thermometer, such as thermocouple or PT-100 type sensor, attached with removable non-conductive adhesive to the back of the sample patch, a radiation thermometer, or a flat thin thermometer inserted between the colourant layer and the substrate layer of the sample patch.

   NOTE 3 The radiation thermometer is incapable of being used with intervening material between the instrument and the samples.

   NOTE 4 If a sample print has a sample backing, temperature measurement using a thermocouple type sensor attached with removable non-conductive adhesive to the backing layer behind a sample patch will likely be similar to the air temperature rather than the sample face temperature. Alternatively, insert the thermocouple sensor between the sample and the backing.

e) The average sample temperature for the current configuration shall be computed.

f) If the objective is to record the average sample temperature that corresponds to the preset BPT (uninsulated) or WPT and confirm that the temperatures obtained meet the sample temperature and air temperature requirements of this International Standard, then the obtained average sample temperature and air temperature shall be recorded and the temperature calibration procedure ended.

g) If the objective is to obtain a particular average sample temperature and this result was not obtained in the initial configuration, then the equipment and room configuration shall be adjusted as needed to obtain the average sample temperature. The room configuration refers to the configurable components of the chamber and the room environment (the temperature of the air inside or outside of the equipment chamber, the airflow rate inside and outside of the equipment chamber, addition of an IR filter, the irradiance level, etc.) shall be incrementally adjusted to obtain the aim average sample temperature and to ensure that the air temperature and sample temperature are within 5°C of each other.

h) After adjusting the configuration, the manufacturer’s recommendation for equipment stabilization shall be followed before repeating sample temperature measurements. The sample temperature measurements shall be repeated at least once again after the aim sample temperature and required air temperature are achieved.

   NOTE 5 When the light fade chamber is properly controlled, and taking multiple sample measurements, the standard deviation of the sample measurements is expected to be less than 2°C. When the standard deviation of the sample measurement is larger than 2°C, more measurements with more samples can reduce measurement error. If the standard deviation of the sample temperatures cannot be reduced sufficiently, then the chamber does not meet requirements of this International Standard. One mitigation approach is to avoid using certain volume regions of the chamber.

i) The BPT (uninsulated) or the WPT that corresponds to the verified aim average sample temperature and air temperature shall be the control value of the BPT (uninsulated) or the WPT used in actual light exposure tests.

The air temperature test conditions shall be reported. For the measurement of air temperature when the illumination source is in operation, air temperature-sensing equipment shall be shielded from the light source as stipulated in ISO 4892-1 and ISO 4892-2. A practical method for determining the air temperature may be to measure the temperature at the exit of the test chamber, depending on chamber design.

Sample surface temperature should be measured according to the procedures described in Annex C.

5.8 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 samples are made, dried, and measured, should be sufficiently free of these pollutants. In particular, for materials sensitive to ozone, levels of that gas shall be less than 2 nl/l average ozone concentration over any 24 h period. Ozone sensitivity of materials shall be 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 test condition temperature and humidity, over time periods consistent with test time duration.

NOTE 1 nl/l = 1ppb (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.

To ensure that ozone levels meet this requirement either active or passive 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 the minimum during the test. Active monitoring is to be preferred as passive monitoring cannot indicate whether test conditions were valid until the test is completed.

5.9 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 end point 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 end point criteria specified in the applicable International Standards for specification of print life.

This test method does not include test end points to establish test duration. When the end point requirements of a print life specification standard are not applicable to a test and the materials under test are highly stable, such that the materials require a long test period to show a light fade change, it is acceptable to halt the test when a change is reliably detected. A reliable change is considered detected when the test result has progressed beyond the noise of the test system. The smaller of the test result changes: percentage colourant loss, change in colour balance, or change in D_{min}, may be assessed for highly stable materials to determine that a signal can be distinguished from test system noise.

6 Test equipment

6.1 Light source measurements

Light sources shall be measured at the sample plane in terms of illuminance or irradiance. Illuminance (lx) shall be measured with an illuminance meter as specified in CIE S 023. Irradiance (W/m^2) shall be measured with a radiometer as specified in ISO 9370 over a wavelength range from 300 nm to 400 nm, which is effective to monitor the overall light intensity when used with a defined spectral power distribution of this standard."

NOTE Measurement of 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

6.2.1 Xenon arc light exposure equipment

Xenon arc lamp equipment that can achieve the test conditions and the tolerances stipulated in Clause 5 shall be used.[10] Temperature and humidity control equipment shall be used to attain the sample temperatures and the air relative humidity stipulated in this International Standard.

Any configuration of xenon arc light exposure equipment can be used while it achieves the required test conditions and the tolerances. One illustrative configuration with vertical sample holders rotating around a xenon arc lamp is shown in Figure E.1. Other configurations may have fixed horizontal sample holders placed below horizontal xenon arc lamps, or may be constructed using a stand-alone xenon arc unit designed to be placed in a temperature and humidity controlled room.

6.2.2 Fluorescent light exposure equipment

Fluorescent light exposure equipment that can achieve the test conditions and the tolerances stipulated in Clause 5 shall be used. Temperature and humidity control equipment shall be used to attain the sample temperature and the air relative humidity stipulated in this International Standard.

An illustrative example of a fluorescent light fading test unit is shown in Figure E.2.

6.2.3 Equipment with other light sources

Equipment with other light sources shall meet the requirements stipulated in Clause 5. Temperature and humidity control equipment shall be used to attain the sample temperature and the air relative humidity stipulated in this International Standard.

6.3 Specifications for optical filters

6.3.1 General

The spectral power distribution of the test illumination source can be modified by the use of optical filters in order to simulate a particular usage condition. UV filters with cut-off wavelengths below 400 nm are especially important in that context.

To control the sample surface temperature at the desired aim value, it may be required to employ one or more IR filters in order to reduce infrared energy above 800 nm.

Suitable UV cut-off filters and IR filters are described in the following subclauses.

NOTE Ultraviolet radiation is considerably more harmful to some types of pictorial colour hard copy images than it is to others and, therefore, variations in the level (and spectral power distribution) of the ultraviolet radiation in the illumination will affect some materials more than others.

6.3.2 Specifications for “standard” window glass

The window glass specified in some of these tests shall be a soda lime float glass. Spectral transmission characteristics shall conform to the tolerance of Table 1. The typical spectral transmission characteristics of the “standard” window glass are shown in Table D.1.

In order to maintain conformance, the glass shall be cleaned or replaced when it is stained or damaged and it does not conform to the values given in Table 1.

Table 1 — Relative spectral transmittance of standard window glass

Wavelength nm	Relative transmittance	Wavelength nm	Relative transmittance
300 to 315	<0,5	380	80 to 99
320	<3	385	83 to 102
325	3 to 9	390	86 to 105
330	9 to 20	395	87 to 107
335	21 to 35	400 to 475	88 to 109
340	37 to 51	480 to 555	90 to 111
345	53 to 66	565 to 610	88 to 109
350	64 to 79	615 to 645	86 to 106
355	72 to 89	650 to 685	84 to 104
360	78 to 96	690 to 715	82 to 101
365	81 to 100	720 to 740	80 to 98
370	83 to 102	745 to 765	78 to 96
375	82 to 101	770 to 780	76 to 94

NOTE Data are normalized to 100 at 560 nm. An example of the spectral data of standard window glass is shown in Table D.1.

6.3.3 Specifications for standard UV cut-off filter (half cut wavelength of 370 nm to 375 nm) for simulating indoor daylight typical home display

The standard UV cut-off filter with half cut wavelength (λ at T = 50 %) of 370 nm to 375 nm shall be used for simulating indoor daylight typical home display. The standard UV cut-off filter shall meet the spectral transmission characteristics shown in Table 2.

In order to maintain conformance, the filter shall be cleaned or replaced when it is stained or damaged and it does not conform to the values given in Table 2.

NOTE 1 Examples of the UV cut-off filter are L-37 and SC-37. The spectral transmission data for L-37 and SC37 are shown in Table D.2 and Table D.3, respectively.

NOTE 2 When SC-37 filter is used, the general practice is to replace the filter within two months or before it reaches a total exposure of 150 Mlx h.

Table 2 — Transmission characteristics of UV cut-off filter

Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
< 330	<0,5	375	50 to 70
335	<0,7	380	55 to 80
340	<1	385	60 to 80
345	<2	390	>70
350	<5	395	>75
355	<13	400	>80
360	<25	405	>85
365	5 to 37	>410	>85
370	20 to 50		

6.3.4 Specifications for UV filter (half cut wavelength of 402 nm to 414 nm) for protecting prints from exposure to UV radiation with all illumination sources

A polycarbonate plastic filter shall be used as a standard UV filter to simulate the protective effects of plastic or treated glass UV filters placed in front of illumination sources or used as a glazing material for framed and displayed prints and to simulate the effect of diffusers in some fixtures. The spectral transmittance of the standard polycarbonate filter is shown in Table 3. The polycarbonate shall be cleaned or replaced when it is stained or damaged and it does not conform to the values given in Table 3.

Table 3 — Transmission characteristics of the standard polycarbonate filter

Wavelength nm	**Transmittance** %	**Wavelength** nm	**Transmittance** %
<385	<0,5	410	34 to 82
390	<2	415	53 to 89
395	<14	420	69 to 96
400	4 to 47	425 to 650	>77
405	16 to71	>660	>77

NOTE An example of the spectral data of standard polycarbonate filter is shown in Table D.4.

6.3.5 Specifications for IR cut-off filter

An IR filter may be used as needed to meet the sample and surrounding air temperature requirements of this International Standard.

NOTE ISO 105-B02 is recommended as a reference.

6.3.6 Filter configuration

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

Examples of a layout for light sources and filters are shown in Figure F.1 or Figure F.2.

6.4 Chamber fade uniformity

Chamber fade uniformity (CFU) assessment is required to qualify the initial irradiance configuration, sample mounting, air flow configuration, and filter placement configuration with the light stability test conditions (including lamp and filter SPD, light intensity, air quality, temperature and humidity conditions) configured according to the light stability test plan.

The chamber fade uniformity, U_{CF}, between any two locations in the sample plane used for sample print exposure, as indicated by percentage optical density change, shall be at least 80 %; however, a U_{CF} of 85 % or higher is preferred:

$$U_{CF} = \frac{C_{SOC}}{C_{LOC}} \times 100 \qquad (1)$$

where

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

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

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

For chamber fade uniformity testing, the following requirements apply:

Design the sample and equipment configuration that will be used in the light stability testing before evaluating chamber fade uniformity. Each aspect of the sample and equipment configuration including number of samples, size of samples, placement of samples, sample holders, light intensity, filtration, use of refrigeration, percentage RH of the environment, and chamber airflow shall be specified in the design and fixed before beginning the chamber fade uniformity verification.

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 in Annex I.

The chamber fade uniformity samples shall include media types that are sensitive to air contamination such as ozone, and temperature and humidity variation. A combination of silver halide photo media and dye inkjet on porous photo media can satisfy this requirement. The media types selected shall be each distributed throughout the chamber.

In a chamber with stationary samples, print materials shall be evenly distributed to fill all the sample holders planned for use in the light fade test. In a chamber design in which samples 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 samples 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 percentage for the samples 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 sample location and patch within sample 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 samples 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 sample area, sample mounting, sample rearrangement plan, air flow system, and filter placement to achieve the required chamber fade uniformity, while maintaining the required sample temperature. Sample rearrangement, if expected in the light stability test plan, may be included to manage fade uniformity.

One method to improve uniformity without changing equipment is simply to reduce the utilized sample holder light exposure area by reducing the area used by the test sample print within the sample 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 above-mentioned example, in which the magenta uniformity was calculated to be 64 %, if eliminating the outer most patches of the sample area results in a range of 22 % to 25 % OD fade, then the uniformity is improved to 88 %.

