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Imaging materials — Pictorial colour reflection prints — Methods for evaluating image stability under outdoor conditions

National foreword

This British Standard is the UK implementation of ISO 18930:2011. It supersedes PD ISO/TR 18930:2001 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee CPW/42, Photography.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Imaging materials — Pictorial colour reflection prints — Methods for evaluating image stability under outdoor conditions

Matériaux pour l'image — Impressions de couleurs de réflexion picturale — Méthodes d'évaluation de la stabilité d'image dans des conditions extérieures

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Foreword

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

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 18930 was prepared by Technical Committee ISO/TC 42, *Photography*.

This first edition of ISO 18930 cancels and replaces ISO/TR 18930:2001, which has been technically revised.

Introduction

Printed digital images are used in many applications in which they are exposed to outdoor weathering. This International Standard provides standardized test procedures to evaluate image stability both in real-time outdoor weathering tests and in accelerated laboratory simulations of the weathering process.

Accelerated laboratory weathering tests have been developed as a result of the desire to obtain test results faster than would be obtained by actual outdoor exposure. However, accelerated weathering tests only have value if they can be correlated with actual outdoor performance. In outdoor testing, critical factors that cause image degradation include light, water, heat, ozone, and local and diurnal variations in climate. In accelerated testing, it is important that the most critical factors of light, water and heat are included. The use of xenon arc lamps with “daylight” filters has become an industry standard procedure for the most accurate simulation of the spectral power distribution of sunlight. The coupling of the xenon arc lamps and “daylight” filters with a water spray and elevated temperatures forms the basis for testing with accelerated laboratory weathering instruments. The accelerated weathering test procedure described in this test method is intended to provide a means for predicting the behaviour under actual outdoor exposure.

Imaging materials — Pictorial colour reflection prints — Methods for evaluating image stability under outdoor conditions

1 Scope

This International Standard describes test equipment and test procedures for determining the colour stability of photographic colour images when subjected to outdoor conditions. It does not specify limits of acceptability or failure criteria. Instead, it provides means for measuring image changes that take place during the aging of pictorial photographic images and indicates the critical image-change parameters that should be reported. Users of this International Standard should determine which test end-points best simulate the intended display application.

This International Standard is applicable to pictorial images made with digital printing media, for example:

— prints on coated papers, coated and uncoated clear and opaque films, vinyl, polyester, synthetic papers and other plastic substrates, laminated and not laminated;

— dye-based and pigment-based inkjet prints with aqueous, solvent, phase-change, or UV curing inks;

— thermal dye and mass transfer;

— dye sublimation prints;

— digitally-printed dye-diffusion-transfer prints;

— liquid- and dry-toner xerographic prints;

— liquid toner electrostatic prints;

— digitally printed images made with traditional chromogenic and silver dye-bleach photographic materials;

— colour direct thermal prints.

In these digital printing processes, the ink laydown is controlled by means of digital pixel information, and all of the settings and controls of the printing system can be documented and repeated. In contrast, for many analogue printing systems, the control over the ink film thickness can be subject to manual adjustment. Window graphics on the outside of windows are covered by this International Standard. Window graphics on the inside of windows, for which sunlight is filtered by a layer of glass, will be covered by ISO 18937.

This International Standard does not include test procedures for 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 image stability, will determine the useful life of a print material.

NOTE Image print stability results determined for one printer model, ink set, printing mode, print resolution and media combination are not applicable to image prints produced through another printer model, ink set, printing mode, print resolution and media combination, even if the ink jet cartridges and/or media used in testing are the same.

2 Normative references

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

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

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

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

CIE 85:1989, Solar Spectral Irradiance

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
digital printing media
recording elements used by digital printers to receive inks or pre-formed colorants

EXAMPLE The substrate might be paper, plastic, canvas, fabric, or other ink-receptive material; the substrate might, or might not, be coated with an ink-receptive layer. The category of digital printers includes inkjet, electrophotographic and thermal transfer.

3.2
encapsulation
sealing of all edges of a specimen that has been laminated on both front and back surfaces

NOTE This is usually done by laminating with sheets that are larger in dimension than the specimen and then sealing at the overlaps.

3.3
laminate
layer of material that goes over the top or bottom of a specimen

NOTE This is usually to provide water-resistance, physical, and/or ultraviolet (UV) light protection of the specimen during a weathering test. A layer of protective film is applied with a pressure-sensitive or heat-activated adhesive.

3.4
accelerated laboratory weathering
simulated weathering where instruments (weathering devices) are used to obtain very controlled conditions that simulate, to some degree, and generally accelerate, the outdoor weathering results

NOTE The use of such instruments is described in ISO 4892-1 and ASTM G151.

3.5
outdoor weathering
actual placement of specimens outdoors in specific locations

NOTE This is differentiated from simulated weathering where instruments (weathering devices) are used to obtain very controlled conditions that simulate, to some degree, and generally accelerate, the outdoor weathering results. Use of such instruments is described in ISO 4892-1 and ASTM G151.

3.6
accelerated outdoor weathering
use of mirrors or lenses to focus sunlight onto specimens for increased intensity

NOTE The use of such devices is described in ISO 877-3.

3.7
reciprocity failure
non-equivalence in weathering results between a long exposure/low-intensity experiment and its short exposure/high-intensity counterpart with an equivalent intensity-time product

3.8
total solar UV irradiance
irradiance in the wavelength range from 300 nm to 400 nm integrated over the duration of a test

NOTE This quantity is usually fairly consistent from year to year in a given location, and is usually given in units of MJ/m^2.