With each change in the configuration to improve chamber fade uniformity, the chamber fade uniformity test shall be repeated. If space allows, the chamber fade uniformity samples may be conducted concurrently with a light fade test in a rotating rack style test chamber; however, any patches corresponding to locations outside the required uniformity criteria shall not be used in the analysis of light fade test results.

In general, in chamber configurations using a filter near the sample, non-uniformity due to airflow issues can be reduced by moving the filter away from the sample, to a position near the lamp. Flat panel configurations typically are arranged so that the airflow direction is perpendicular to the sample and the air gap. For this reason, flat panel xenon chambers should be configured to locate the filter near the lamp rather than close to the sample.

The black panel or white panel sensor that is calibrated to indirectly control sample temperature should be configured with airflow conditions identical to the samples. For example, if a filter is located near sample, then a filter should also be located near the temperature sensor so that it experiences the same airflow conditions as the samples.

In a rack configuration, if the in-tier fade measurements meet the required fade uniformity and the overall chamber fade uniformity does not, sample rearrangement from tier to tier several times through the period of the test time can be evaluated to improve overall chamber fade uniformity.

In a single-tier system, if the non-uniformity appears to occur primarily at either the upper or the lower end of the sample holder light exposure area, inverting the test sample target print in the sample holder several times through the period of the test time can be evaluated to improve uniformity.

If any related aspects of the light stability test plan, such as placement and size of samples, number of sample holders, light intensity, filtration or filter placement, use of refrigeration, and chamber airflow, are changed to achieve the required chamber fade uniformity, the temperature calibration procedure of this International Standard shall be repeated to re-establish sample temperature control.

NOTE 1 Internal 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 sample, airflow configurations that control and direct airflow over the samples can exhibit excellent uniformity. A small air gap can be effective for maintaining sample uniformity in configurations with air forced through the sample filter gap. On the other hand, in configurations which do not control and direct airflow over the sample, increasing the sample filter spacing to allow a larger air gap can be ineffective.

7 Illumination specifications

7.1 General

A number of different types of light stability tests are described in this subclause. These tests are intended to simulate common use conditions found in houses, apartments, and other dwelling places, offices, and commercial display, and in gallery and museum display. Selection of the appropriate tests to address specific environments should be based on the conditions of intended use.

7.2 Simulated indoor daylight typical home display

7.2.1 Purpose

This test is intended to simulate common use conditions found in houses, apartments and other dwelling places. In many homes, for example, indirect or direct daylight through window glass is often the principal illumination causing displayed photographs to fade. UV-filtered xenon illumination is found to provide a reasonable match to indirect, window-filtered daylight. [18][34][35]

7.2.2 Filtered xenon arc configuration to simulate typical indoor display conditions

A xenon arc lamp stipulated in 6.2.1 shall be used as the light source. The xenon lamp shall be configured with an UV 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 BPT (uninsulated) or WPT specified in 7.2.5.)

Optical filters shall be positioned according to 6.3.6.

7.2.3 Spectral power distribution (SPD)

The spectral power distribution (SPD) shall conform closely to the Table G.1 or Table G.2 and conform to the tolerances in Table 4 and Table 5.

Table 4 — Relative spectral power distribution for filtered Xe-arc lamp for indoor daylight home display (up to 450nm) normalized at 540 nm to 550 nm

Wavelength nm	**Relative spectral power**	**Wavelength** nm	**Relative spectral power**
<310	<0,2	380 to 390	33 to 56
310 to 320	<0,2	390 to 400	49 to N.D.*
320 to 330	<0,2	400 to 410	59 to 82
330 to 340	<0,5	410 to 420	65 to 85
340 to 350	0 < 1,0	420 to 430	70 to 88
350 to 360	0,2 to 3,0	430 to 440	74 to 90
360 to 370	3,5 to 14	440 to 450	78 to 93
370 to 380	17 to 35		

NOTE The upper limit is not specified for 390 nm to 400 nm, because Xe-arc lamp has a spike in this range.

Table 5 — Relative spectral power distribution for filtered Xe-arc lamp for indoor daylight home display (overall)

Spectral passband λ = wavelength nm	**Energy** %
$310 < \lambda < 340$	0,0 to 0,1
$340 \leqq \lambda < 370$	0,1 to 1,0
$370 \leqq \lambda < 400$	2 to 5
$400 \leqq \lambda < 430$	4 to 8
$430 \leqq \lambda < 800$	86 to 93

7.2.4 Illumination intensity

Illumination intensity shall be less than or equal to 80 klx. The light intensity shall be maintained and controlled throughout testing with an operational fluctuation within ±7 % of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±4 % of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h. If a reciprocity behaviour test is conducted, lower illumination intensity, e.g. 10 % of nominal condition, shall be used (details are described in Annex A).

NOTE Illumination intensity can be measured in irradiance units in place of the stated illuminance units.

7.2.5 Temperature and humidity

The temperature and humidity conditions of 5.6 and 5.7 are required.

7.3 Simulated direct sunlight indoor in-window display

7.3.1 Purpose

This test is intended to simulate direct sunlight indoor in-window display. 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.[14),24)]

7.3.2 Spectral power distribution (SPD)

The SPD shall conform closely to the Table G.3 and conform to the tolerances in Table 6 and Table 7.

Table 6 — Relative spectral power distribution for filtered Xe-arc lamp for indoor daylight home display (up to 450 nm) normalized at 540 nm to 550 nm

Wavelength nm	**Relative spectral power**	**Wavelength** nm	**Relative spectral power**
< 310	<0,9	380 to 390	61 to 69
310 to 320	0,5 < 7	390 to 400	73 to 82
320 to 330	6 < 17	400 to 410	72 to 80
330 to 340	16 < 29	410 to 420	76 to 85
340 to 350	28 to 41	420 to 430	79 to 86
350 to 360	39 to 51	430 to 440	79 to 89
360 to 370	49 to 58	440 to 450	84 to 94
370 to 380	57 to 64	-	-

Table 7 — Relative spectral power distribution for filtered Xe-arc lamp for indoor daylight home display (overall)

Spectral passband λ = wavelength nm	**Energy** %
310 < λ < 340	0,5 to 1,2
340 ≦λ < 370	2,8 to 3,5
370 ≦λ < 400	3 to 5
400 ≦λ < 430	4 to 7
430 ≦λ < 800	83 to 88

7.3.3 Light source and filter

Xenon lamp stipulated in 6.2.1 shall be used as the light source.

The standard window glass defined in 6.3.2 shall be used as the filter. An IR filter may be used in order to achieve lower temperatures, as specified in Table 8.

Optical filters shall be positioned according to 6.3.6.

7.3.4 Illumination intensity, temperature and humidity

Intermittent exposure shall be used for this test.[14),24)] The conditions of illumination and temperature and relative humidity for the light cycle and dark cycle are shown in Table 8. If a reciprocity behaviour test is conducted, lower illumination intensity, e.g. Ten % of nominal condition, shall be used (details are described in Annex A).

Table 8 — Set values for cycling conditions for simulated sunlight indoor in-window display

	Light cycle	Dark cycle
Illumination intensity at the sample plane	less than 100 klx	less than 10 lx
Cycle duration	3,8 h	1,0 h
Air temperature	40°C	25°C
Air relative humidity	40 %RH	80 %RH
BPT (uninsulated)	63°C	

The light intensity shall be maintained and controlled throughout testing with an operational fluctuation within ± 7 % of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ± 4 % of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h.

If a reciprocity behaviour test is conducted, lower illumination intensity, e.g. 10 % of nominal condition, shall be used (details are described in Annex A).

NOTE Illumination intensity can be measured in irradiance units in place of the stated illuminance units.

7.4 Fluorescent illumination using “cool white” fluorescent lamps

7.4.1 Purpose

This test is intended to simulate cool white fluorescent illumination in houses, apartments, and other dwelling places, offices and commercial display.

7.4.2 Light source

“Cool white” fluorescent lamps shall be used for this test. The spectral distribution of cool white lamps shall conform closely to that given in Annex H and shall conform to the tolerance in Table 9.

Table 9 — Relative spectral power distribution for F-6 cool white fluorescent lamps

Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power
300	<1	465	92 to 112	630	111 to 136
305	<1	470	93 to 114	635	96 to 117
310	6 to 24	475	94 to 115	640	82 to 100
315	14 to 54	480	94 to 115	645	70 to 85

Table 9 *(continued)*

Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power
320	<1	485	94 to 115	650	60 to 73
325	<1	490	94 to 115	655	51 to 62
330	<1	495	92 to 112	660	43 to 53
335	<5	500	90 to 110	665	37 to 45
340	<1	505	89 to 109	670	32 to 39
345	<2	510	89 to 108	675	27 to 33
350	<2	515	90 to 110	680	23 to 28
355	<4	520	95 to 116	685	20 to 24
360	10 to 12	525	102 to 125	690	18 to 23
365	50 to 168	530	114 to 139	695	15 to 18
370	26 to 60	535	130 to 159	700	13 to 16
375	13 to 16	540	150 to 184	705	12 to 14
380	15 to 18	545	284 to 636	710	10 to 12
385	19 to 23	550	263 to 305	715	9 to 11
390	23 to 29	555	224 to 274	720	<9
395	27 to 33	560	247 to 302	725	<8
400	45 to 54	565	266 to 325	730	<8
405	143 to 422	570	278 to 340	735	<8
410	49 to 60	575	330 to 390	740	<7
415	47 to 58	580	338 to 424	745	<6
420	53 to 64	585	278 to 340	750	<7
425	58 to 71	590	266 to 325	755	<6
430	64 to 78	595	250 to 305	760	<7
435	295 to 968	600	231 to 282	765	<7
440	129 to 255	605	210 to 256	770	<6
445	79 to 96	610	188 to 230	775	<5
450	83 to 101	615	167 to 205	780	<4
455	86 to 106	620	147 to 180		-
460	90 to 109	625	128 to 157		-

The oldest one-half of the lamps shall be replaced after each 2 000 h of test equipment operation.

NOTE The spectral power distributions of other types of fluorescent light sources might not correspond to cool white fluorescent due to differences in phosphors, etc.

7.4.3 Filters

In this test method, a window glass filter stipulated in 6.3.2 is the standard filtration condition. In addition to window glass filtration, users of this International Standard may also conduct tests with a polycarbonate filter stipulated in 6.3.4 to simulate the use of plastic or treated glass UV absorbing filters with the illumination source or as a UV-absorbing glazing material for framed prints and to simulate some fixtures of ceiling mounted equipment with metal or plastic diffuser plates. Users of this International Standard may also conduct tests with “bare-bulb” exposure with no filter in place to simulate direct exposure to the illumination from bare-bulb fluorescent lamps where no glass or plastic diffuser is used with the fluorescent lamps and when displayed prints are not protected with glass or plastic glazing.

Optical filters shall be positioned according to 6.3.6.

7.4.4 Illumination intensity

Illumination intensity shall be less than or equal to 80 klx. The light intensity shall be maintained and controlled throughout testing with an operational fluctuation within ±7 % of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±4 % of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h.

If a reciprocity behaviour test is conducted, lower illumination intensity, e.g. 10 % of nominal condition, shall be used (details are described in A.2).

NOTE Illumination intensity can be measured in irradiance units in place of the stated illuminance units.

7.4.5 Temperature and humidity

The temperature and humidity conditions of 5.6 and 5.7 are required.

7.5 Other light sources

7.5.1 Purpose

These tests are intended to simulate use conditions found in houses, apartments and other dwelling places, in offices, commercial display, and in galley and museum display where prints are illuminated with multiple phosphor fluorescent lamps with improved colour rendering characteristics and energy efficiency, compact fluorescent bulbs, tungsten-halogen lamps, LED lamps, halogen discharge lamps, and other types of illumination technologies.

7.5.2 Spectral power distribution

The relative SPD (250 nm to 800nm) shall be measured and reported, accurate to within 5 % at each 5 nm value, so as to permit other users of this International Standard to reproduce the result.

7.5.3 Filters

Various types of filters (e.g. window glass, polycarbonate, and acrylic UV filters) may be used to simulate specific user conditions.

Optical filters shall be positioned according to 6.3.6.

7.5.4 Illumination intensity

A sample-plane illumination intensity shall be less than or equal to 80 klx. The light intensity shall be maintained and controlled throughout testing with an operational fluctuation within ±7 % of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±2 % of aim. The running average shall not include the test condition transition time which occurs when the test condition is initiated. This transition time shall be at most 1 h.

If a reciprocity behaviour test is conducted, lower illumination intensity, e.g. 10 % of nominal condition, shall be used (details are described in A.2).

NOTE Illumination intensity can be measured in irradiance units in place of the stated illuminance units.

7.5.5 Temperature and humidity

The temperature and humidity conditions of 5.6 and 5.7 are required.

8 Sample preparation

8.1 Samples

8.1.1 Use of replicates and reference samples

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 samples 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).

8.1.2 Backing of test sample prints during light stability tests

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 aluminium or stainless steel plate) to ensure dimensional stability. If a backing material is used, it shall be reported (as specified in ISO 2471).

8.1.3 Setting of dummy samples for the open space

In a light exposure chamber, all sample positions shall be filled with samples (or with dummy samples which are equivalent in average density or reflectance to the actual test samples) for both light exposure tests and for the calibration of light and temperature/humidity.

8.2 Sample preparation

8.2.1 Test target design and format

For general testing purposes, users of this International Standard 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 sample preparation. Applicable International Standards for specification of print life may require the use of specific standard targets. Other recommendations for sample preparation are given in ISO 18909. Prints with pictorial or other images may also be used.

8.2.2 Processing of traditional photographic materials

The exposed test sample prints shall be processed using the processing system of primary interest and in accordance with the manufacturer's recommendations.

The processing chemicals and processing procedure can have a significant effect on the dark-keeping and light-keeping stability of a colour photographic material. For example, a chromogenic ("silver-halide") colour negative print paper processed in a "washless" or "non-plumbed" system with a stabilizer rinse bath instead of a water wash can have stability characteristics that are different from the same colour paper processed in a "traditional" chemistry and a final water wash. Therefore, the specific processing chemicals and procedure shall be listed along with the name of the colour product in any reference to the test results.

Stability data obtained from a colour material processed in certain processing chemicals shall not be applied to the colour material processed in different chemicals, or using a different processing procedure.

8.2.3 Conditioning the prints after printing

Aqueous and solvent inkjet prints, and prints of any type that require curing/stabilization/dry-down shall be conditioned for two weeks after printing, in an environment with a temperature of (23 ± 2) °C, with a RH 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 Measurements and calculations

9.1 Holding and measurement conditions

The measurement environment and sample holding environment can influence measured densities. Measurements and sample holding for measurement and next test phase preparation shall be conducted in a controlled environment with no time constraint or may be conducted in a less controlled environment with a time constraint.

NOTE 1 Sample holding environment refers to the environment in which sample prints are held in-between test phases, such as before and after measurement, while the sample prints are not in the active test environment.

The controlled sample holding environment with no time constraint shall meet the following set of conditions: Sample prints shall be kept in dark, (23 ± 2)°C, (50 ± 10) %RH conditions while waiting for measurement and while holding between test stages.

The controlled sample holding environment shall be ozone-free (≤2 nl/l average concentration over any 24 h period) for ozone sensitive sample prints. Ozone sensitivity shall be 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, over time periods consistent with measurement and test staging time periods.

The controlled measurement environment with no measurement process time constraint shall meet the following set of conditions: ambient illuminance on the sample print surface no greater than 200 lx, temperature (23 ± 2)°C, humidity (50 ± 10)%RH, and ozone-free (≤2 nl/l average concentration over any 24 h period) for ozone sensitive samples.

NOTE 2 One way to comply with the requirement for the ozone free condition is to use humidified environmental chambers which rely on the air of the laboratory to have an average ozone concentration of ≤ 2 nl/l over any 24 h test period. An alternative method is to use humidified environmental chambers which themselves can maintain an average ozone concentration of ≤ 2 nl/l over any 24 h test period.

When sample holding or measurement are conducted in the less controlled environment, sample prints shall be held or measured in the less controlled environment for a maximum of 2 h for each test stage. The less controlled environment may be unfiltered for ozone, and shall have a maximum RH of 75 % RH and a maximum temperature of 30°C, with ambient illuminance on the sample print's surface less than or equal to 1 000 lx.

NOTE 3 Stray light decreases the accuracy of measurements taken in less controlled lighting environments. Shielding the measurement instrument from direct lighting so that the actual measurement surface lighting is no more than 200 lx can improve measurement accuracy and repeatability.

The temperature and humidity tolerances for the sample holding and measurement environments apply specifically to the vicinities in which the samples are held and measured. Operational fluctuations, operational uniformity, and uncertainty of measurement shall be contained within the stated tolerances in those vicinities.

Measurement environment and sample holding conditions, if differing from those specified with respect to temperature, relative humidity, ozone, and light levels, fluctuations, and uniformity, shall be reported in the test report.

The CIELAB colour space values of the D_{min} patch, i.e. unprinted paper patch, shall be obtained from measurements using ISO 13655 measurement condition M0 for the relative spectral power distribution of the flux incident on the sample print's surface. In accordance with the M0 illuminant, the relative spectral power distribution of the flux incident on the sample print's surface shall conform to CIE illuminant A (corresponding to a distribution temperature of 2 856 K ± 100 K). The metamerism index of the M0 light source used in the measurements, comparing with CIE illuminant A (corresponding to a distribution temperature of 2 856 K), shall be equal or less than 1,5.

NOTE 4 Measurement condition M0 is used for the relative spectral power distribution of the flux incident on the sample print's surface. Instruments conforming to M1 are not generally available at the time of publication of this International Standard. Image permanence measurement deals primarily with relative data and image permanence test results do not rely on visual matching in a corresponding viewing environment.

White backing is recommended in accordance with ISO 13655. Report the backing used or report the material opacity, in accordance with ISO 2471, such that backing has no influence on the measurement. Measurement conditions shall be consistent throughout the test process.

NOTE 5 With completely opaque materials, such as the aluminium substrate used in outdoor testing, the backing has no relevance.

Conforming to ISO 13655, calculated tristimulus values and corresponding CIELAB values shall be computed using CIE illuminant D50 and the CIE 1931 standard colourimetric observer (often referred to as the 2° standard observer).

Optical densities of the colourant patches shall be measured in accordance with ISO 5-3, with the relative spectral power distribution of the flux incident on the sample print's surface conforming to CIE illuminant A (corresponding to a correlated colour temperature of 2 856 K). The tolerance of the colour temperature is 2 856 K ± 100 K. A UV-cut filter shall not be used. Spectral products conforming to status A or status T density shall be formed as appropriate for the material under test. Use standard reflection density as defined in ISO 5-4, allowing either annular influx mode or annular efflux mode. White backing is recommended as noted in ISO 5-4, particularly for measurements of spectral data used to compute both density and colourimetry. Either white or black backing is allowed. Report the backing used. Measurement conditions shall be consistent throughout the test process (as specified in ISO 2471).

NOTE 6 When testing in accordance with an image life specification standard, either standard status A or status T density is selected according to that specification standard.

A single measurement instrument shall be used for all of the measurements taken pertaining to a particular test. For example, initial patch values of a test target print and subsequent degraded patch values of that particular test target print shall be measured using the same measurement instrument. Replicate prints may be measured on separate measurement instruments as long as each is consistently measured on the same instrument used for its initial readings. According to best practice, in the case of equipment failure, the test should be invalidated. A replacement instrument with a known offset, determined for the test measurement conditions and materials being measured, may be used when the original instrument is not available. In this case all measurements shall be corrected with the known offset.

NOTE 7 It is useful to retain freezer check print samples of the measurement materials so that instrument offsets can be measured if needed. Offset measurements from materials matched to those under test are preferred to measurements using British Ceramic Research Association (BCRA) tiles. For cold storage methods, see ISO 18920.

9.2 Attributes to be measured

9.2.1 General

Any change in density, contrast, or stain, whether due to colourant fading, changes in colourant morphology, or discolouration of residual substances, can change the appearance of a photograph.

With many materials exposed to light during display, the most damaging change tends to be colour balance distortions brought about by differential fading of the image colourants. These manifest themselves as shifts in colour balance from highlights to shadows that are especially noticeable in a scale of neutrals; e.g. a shift from magenta to green due to fading of the photograph's magenta image colourant, or from yellow to blue or cyan to red due to fading of the yellow or cyan colourant.

Also important are changes that can be caused by an increase in stain. The result could simply be a discolouration of the D_{min} areas or a change in the D_{min} colour balance.

9.2.2 Density attributes to be measured

d is the symbol for measured density. D_{min} density is included; no correction for changes of D_{min} during exposure shall be applied.

The following status A or status T densities of the sample prints shall be measured before and after the treatment interval.

a) $d\mathrm{N(R)_t}$, $d\mathrm{N(G)_t}$, $d\mathrm{N(B)_t}$

the red, green and blue status A or status T densities of neutral patches that have been treated for time t, where t takes on values from 0 (zero) to the end of the test;

b) $d\mathrm{C(R)_t}$, $d\mathrm{M(G)_t}$, $d\mathrm{Y(B)_t}$

the red, green and blue status A or status T densities of cyan, magenta and yellow colour patches that have been treated for time t, where t takes on values from 0 to the end of the test,

c) $d\mathrm{R(G)_t}$, $d\mathrm{R(B)_t}$, $d\mathrm{G(R)_t}$, $d\mathrm{G(B)_t}$, $d\mathrm{B(R)_t}$, $d\mathrm{B(G)_t}$,

the red, green and blue status A or status T densities of the composite secondary R, G, B colour patches that have been treated for time t, where t takes on values from 0 to the end of the test.

9.2.3 Definitions of colourimetry terms

L^* is CIELAB lightness, a^* and b^* are the CIELAB a^* and b^* coordinates, respectively, as defined in ISO 11664-4.

9.2.4 Colourimetry values to be measured

The following colourimetry values of the sample prints, prepared according to the sample preparation, testing, and measurement condition requirements of this International Standard shall be measured before and after the treatment interval.

L^*_{t}, a^*_{t}, b^*_{t}

The lightness, red-green, and blue-yellow colour coordinates for the unprinted areas of sample prints (paper white), which have been treated for time t, where t takes on values from 0 to the end of the test.

9.3 Calculations and computations

9.3.1 Computation of densitometric attributes

Calculations for 9.3.2 to 9.3.7 shall be performed for selected patches with a range of initial densities.

9.3.2 Density change in d_{min} patches

a) Red density change: $\Delta d_{\mathrm{min}}(\mathrm{R})_{\mathrm{t}} = d_{\mathrm{min}}(\mathrm{R})_{\mathrm{t}} - d_{\mathrm{min}}(\mathrm{R})_0$

b) Green density change: $\Delta d_{\mathrm{min}}(\mathrm{G})_{\mathrm{t}} = d_{\mathrm{min}}(\mathrm{G})_{\mathrm{t}} - d_{\mathrm{min}}(\mathrm{G})_0$

c) Blue density change: $\Delta d_{\mathrm{min}}(\mathrm{B})_{\mathrm{t}} = d_{\mathrm{min}}(\mathrm{B})_{\mathrm{t}} - d_{\mathrm{min}}(\mathrm{B})_0$

9.3.3 Percent density change in primary colour patches

a) Cyan patch: $\%\Delta dC(R)_t = [(dC(R)_t - dC(R)_0) \div dC(R)_0] \times 100$

b) Magenta patch: $\%\Delta dM(G)_t = [(dM(G)_t - dM(G)_0) \div dM(G)_0] \times 100$

c) Yellow patch: $\%\Delta dY(B)_t = [(dY(B)_t - dY(B)_0) \div dY(B)_0] \times 100$

9.3.4 Percent density change in secondary (mixed) colour patches

a) Magenta in red patch: $\%\Delta dR(G)_t = [(dR(G)_t - dR(G)_0) \div dR(G)_0] \times 100$

b) Yellow in red patch: $\%\Delta dR(B)_t = [(dR(B)_t - dR(B)_0) \div dR(B)_0] \times 100$

c) Cyan in green patch: $\%\Delta dG(R)_t = [(dG(R)_t - dG(R)_0) \div dG(R)_0] \times 100$

d) Yellow in green patch: $\%\Delta dG(B)_t = [(dG(B)_t - dG(B)_0) \div dG(B)_0] \times 100$

e) Cyan in blue patch: $\%\Delta dB(R)_t = [(dB(R)_t - dB(R)_0) \div dB(R)_0] \times 100$

f) Magenta in blue patch: $\%\Delta dB(G)_t = [(dB(G)_t - dB(G)_0) \div dB(G)_0] \times 100$

9.3.5 Percent density change in composite neutral patch

a) Cyan in neutral patch: $\%\Delta dN(R)_t = [(dN(R)_t - dN(R)_0) \div dN(R)_0] \times 100$

b) Magenta in neutral patch: $\%\Delta dN(G)_t = [(dN(G)_t - dN(G)_0) \div dN(G)_0] \times 100$

c) Yellow in neutral patch: $\%\Delta dN(B)_t = [(dN(B)_t - dN(B)_0) \div dN(B)_0] \times 100$

9.3.6 Colour balance shift in composite neutral patch

Contrast and colour balance distortions brought about by differential fading of the image colourants can result in significant visually degrading effects. These can be measured as shifts in colour balance from highlights to shadows and are especially noticeable in a scale of neutrals; for example a shift from magenta to green due to fading of the photograph's magenta image colourant, or from yellow to blue or cyan to red due to fading of the yellow or cyan colourant.

Neutral colour balance shift is calculated as the difference in percentage change between any two primary colours of a neutral patch. (The percentage change of individual primary colours in a neutral patch is defined in 9.3.5.)

a) Cyan-magenta shift: $\%\Delta dN(R\text{-}G)_t = |\%\Delta dN(R)_t - \%\Delta dN(G)_t|$

b) Magenta-yellow shift: $\%\Delta dN(G\text{-}B)_t = |\%\Delta dN(G)_t - \%\Delta dN(B)_t|$

c) Yellow-cyan shift: $\%\Delta dN(B\text{-}R)_t = |\%\Delta dN(B)_t - \%\Delta dN(R)_t|$

9.3.7 Colour balance shift in secondary (mixed) colour patches

Secondary colour balance shift is calculated as the difference in percentage change between the two primary colours of each secondary colour patch. (The percentage change of the individual primary colours in each secondary colour patch is defined in 9.3.4.)

a) Cyan-magenta shift in blue patch: $\%\Delta dB(R\text{-}G)_t = |\%\Delta dB(R)_t - \%\Delta dB(G)_t|$

b) Magenta-yellow shift in red patch: $\%\Delta dR(G\text{-}B)_t = |\%\Delta dR(G)_t - \%\Delta dR(B)_t|$

c) Yellow-cyan shift in green patch: $\%\Delta dG(B\text{-}R)_t = |\%\Delta dG(B)_t - \%\Delta dG(R)_t|$

9.3.8 Colour balance in d_{min} patches by colourimetry

Colour balance in the d_{min} patches is calculated using Formula (3):

$$\Delta E^*_{\mathrm{ab}} = \sqrt{(L_{\mathrm{t}}^* - L_0^*)^2 + (a_{\mathrm{t}}^* - a_0^*)^2 + (b_{\mathrm{t}}^* - b_0^*)^2} \qquad (3)$$

where L^*, a^*, and b^* are the colour coordinates of the d_{min} patch at the initial time 0 and at time t, as defined by ISO 11664-4.

10 Test report

The requirements of this clause supersede statements of reporting in other clauses of this International Standard.

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 inkset used with a specific paper have very different results from another. Test reporting shall include this disclaimer.

The results of these tests are reported as the amount of densitometric or colourimetric change observed for a given cumulative exposure [lx h (or lx·hour)], or cumulative exposure to reach the observed densitometric or colourimetric change.

The report of test results shall include the following.

a) A reference to this International Standard, i.e. ISO 18937.

b) Details of sample prints. For digital output sample prints, the printer model, printer driver version, printer driver settings, printer front panel settings, the name of the host application used in generating the print, and the colour controls selected in that application; the cartridge configuration/ink/donor or colourant used (manufacturer's name and part number); 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 International Standard. For silver-halide based sample prints, the processing conditions (i.e. chemicals, procedures). In all cases, any post-processing treatments that could have been applied to the prints.

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 sample prints included in the test.

d) The test method (the light source and the filtration) and test conditions (light intensity, aim value of sample temperature, BPT (uninsulated) or WPT, air temperature, relative humidity). If the actual test conditions deviate from the nominal conditions specified in this International Standard then an explanation shall be provided. If alternative illuminants such as those described in 7.5 are used, the spectral characteristics of the illuminant shall be specified in sufficient detail, explicitly or by reference, so as to permit other users of this International Standard to reproduce the result.

e) A statement as to whether or not a backing material was used behind the sample print in the test (if a backing material was used, specify its characteristics).

f) The duration of the test, including the extent and level to which the test was conducted.

   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.

g) Measurement environment and sample holding conditions, temperature, relative humidity, ozone, and light levels, fluctuations, and uniformity, if they differ from the stipulated conditions.

h) The backing used during measurement or the material opacity in accordance with ISO 2471.

In cases where results from the testing methods of this International Standard are cited in part (such as a paper appearing in a technical journal or a product reference sheet), there shall be a reference to an easily accessible source (such as an Internet website) that supplies information and data, which meets the complete reporting requirements detailed above (in this clause).

Annex A
(informative)

Evaluation of light stability reciprocity behaviour

A.1 General

It can be important for the user to know how well products track for light degradation at high intensities versus lower intensities. This would be important, for example, if the user was going to make predictions of performance at ambient light levels based on tests at the higher light levels of accelerated testing. An assumption of reciprocal behaviour, or adherence to the reciprocity law, may not be a valid assumption.

The reciprocity law was originally proposed in 1862 by Bunsen and Roscoe (Bunsen-Roscoe reciprocity law). 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 International Standard, 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 sample 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.[19]

A reciprocity factor is defined as the ratio of the change in density at low intensity, $\rho_{\text{low intensity}}$, to the change in density at high intensity, $\rho_{\text{high intensity}}$, with both intensities run to a common cumulative exposure, as provided by Formula (A.1):

$$R_{\text{f}} = \Delta\rho_{\text{low intensity}} : \Delta\rho_{\text{high intensity}} \tag{A.1}$$

for a specified cumulative exposure.

Reciprocity factors greater than one and less than one have been observed in imaging systems,[19][20] 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 dark 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][36]

If reciprocity failure is still noted after double checking for confounding factors, 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]

IMPORTANT — 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 illumination 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)

Method for interpolation

Often there will 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 may be used to predict the values for the exact desired starting density. For example, the densities of the two steps nearest to 1,0 may be used to calculate the desired density by linear interpolation. After each fading time, the same coefficient is used for interpolating the density after fading.

Firstly, on the unfaded strip, the step with the density d_1 just below 1,0 and the step with the density d_2 just above 1,0 are chosen (see Figure B.1). After fading, these two steps will have reached the densities $d_1(t)$ and $d_2(t)$. The density $d(t)$ of the initial d = 1,0 is then estimated through linear interpolation:

$$d_{\mathrm{t}} = d_{1(\mathrm{t})} + [d_{2(\mathrm{t})} - d_{1(\mathrm{t})}]\alpha \tag{B.1}$$

where

$$\alpha = \frac{1{,}0 - d_{1(\mathrm{t}=0)}}{d_{2(\mathrm{t}=0)} - d_{1(\mathrm{t}=0)}} \tag{B.2}$$

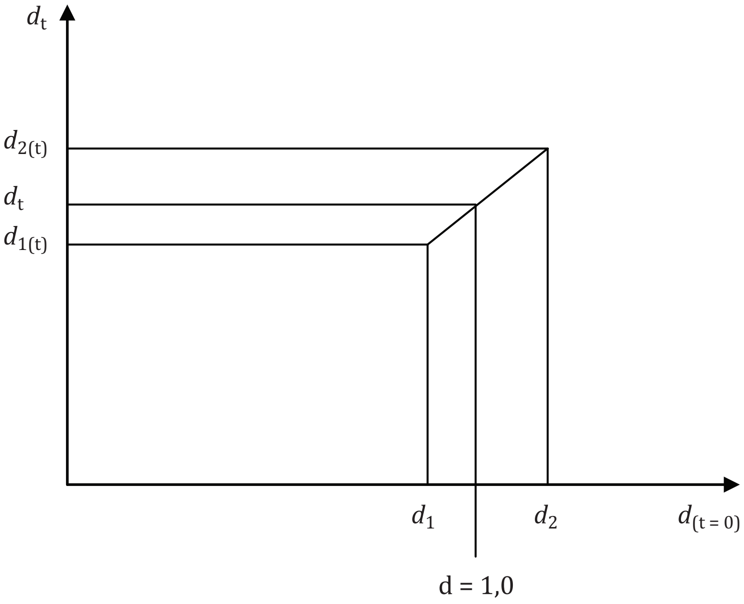


Figure B.1 — Interpolation of a test target starting density patch

Annex C
(informative)

Procedure to calibrate the temperature relationship between the test sample prints and the control set point of the black panel or white panel used to control temperature in a light stability testchamber or test room

C.1 Principle

In a light stability test chamber a calibrated relationship between the temperatures of the actual sample prints and the control set point temperature for the black panel or white panel is required as the basis for overall temperature control in the chamber.

NOTE The specific differential between a BP or WP and sample temperature can change and affect temperature related light stability results each time the sample and equipment configuration is changed.

C.2 Equipment and preparation

The following equipment and setup are required for the calibration procedure in addition to the instruments and features of the light stability test chamber and its typical setup:

C.2.1 Five or more movable and qualified temperature sensors, with removable non-conductive adhesive used to attach the sensors as needed.

Two sensors will be used for the BP/WP temperature measurement and one will be used for the air temperature measurement. If it is feasible in the equipment to extract the built-in equipment BP/WP temperature or air temperature sensor readings to a spreadsheet then reduce the number of additional sensors needed accordingly.

EXAMPLE Examples of temperature-measurement equipment are type T thermocouple, using two-point calibration with respect to chilled mirror hygrometer (RTD) and digi-sense 12-channel scanning thermocouple thermometer used to capture data.

Temperature sensors are to be qualified by determining the temperature sensor uncertainty. Use the following procedure to qualify temperature sensors.

a) Use the adhesive to attach all of the temperature sensors to be used in the test on the BP or WP of the equipment as close together as possible.

b) Turn light source off.

c) Operate the equipment (with light source off) until it reaches steady-state before beginning to take measurements. Disable rack rotation if this is a feature of the equipment.

d) Record the WP/BP temperature readings no less frequently than every 15 s, continue collecting readings for at least 10 min.

e) Analyse the data collected to ensure that the temperature readings are all within a 0,2 °C range of each other.

f) Recalibrate or discard any sensor that does not fit the required uncertainty bounds.

g) Repeat until the full set of sensors that will be used conforms.

C.2.2 Data collection mechanism, to collect the sensor readings from the five or more temperature sensors used in this measurement procedure and convey the sensor readings to a spreadsheet application or similar analysis program.

NOTE To understand additional details regarding the sources of variability in temperature measurement in light stability testing, see ASTM G113.

C.3 Procedure

C.3.1 Step 1: design the sample and equipment configuration that will be used in the light stability testing for which the calibration result of this procedure is intended. Each aspect of the sample and equipment configuration including number of samples, size of samples, placement of samples, sample holders, light intensity, filtration, use of refrigeration, percentage relative humidity of the environment, and chamber airflow shall be specified in the design and fixed before beginning the calibration procedure. A sample and equipment configuration includes the design of the patch layout. A sample and equipment configuration may or may not include constraining the media and ink types. Samples should not be planned to be located near the incoming air stream to the chamber, as the incoming air might be colder than the bulk chamber air temperature.

- Consult the equipment/light source supplier to determine how frequently to conduct this procedure for a given sample and equipment configuration. This will depend on the light and filter aging characteristics of the equipment.
- Consider redoing this procedure after any recalibration of the light or temperature sensors in the equipment.
- During the operation of the light stability testing for which the calibration result of this procedure is intended, keep the number and placement of samples consistent with the sample and equipment configuration of the calibration by using extra non-test (i.e. “dummy”) samples when actual test samples do not fill chamber.

C.3.2 Step 2: prepare the sample and equipment configuration.

a) Print the samples required according to the sample and equipment configuration design. Each sample shall contain the target design, i.e. patch layout, size, and OD, to be used in the light stability testing for which the calibration result of this procedure is intended. The target design shall contain at least a white patch and a gray patch with a density of 0,75 OD ± 0,1 OD. The patch size of the design shall be sufficient so that the temperature sensors to be used can be placed on the back of a single patch. Dry the samples according to the standard light stability test procedure.

   If the light stability testing for which the calibration result of this procedure is intended will test a variety of ink and media combinations, calibration results may be improved by including an equal number of samples representing each type of ink and media system that will eventually be tested.

b) Set the air temperature operational control set point, and airflow operational control set point if controllable, to an initial value according to the sample temperature operational control set point and the sample and equipment configuration design.

   1) Initially chamber airflow rate, if adjustable, should be set to 1-3 m/s at the sample.

   2) After adjustment as needed for temperature calibration, hold chamber airflow consistently for a given air temperature operational control set point and illumination intensity control set point.

   3) Measure chamber air temperature out of direct line of sight of the light source, but within the chamber.

   NOTE 1 Xenon sample temperature is typically 3 °C to4 °C above air temperature at 80 klx and 2 m/s airflow.

c) Set the relative humidity operational control set point according to the sample and equipment configuration design.

   Chamber humidity sensor should be measured out of direct line of sight of the light source, but within the chamber so that it measures the humidity near the sample.

   NOTE 2 Humidity sensors not within the chamber might not be at the same temperature and therefore can measure a different relative humidity than the relative humidity of air near the samples.

d) Position the BP or WP of the equipment if this option is available.

   Chamber black panel or white panel sensor should be located at the same distance from light source as the test samples. The sensor should be insulated to prevent conduction with the mounting so as to better mimic test samples, which are not conductive.

e) Place all of the samples into the equipment according to the sample and equipment configuration design.

NOTE 3 Varying sample position, patch size, etc. can influence the temperature.

C.3.3 Step 3: measure and collect temperature data for the combined operational uniformity and operational fluctuation of control of the sample and equipment configuration.

a) Configure retrieval of measurements from the equipment BP/WP temperature sensors if data output is available.

   1) Alternatively, using the adhesive, attach two temporary temperature sensors on the BP/WP. Locate the temperature sensors on the panel facing the light source on either side of the panel sensor.

   2) Configure retrieval of measurements from the temporary BP/WP temperature sensor or built-in BP/WP sensor into the data collection mechanism used to convey the sensor readings to a spreadsheet or similar analysis program.

NOTE 1 Temporary sensors are used when it is not feasible to extract the built-in equipment BP/WP sensor readings to a spreadsheet.

b) Configure retrieval of measurements from the equipment air temperature sensor if data output is available.

   1) Alternatively, using the adhesive, attach a small conductive thermal mass (e.g. a couple grams, such as a metal washer 10 mm to 12 mm in diameter) to a temperature sensor and dangle it hanging in the vicinity of the sample that will be used to measure sample temperature. The air temperature sensor shall not be in direct line of sight with the light source and air flow should not be obstructed in its vicinity. The air temperature sensor should be near the relative humidity sensor.

   2) Configure retrieval of measurements from the temporary air temperature sensor or built-in air sensor into the data collection mechanism used to convey the sensor readings to a Microsoft Excel spreadsheet or similar analysis program.

   NOTE 2 Temporary sensors are used when it is not feasible to extract the built-in equipment air temperature sensor readings to a spreadsheet.

c) Set the illumination intensity operational control set point according to the sample and equipment configuration design.

d) Place two temperature sensors on a single sample. Place one sensor contacting the back of a white patch, and one sensor contacting the back of a gray patch that has a density of 0,75 OD ± 0,1 OD. Disable rack rotation if this is a feature of the equipment. Select a sample location that is moderate with respect to the light source and the airflow vents. As closely as possible, position the sensor in contact with the back of the sample to be within the area of a single patch.

Configure retrieval of measurements from the sample temperature sensors into the data collection mechanism used to convey the sensor readings to an excel spreadsheet or similar analysis program.

If additional pairs of temperature sensors are available, place each pair on another sample located in another part of the chamber volume. Select alternative patches of different colours or densities if such are available in the target design.

e) Operate the equipment until it reaches steady-state before beginning to take measurements.

f) Record the two sample temperature readings, the configured WP/BP sensor temperature readings, and the configured air temperature readings, no less frequently than every 15 s; continue collecting readings for at least 10 min.

During the first iteration, if the built-in equipment BP/WP sensor is limited to manual reading, manually record the built-in equipment BP/WP sensor readings. As closely as possible, record the temporary BP/WP and equipment BP/WP temperature readings on the same time interval.

g) Repeat steps d), e) and f), placing the two sample measurement sensors on different samples in different parts of the chamber, until temperature measurements have been collected for the full range of conditions: sample proximity to various localized airflow conditions, sample position in the chamber, patch position in the sample, patch colour, and patch density. In each test iteration, select a sample to test for the effect of: sample proximity to localized airflow, sample position in the chamber. Select the two patches in the selected sample to test for the effects of: patch position in the sample, patch colour, and patch density. Ensure that the full set of samples' temperature measurements is evenly distributed over the range of conditions. If a variety of sample print types (ink and media combinations) is included in the samples to be tested, then include measurements of those samples in the data collected. Include measurements of patch densities over the range of paper white to 0,75OD ± 0,1OD for each of the hue colour groups contained in the target design.

NOTE 4 For example, if the target design contains various hue colour groups and patch densities, the balance of the measurement data are improved if the same number of measurements is taken from each.

C.3.4 Step 4: prepare the measurement data for analysis.

a) For each time recording of a configured pair of sample temperature readings of the same sample, average the two sample temperature readings [t_{ji} = (first t_{ji} + second t_{ji}) divided by 2] .

b) For each time recording of the configured pair of WP/BP temporary sensor temperature readings, average the two WP/BP temperature readings [p_i = (first p_i + second p_i) divided by 2].

c) For each time recording, record b_i, the ith time built-in equipment BP/WP sensor reading. If the built-in equipment BP/WP sensor readings are taken manually, the number of readings will be less than n due to manual recording only in the first iteration.

C.3.5 Step 5: determine the statistics of the sample and equipment configuration.

a) Determine the "mean WP/BP temperatures", "mean samples temperature" and "mean samples temperature to WP/BP difference" due to operational uniformity and fluctuation of control, using the statistical sample mean equation:

$$\overline{B_u}=\sum_{i=1}^{n^*}\frac{[b_i]}{n^*}\text{ , }\overline{P_u}=\sum_{i=1}^{n}\frac{[p_i]}{n}\text{ , }\overline{T_u}=\sum_{j=1,i=1}^{m,v}\frac{[t_{ji}]}{n}\text{ and }\overline{D_u}=\sum_{j=1,i=1}^{m,v}\frac{ABS[t_{ji}-p_i]}{n} \qquad \text{(C.1)}$$

where

$\overline{P_u}$ and p_i are not required if $\overline{B_u}$ is computed from b_i configured and collected for all n temperature readings ($n = n^*$). If $\overline{B_u}$ is computed from b_i configured and collected for all n temperature readings, then use b_i in the $\overline{D_u}$ equation;

n is the number of temperature readings measured [number of samples measured (m) X number of times at which measurements are taken (v)];

n^* is the number of temperature readings available for the built-in equipment BP/WP sensor;

t_{ji} is the averaged sample temperature reading of jth sample at ith time;

NOTE t_{ji} includes the sample temperature readings across all samples ($j = 1 - m$) over time ($i = 1 - v$);

p_i is the averaged WP/BP temporary sensor temperature readings at each ith time;

b_i built-in equipment BP/WP sensor temperature reading at each ith time;

$\overline{P_u}$ is the mean WP/BP temperature, measured from the temporary sensors;

$\overline{B_u}$ is the mean WP/BP temperature, measured from the built-in equipment BP/WP sensor;

$\overline{T_u}$ is the mean samples temperature, computed from all of the sample measurements;

$\overline{D_u}$ is mean samples temperature to WP/BP difference.

NOTE Each ith difference ABS($t_{ji} - p_i$) or ABS($t_{ji} - b_i$) is calculated using ith temperature readings recorded at the same time.

b) Calculate the standard deviation of the “samples temperature to WP/BP difference”. Calculated using p_i or b_i according to the prior calculation of $\overline{D_u}$.

$$s_u=\sqrt{\sum_{j=1,i=1}^{m,v}\frac{\left(ABS[t_{ji}-p_i]-\overline{D_u}\right)^2}{(n-1)}}$$

using the statistical sample variance equation.

c) Calculate the standard error of the estimated mean, s_{ue}, using the standard deviation. This step checks the quality of the data collected. If the standard error of the estimated mean approaches 10 % of the tolerance interval required for the aim sample temperature, this provides a warning that the mean samples temperature mean is not a reliable indicator.

$$s_{ue}=\frac{s_u}{\sqrt{n}}$$

NOTE 1 If the standard error of the estimated mean indicates a problem, consider increasing the number of samples used in this calibration procedure (i.e. increase n). If a large number of samples has been measured, then consider addressing the inconsistencies in the conditions throughout the test volume in the equipment. For example if “aim” tolerance interval is ±2 °C then 10 % = 0,4 °C.

NOTE 2 Decreasing light intensity will generally decrease the variation in conditions in the test volume in the equipment. Low airflow and very high airflow can be expected to decrease the variation in conditions in the test volume in the equipment. Midrange airflow might contribute to variation in conditions in the test volume in the equipment.

C.3.6 Step 6: determine the set point for the temperature control of the equipment.

a) If ($n > n^*$) and p_i was used in the prior calculation of $\overline{D_u}$, then compare $\overline{P_u}$ (the mean BP/WP temperature, measured from the temporary sensor) to $\overline{B_u}$ (the mean BP/WP temperature, measured from the built-in equipment BP/WP sensor) and compute the plus or minus (±) difference (i.e. tolerance) between these. Record the difference as the BP/WP sensor ‘Adjustment’.

Compute $\overline{D_u}' = \overline{D_u}$ ± “adjustment” so that $\overline{D_u}'$ is the “mean sample temperature to WP/BP difference” referenced to the built-in equipment BP/WP sensor.

b) Determine the correct temperature control setting for the sample and equipment configuration tested.

If ($n > n^*$) and p_i was used in the prior calculation of $\overline{D_u}$:

WP/BP temperature operational control set point = $\pm\, \overline{D_u}'$ + required aim sample temperature. Determine the sign of $\overline{D_u}'$ by comparing $\overline{T_u}$ and $\overline{P_u}$.

For example $\overline{D_u}'$ is negative in the equation if $\overline{T_u} > \overline{P_u}$.

If ($n = n^*$) and b_i was used in the prior calculation of $\overline{D_u}$:

WP/BP Temperature Operational Control Set Point = $\pm\, \overline{D_u}$ + required aim sample temperature.

Determine the sign of $\overline{D_u}$ by comparing $\overline{T_u}$ and $\overline{B_u}$.

For example $\overline{D_u}$ is negative in the equation if $\overline{T_u} > \overline{B_u}$.

c) With the equipment operating at the WP/BP Temperature Operational Control Set Point and the required aim sample temperature, repeat temperature measurements of actual sample temperatures in various locations in the chamber to verify that the operational uniformity behaviour is such that at least 95 % of the time the sample temperatures throughout the chamber are within two standard deviations of the mean $\overline{T_u}$. Hot spot and cold spot regions of the chamber, operating consistently outside of that range, should be eliminated from use.

C.3.7 Step 7: determine the air temperature at the established WP/BP equipment temperature operational control set point.

a) Locate the air temperature sensor near the RH sensor, out of the line of sight of any light source, with unrestricted air flow in its vicinity.

If the built-in air sensor is not located near the RH sensor, using adhesive, attach a small conductive thermal mass (e.g. a couple grams, such as a metal washer 10 mm to 12 mm in diameter) to a temperature sensor and dangle it hanging in the vicinity of the RH sensor. The air temperature sensor shall not be in direct line of sight with the light source and air flow should not be obstructed in its vicinity.

b) Operate the equipment at steady-state according to the WP/BP temperature operational control set point and the designed sample and equipment configuration.

c) Record the air temperature, no less frequently than every 15 s; continue collecting readings for at least 10 min.

d) Compute the mean air temperature:

$$\overline{A} = \sum_{i=1}^{n} \frac{[a_i]}{n} \tag{C.2}$$

C.3.8 Step 8: adjust the relative humidity operational control set point according to $\overline{A}$ so that it corresponds to 50 %RH at the chamber air temperature (e.g. use a relative humidity operational control set point of 47 % at a mean air temperature $\overline{A}$ = 24 °C).

Annex D
(informative)

Relative spectral transmittance of filters

D.1 Standard window glass

Table D.1 — Relative spectral transmittance of standard window glass[10]

Wavelength nm	Relative transmittance	Wavelength nm	Relative transmittance	Wavelength nm	Relative transmittance
300	0,0	475	99,9	650	94,2
305	0,0	480	100,0	655	94,0
310	0,0	485	100,2	660	93,7
315	0,1	490	100,4	665	93,4
320	0,9	495	100,4	670	93,2
325	4,6	500	100,5	675	92,9
330	13, 5	505	100,6	680	92,6
335	27,6	510	100,7	685	92,3
340	43,9	515	100,7	690	92,0
345	59,2	520	100,7	695	91,5
350	71,7	525	100,6	700	91,2
355	80,4	530	100,6	705	90,8
360	86,7	535	100,5	710	90,5
365	90,8	540	100,5	715	90,1
370	92,7	545	100,5	720	89,6
375	91,2	550	100,4	725	89,3
380	89,7	555	100,2	730	88,5
385	92,3	560	100,0	735	88,4
390	95,6	565	99,8	740	87,9
395	97,5	570	99,6	745	87,6
400	98,5	575	99,2	750	87,1
405	98,7	580	98,9	755	86,6
410	98,3	585	98,5	760	86,1
415	97,9	590	98,1	765	85,8
420	97,8	595	97,7	770	85,3
425	97,8	600	97,5	775	84,9
430	97,8	605	97,2	780	84,4
435	97,7	610	96,9		
440	97,7	615	96,6		
445	98,0	620	96,3		

Table D.1 *(continued)*

Wavelength nm	Relative transmittance	Wavelength nm	Relative transmittance	Wavelength nm	Relative transmittance
450	98,4	625	95,9		
455	98,8	630	95,6		
460	99,3	635	95,2		
465	99,6	640	94,9		
470	99,8	645	94,6		
NOTE Data are normalized to 100 at 560 nm.					

D.2 L37 filter

Table D.2 — Relative spectral transmittance of L37 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

Table D.2 *(continued)*

Wavelength nm	Transmittance %	Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
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		

D.3 SC37 filter

Table D.3 — Relative spectral transmittance of SC37 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

Table D.3 *(continued)*

Wavelength nm	Transmittance %	Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
460	92,0	630	92,3	800	92,7
465	92,0	635	92,4		

D.4 Polycarbonate filter

Table D.4 — Relative spectral transmittance of polycarbonate filter

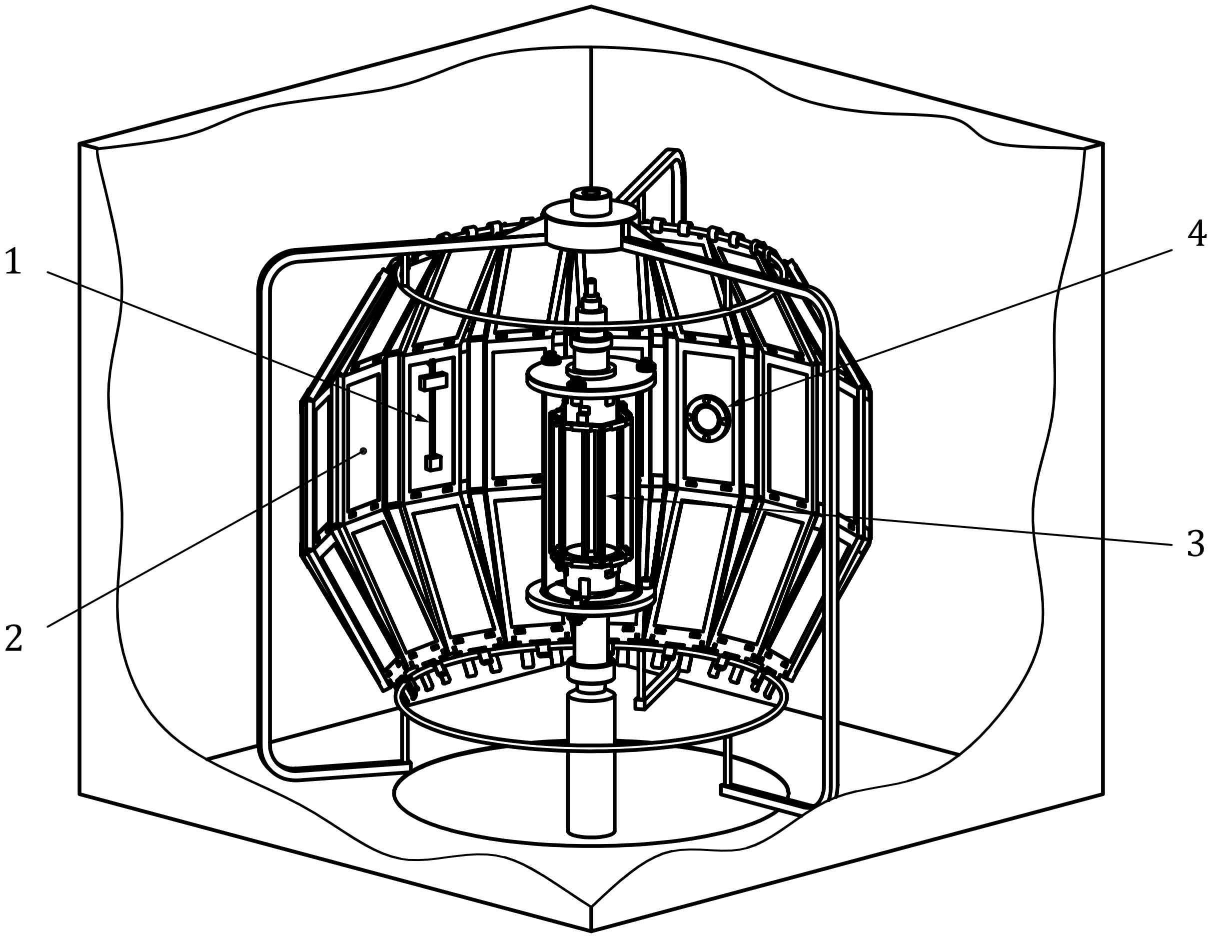
Wavelength nm	Transmittance %	Wavelength nm	Transmittance %	Wavelength nm	Transmittance %
300	0,0	470	85,6	640	86,3
305	0,0	475	85,5	645	86,2
310	0,0	480	85,4	650	86,5
315	0,0	485	85,4	655	86,5
320	0,0	490	85,4	660	85,4
325	0,0	495	85,2	665	82,5
330	0,0	500	85,2	670	78,1
335	0,0	505	85,1	675	75,5
340	0,0	510	84,9	680	76,7
345	0,0	515	84,6	685	80,6
350	0,0	520	84,5	690	84,5
355	0,0	525	84,1	695	87,2
360	0,0	530	84,1	700	88,5
365	0,0	535	83,9	705	89,2
370	0,0	540	83,7	710	89,4
375	0,0	545	83,4	715	89,8
380	0,0	550	83,5	720	90,0
385	0,0	555	83,3	725	90,1
390	0,0	560	83,2	730	90,3
395	1,1	565	83,3	735	90,2
400	13,8	570	83,3	740	90,2
405	40,6	575	83,4	745	90,2
410	63,7	580	83,6	750	90,4
415	75,5	585	83,8	755	90,4
420	80,8	590	83,9	760	90,4
425	83,1	595	84,2	765	90,4
430	84,2	600	83,9	770	90,4
435	84,7	605	83,6	775	90,5
440	85,2	610	83,7	780	90,4
445	85,3	615	84,5	785	90,4
450	85,5	620	85,3	790	90,4
455	85,5	625	85,8	795	90,4
460	85,5	630	86,1	800	90,3
465	85,5	635	86,4		

Annex E
(informative)

Examples of light exposure equipment

E.1 Xenon light exposure equipment

See Figure E.1.



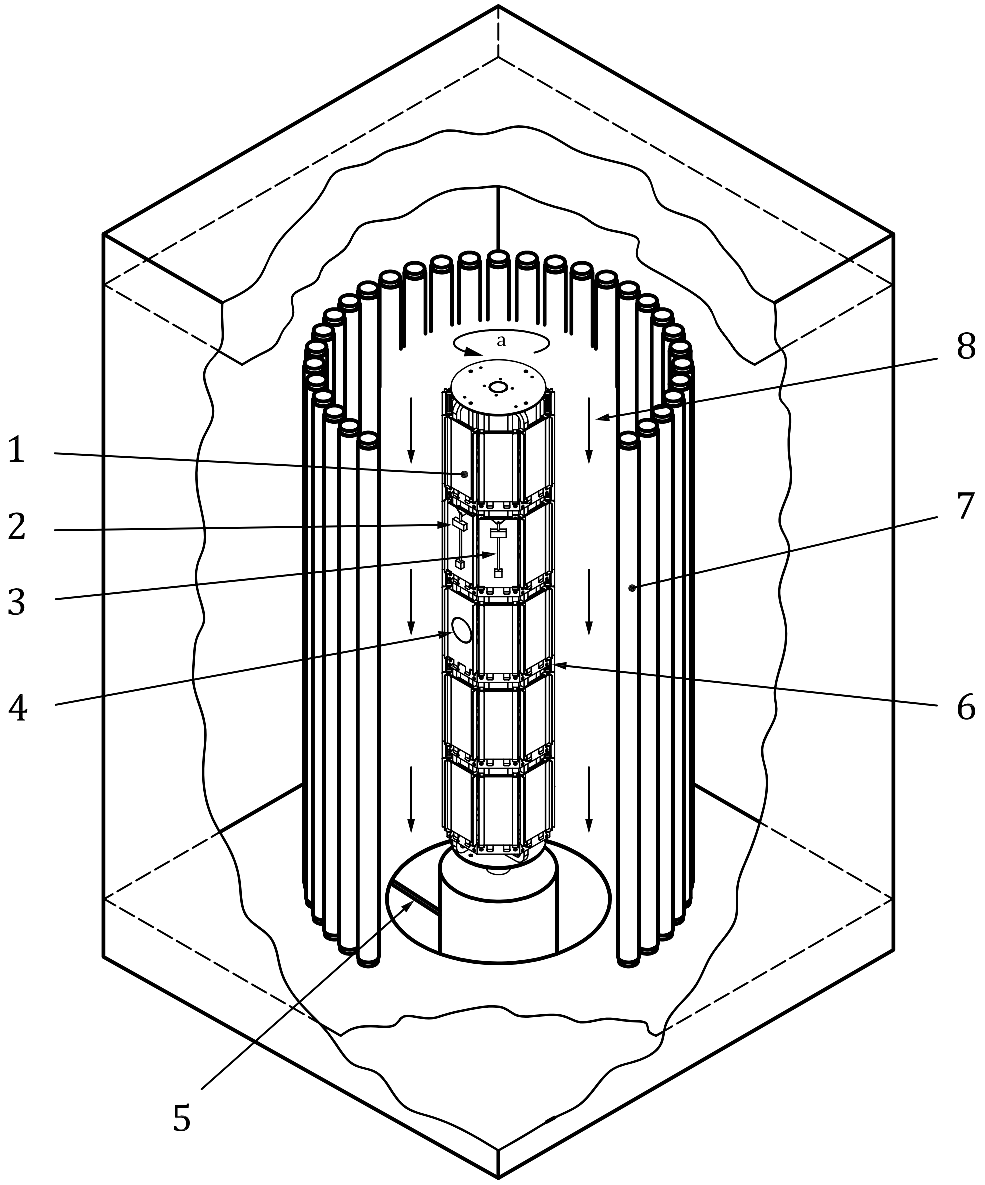
Key

1	black panel thermo sensor or white panel thermo sensor
2	sample prints
3	xenon arc lamp with filters
4	light receptor

Figure E.1 — Example of xenon light exposure equipment

E.2 Fluorescent light exposure equipment

An example of typical chamber and configuration for fluorescent light exposure equipment is shown in Figure E.2.



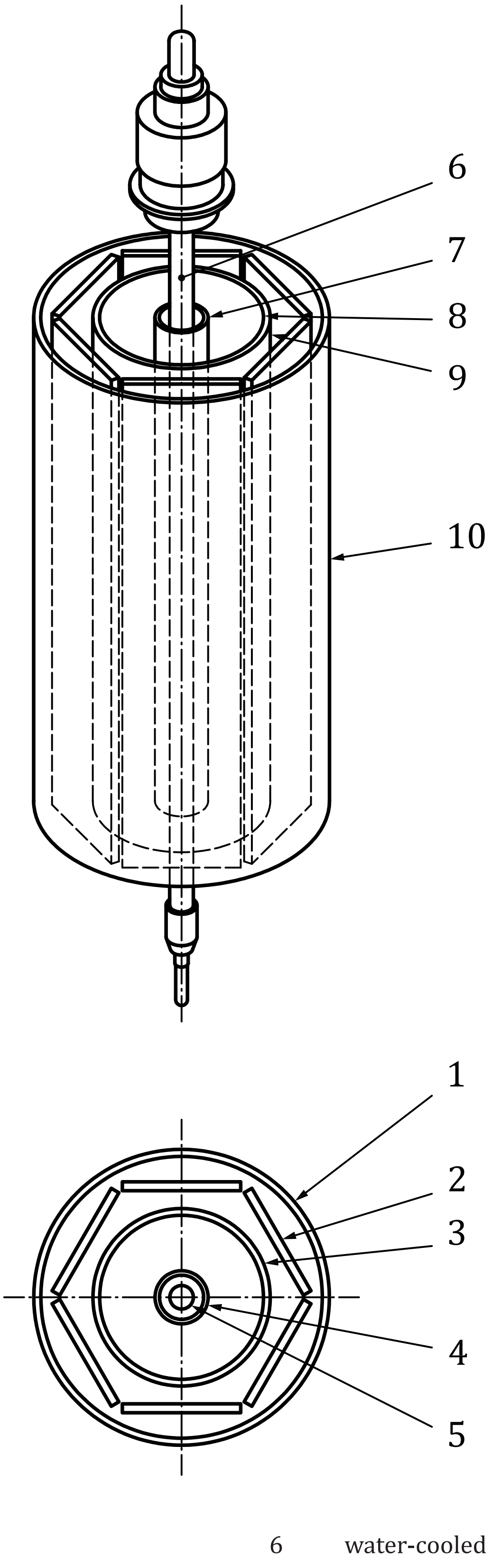
Key

1	specimen
2	black panel thermo sensor
3	white panel thermo sensor
4	photo receptor
5	thermal sensor
6	specimen frame
7	fluorescent lamps (40 pieces)
8	air stream

Figure E.2 — Example of fluorescent test equipment

Annex F
(informative)

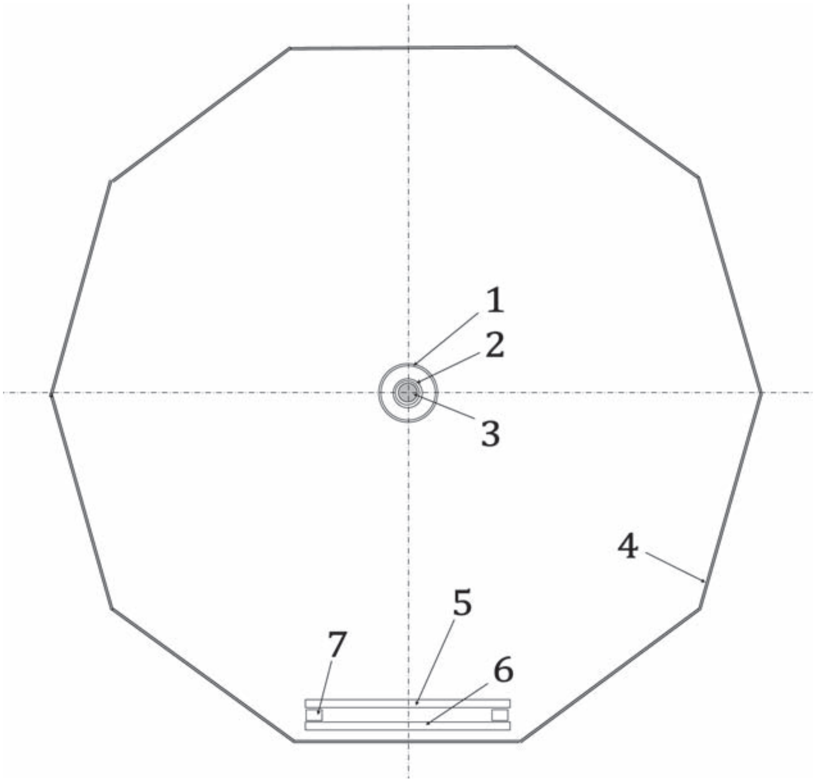
Example of filter configuration



Key

1	outer filter, IRcut	6	water-cooled xenon lamp
2	middle filter, L37	7	inner filter, quartz
3	middle filter, IRcut	8	middle filter, IRcut
4	inner filter, quartz	9	middle filter, L37
5	water-cooled xenon lamp	10	outer filter, IRcut

Figure F.1 — Example of a filter combination of xenon lamp



Key

1	outer filter
2	inner filter
3	xenon lamp
4	rotating rack
5	SC-37 filter
6	specimen
7	space

Figure F.2 — Another example of a filter combination of xenon lamp

Annex G
(informative)

Spectral irradiance for simulated indoor daylight

Table G.1 — Example of relative spectral irradiance for simulated indoor indirect daylight typical home display (xenon lamp with quartz inner filter, L-37 plus IR filters and borosilicate glass outer filter)

Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm
250 to 260	0,00	450 to 460	100,9	650 to 660	69,1
260 to 270	0,00	460 to 470	149,4	660 to 670	65,1
270 to 280	0,00	470 to 480	116,8	670 to 680	59,1
280 to 290	0,01	480 to 490	118,3	680 to 690	91,7
290 to 300	0,02	490 to 500	110,7	690 to 700	61,7
300 to 310	0,01	500 to 510	100,1	700 to 710	43,1
310 to 320	0,01	510 to 520	101,2	710 to 720	61,0
320 to 330	0,03	520 to 530	100,3	720 to 730	49,0
330 to 340	0,00	530 to 540	100,6	730 to 740	49,1
340 to 350	0,26	540 to 550	100,0	740 to 750	38,3
350 to 360	0,71	550 to 560	100,1	750 to 760	43,3
360 to 370	6,31	560 to 570	96,2	760 to 770	63,2
370 to 380	22,8	570 to 580	94,7	770 to 780	20,6
380 to 390	38,6	580 to 590	103,5	780 to 790	23,1
390 to 400	58,1	590 to 600	94,0	790 to 800	25,0
400 to 410	63,2	600 to 610	76,7		
410 to 420	72,5	610 to 620	94,5		
420 to 430	75,3	620 to 630	87,5		
430 to 440	79,8	630 to 640	79,6		
440 to 450	86,0	640 to 650	75,0		
Source: Test instruments (Tokyo, Japan)					

Table G.2 — Example of relative spectral irradiance for simulated indoor indirect daylight typical home display (xenon lamp with quartz inner filter, L-37 and borosilicate glass outer filter)

Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550 nm
250 to 260	0,00	450 to 460	98,9	650 to 660	93,6
260 to 270	0,00	460 to 470	145,9	660 to 670	91,2
270 to 280	0,00	470 to 480	113,4	670 to 680	85,7
280 to 290	0,00	480 to 490	114,1	680 to 690	143,1
290 to 300	0,00	490 to 500	106,6	690 to 700	100,6
300 to 310	0,00	500 to 510	96,4	700 to 710	72,0

Table G.2 *(continued)*

Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550 nm
310 to 320	0,00	510 to 520	97,7	710 to 720	110,5
320 to 330	0,00	520 to 530	97,7	720 to 730	93,6
330 to 340	0,00	530 to 540	99,2	730 to 740	97,7
340 to 350	0,46	540 to 550	100,0	740 to 750	80,3
350 to 360	1,02	550 to 560	101,6	750 to 760	97,8
360 to 370	7,62	560 to 570	99,0	760 to 770	152,9
370 to 380	24,5	570 to 580	99,0	770 to 780	52,0
380 to 390	40,8	580 to 590	111,2	780 to 790	62,7
390 to 400	60,6	590 to 600	103,6	790 to 800	72,4
400 to 410	64,9	600 to 610	85,6		
410 to 420	73,5	610 to 620	110,0		
420 to 430	75,7	620 to 630	105,2		
430 to 440	79,6	630 to 640	99,2		
440 to 450	85,0	640 to 650	96,9		
Source: Test instruments (Tokyo, Japan)					

Table G.3 — Example of relative spectral irradiance for simulated indoor in-window display (xenon lamp with quartz inner filter and borosilicate glass outer filter)

Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm	Wavelength nm	Relative spectral irradiance normalized to 100 at 540 nm to 550nm
250 to 260	0,00	450 to 460	101,73	650 to 660	90,87
260 to 270	0,00	460 to 470	142,72	660 to 670	91,65
270 to 280	0,00	470 to 480	114,73	670 to 680	89,24
280 to 290	0,00	480 to 490	114,45	680 to 690	131,55
290 to 300	0,00	490 to 500	107,68	690 to 700	99,38
300 to 310	0,03	500 to 510	97,83	700 to 710	76,75
310 to 320	2,69	510 to 520	98,54	710 to 720	109,35
320 to 330	11,07	520 to 530	98,36	720 to 730	91,81
330 to 340	22,60	530 to 540	99,20	730 to 740	101,15
340 to 350	34,67	540 to 550	100,00	740 to 750	86,33
350 to 360	45,34	550 to 560	100,62	750 to 760	97,75
360 to 370	54,07	560 to 570	98,72	760 to 770	152,14
370 to 380	60,15	570 to 580	99,06	770 to 780	56,71
380 to 390	64,87	580 to 590	107,57	780 to 790	64,54
390 to 400	77,70	590 to 600	100,82	790 to 800	76,70
400 to 410	76,01	600 to 610	87,94		
410 to 420	80,71	610 to 620	105,36		
420 to 430	80,99	620 to 630	103,96		
430 to 440	84,05	630 to 640	97,63		
440 to 450	88,82	640 to 650	96,08		
Source: Test instruments (Tokyo, Japan)					

Annex H

(informative)

Relative spectral power distribution for F-6 cool white fluorescent lamps

Table H.1 — Relative spectral power distribution for F-6 cool white fluorescent lamps[11]

Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power	Wavelength nm	Relative spectral power
300	0,5	475	104,8	650	66,2
305	0,5	480	104,9	655	56,5
310	12,4	485	104,5	660	48,1
315	27,2	490	104,5	665	40,9
320	0,5	495	102,2	670	35,0
325	0,5	500	100,0	675	29,8
330	0,5	505	98,7	680	25,5
335	4,9	510	98,6	685	21,8
340	1,0	515	100,3	690	20,5
345	1,6	520	105,1	695	16,7
350	2,1	525	113,4	700	14,5
355	3,8	530	126,4	705	12,9
360	10,8	535	144,4	710	11,3
365	89,3	540	167,0	715	9,7
370	37,3	545	401,6	720	8,6
375	15,0	550	277,1	725	7,6
380	16,7	555	248,9	730	7,0
385	20,9	560	274,2	735	6,8
390	26,0	565	295,1	740	6,4
395	30,3	570	309,4	745	5,9
400	49,5	575	349,8	750	6,1
405	235,7	580	366,4	755	5,6
410	54,6	585	309,1	760	6,2
415	52,5	590	295,5	765	6,5
420	58,6	595	277,4	770	5,3
425	64,8	600	256,2	775	4,1
430	70,9	605	233,1	780	3,3
435	519,3	610	209,4		
440	171,0	615	186,0		
445	87,3	620	163,2		

Table H.1 *(continued)*

Wavelength nm	**Relative spectral power**	**Wavelength** nm	**Relative spectral power**	**Wavelength** nm	**Relative spectral power**
450	92,0	625	142,5		
455	96,0	630	123,2		
460	99,5	635	106,5		
465	102,1	640	90,9		
470	103,8	645	77,5		

Source: Tokyo, Japan.

Annex I
(informative)

Example chamber fade uniformity test target

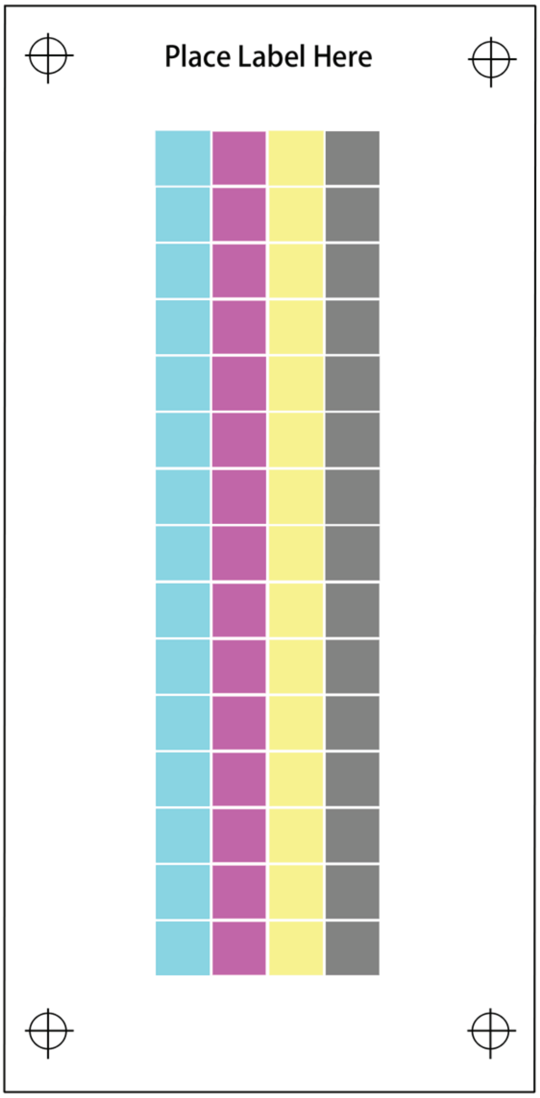


Figure I.1 — Example of chamber fade uniformity test target

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

Bibliography

[1] ISO Guide 98-3:2008, *Uncertainty of measurement — Part 3: — Guide to the expression of uncertainty in measurement (GUM:1995)*

[2] ISO 105-B02, *Textiles — Tests for colour fastness — Part B02: Colour fastness to artificial light: Xenon arc fading lamp test*

[3] ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

[4] ISO 11664-1, *Colorimetry — Part 1: CIE standard colorimetric observers*

[5] ISO 11664-2, *Colorimetry — Part 2: CIE standard illuminants*

[6] ISO 18909, *Photography — Processed photographic colour films and paper prints — Methods for measuring image stability*

[7] ISO 18920, *Imaging materials — Reflection prints — Storage practices*

[8] ANSI/NAPM IT9.9-1996, *American National Standard for Imaging Materials — Stability of Color Photographic Images — Methods for Measuring*

[9] ASTM G156, *Standard Practice for Selecting and Characterizing Weathering Reference Materials Use to Monitor Consistency of Conditions in an Exposure Test*

[10] JIS Z8902, *Xenon standard white light source*

[11] JIS Z 8719, *Metamerism index — Evaluation method of degree of metamerism for change in illuminant*

[12] Henry Wilhelm and Carol Brower. *(contributing author), The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*. Preservation Publishing Company, Grinnell, Iowa, 1993, pp. 67–77.

[13] Bush A., Lindstrom B., LaBarca J., Bugner D.E., Kapecki J. Rf method of reciprocity performance testing — A statistical approach to reducing the time needed to reach accurate conclusions — Part 1, *Proceedings of the International Conference on Imaging Science 2006*. pp. 410–413 (2006)

[14] Bush A., Lindstrom B., LaBarca J., Bugner D.E., Kapecki J. Rf method of reciprocity performance testing — A statistical approach to reducing the time needed to reach accurate conclusions — Part 2, P*roceedings of NIP23: International Conference on Digital Printing Technologies 2007*. p. 733 (2007)

[15] Stroebel L., Compton J., Current I., Zakia R. *Photographic Materials and Processes*. Focal Press, Boston, 1986, pp. 73.

[16] Bugner D.E., & Suminiński C. Filtration and Reciprocity Effects on the Fade Rate of Inkjet Photographic Prints, *Final Program and Proceedings of IS&T's NIP16: International Conference on Digital Printing Technologies*, pp. 90–94, The Society for Imaging Science and Technology; October 16, 2000

[17] Shilin Guo and Nils Miller. Estimating Light-Fastness of Inkjet Images: Accounting for Reciprocity Failures, *Final Program and Proceedings of IS&T's NIP17: International Conference on Digital Printing Technologies*. pp. 186–191, Ft. Lauderdale, Florida, October 3, 2001

[18] Shibahara Y., Ishizuka H., Muro N., Kanazawa Y., Seoka Y. Image stability of digital photographic printing materials, Proceedings of NIP18, 2002, pp. 330–333

[19] Bugner D.E., Kopperl D., Artz P. *Proc. of IS&T's12th International Symp. on Photofinishing*. pp. 54–57 (2002)

[20] Zinn E., Nishimura D.W., Reilly J. *Proc. NIP15*, 1999, pp. 416–420

[21] Wilhelm H. A Review of Accelerated Test Methods for Predicting the Image Life of Digitally-Printed Photographs – Part II, *Final Program and Proceedings of IS&T's NIP20: International Conference on Digital Printing Technologies*. pp. 664–669, Salt Lake City, Utah, October 31, 2004

[22] Wilhelm H., Armah K., Shklyarov D., Stahl B. Improved Test Methods for Evaluating the Permanence of Digitally-Printed Photographs, presentation at *Imaging Conference JAPAN 2009*, 2009

[23] Work R.A. III, & Brown R.T. Dye and Pigment Ink Jet Image Stability and Permanence, *Proceedings of the 17th International Conference on Digital Printing Technologies*. NIP-17, 2001

[24] Wilhelm H. Yellowish Stain Formation in Inkjet Prints and Traditional Silver-Halide Color Photographs, *Final Program and Proceedings of IS&T's NIP19: International Conference on Digital Printing Technologies*. pp. 444 – 449, New Orleans, Louisiana, September 28–October 3, 2003

[25] Quill J., Fedor G., Brennan P., Everett E. Quantifying the Indoor Light Environment: Testing for Light Stability in Retail and Residential Environments, *Final Program and Proceedings of IS&T's NIP20: International Conference on Digital Printing Technologies*. 2004, pp. 689–698

[26] Baumann E., & Hofmann R. The Equivalence of Light Sources in Light Stability Testing, *Final Program and Proceedings of IS&T's NIP20: International Conference on Digital Printing Technologies*. November 1, 2004, pp. 699–703, Salt Lake City, Utah

[27] Lemmon E.W., McLinden M.O., Friend D.G. *Thermophysical Properties of Fluid Systems* in *NIST Chemistry WebBook*. NIST Standard Reference Database Number 69

[28] Meissner M., Baumann E., Hofmann R. The Role of Humidity Cycling in Accelerated Light Fastness Tests. *IS&T DPP Conference*, Barcelona, Spain, 2003

[29] Ikehata Yorhiko *Effect of Relative Humidity on the Light Stability Evaluation of Various Digitally-Printed Pictorial Color Images*. presentation at the 2003 Annual Meeting of The Society of Photographic Science and Technology of Japan, 2003

[30] Kase A., Temmer H., Noshita T., Slagt M., Toda Y. Factors to Influence Image Stability of Inkjet Prints, *Final Program and Proceedings of IS&T's NIP20: International Conference on Digital Printing Technologies*. 2004, pp. 670–672,

[31] Doll P., Shi F., Kelly S., Wnek W. The Problem of Catalytic Fading with Ink-Jet Inks. *IS&T's NIP*. 1998, **14** pp. 118–121

[32] Michael W. Allen, Ph.D., *Stray Light – Measurement and Effect on Performance in UV-Visible Spectrophotometry*. Technical Note: 51170, Thermo Fisher Scientific, Madison, WI, USA

[33] Agilent Technologies Technical Note, *Measuring the Stray Light Performance of UV-visible Spectrophotometers*, Publication Number 5965-9503E

[34] Bugner D., Oakland M., Willard R. A Comparison of Accelerated Light Fade Conditions with Typical Home Display Conditions, *Proceedings of IS&T's 13th International Symposium on Photofinishing Technology*. 2004, pp. 21–24)

[35] Bugner D.E., LaBarca J., Phillips J., Kaltenbach T. Survey of Environmental Conditions Relative to Display of Photographs in Consumer Homes. *J. Imaging Sci. Technol.* 2006, **50** (4) pp. 309–319

[36] Bugner D.E., & Lindstrom B.L. Further Investigations into Accelerated Light Fade Reciprocity of Inkjet Photographic Prints. *IS&T's*. 2006, **NIP22**, pp. 235–238

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