3.9
daylight filter
optical filter, or combination of filters, that modifies the spectral power distribution of a light source to better represent some defined daylight spectrum

NOTE 1 These filters are not related to the blue filters used in the photographic industry for the change of correlated colour temperature of light sources.

NOTE 2 Adapted from ISO 18913.

3.10
operational control point
set point for equilibrium conditions measured at sensor location(s) in an exposure device

[ASTM G113]

3.11
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

NOTE The operational fluctuations are the result of unavoidable machine variables and do not include measurement uncertainty. The operational fluctuations apply only at the location of the control sensor and do not imply uniformity of conditions throughout the test chamber.

[ASTM G113]

3.12
operational uniformity
range around the operational control point for measured parameters within the intended exposure area, within the limits of intended operational range

[ASTM G113]

3.13
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 measurand

NOTE 1 The parameter might be, e.g., a standard deviation (or a given multiple of it), or the half-width of an interval having a stated confidence level.

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

NOTE 3 It is understood that the result of the measurement is the best estimate of the value of the measurand 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.

[ASTM G113]

4 Summary of test practice

4.1 Accelerated laboratory weathering tests

Accelerated laboratory tests performed in weathering chambers should simulate the outdoor environment for which the display is intended. The test specimens should be subjected to light, water, and elevated temperature. The duration of the test can vary widely, depending on the stability of the imaging materials.

During the course of the test, the colour changes in the printed samples are periodically evaluated instrumentally. Results are compared to the initial values for the same specimen prior to testing, and also to a control sample maintained at ambient conditions with light excluded. A further internal control sample with known weathering behaviour is also recommended for laboratory experiments. The change of the test specimens and the reference samples is reported as optical density and/or L* a* b* (or colour difference, ΔE^*_{ab}) before and after the test.

For an accurate assessment of outdoor performance, an ozone test such as that described in ISO 18941 should also be considered, as many colorants are sensitive to atmospheric pollutants. An ozone test is recommended for media that is unlaminated. However, ozone testing is not a part of this International Standard.

4.2 Outdoor weathering tests

Outdoor exposure conditions can vary by orders of magnitude in irradiance depending on the geographical latitude, altitude, specimen orientation, season and weather conditions. Outdoor weathering services are available for some typical climatic conditions, e.g. South Florida's subtropical hot and humid climate and Arizona's hot and dry desert climate. A list of common outdoor test sites is given in ASTM G7. Due to the annual variations in climate, it is recommended that internal control samples with known behaviour be included in outdoor weathering experiments.

5 Significance and use

5.1 Accelerated laboratory weathering tests

Controlled laboratory tests are often used to provide standardized data and to benchmark materials. Predicting outdoor image display life from controlled laboratory tests without correlation data for the material in question between the laboratory test and natural outdoor exposure is not recommended.

Since the ability of images on digital printing media to withstand colour changes is a function of temperature, humidity, air pollutants, light and diurnal changes of environmental parameters, it is important that print stability be assessed under the conditions appropriate to the end use application.

The laboratory procedure described in this test practice is intended to provide a means for predicting the behaviour under actual outdoor exposure. Test results are useful for specification acceptance between producer and user, for quality control, and for research and product development[20][21].

5.2 Outdoor weathering tests

Real-time outdoor exposure is the most reliable method of assessing outdoor image stability, but the actual exposure of a sample depends on the season and the weather. However, it is not as fast as accelerated laboratory tests. The outdoor test procedure described in this International Standard is intended to provide image stability data for an ink/media combination in a selected outdoor location. Note that the image stability indicated in this test will vary with the weather from year to year[22].

6 Apparatus

6.1 Accelerated laboratory weathering test equipment

The exposure equipment shall consist of a light source with simulated direct outdoor daylight with a spectral power distribution as defined in CIE 85:1989, Table 4, and the operating limits defined in Annex A. A recommended match for direct outdoor daylight that is equivalent to CIE 85:1989, Table 4, is a cooled, filtered xenon high-pressure arc lamp. A "daylight filter" that gives the best match to the spectral power distribution of CIE 85:1989, Table 4, should be used. Matching the solar spectral power distribution, especially in the UV region, is extremely important. Irradiance, reference black panel temperature (BPT or BST), chamber (ambient) air temperature, and relative humidity need to be regulated to allow test conditions in the range specified in Clause 12. The apparatus should allow cycling between dark and light phases as well as water spray cycles and dry phases. Annex A shows appropriate operating limits for the spectral power distribution of xenon arc accelerated weathering instruments.

6.2 Outdoor weathering tests

Real-time outdoor weathering may be conducted at test sites that have the ability to mount samples onto racks with fixed or variable angles of inclination. Most testing is performed with the samples facing south (for the northern hemisphere) at a 45° angle of inclination. Advantages of testing at 45° rather than 90° are that seasonal variations in radiant exposure are minimized[22], space requirements are minimized because neighbouring sample racks are less likely to shade each other, and the average annual radiant exposure can be as much as twice as large (e.g. approximately 1,6 to 1,7 times as large for South Florida or Arizona). In some cases where a product is utilized on a vertical surface, such as vehicle graphics, testing is conducted at an angle of inclination of 90° facing either north or south.

Seasonal differences, such as temperature and relative humidity, will occur when tests are run at different times of year. It is critical that the outdoor tests be run for multiples of a calendar year so that separate tests have a basis for comparison. The testing service should provide information on the total solar UV irradiance at 45° for the samples tested, as well as tabulation on a day-to-day basis of the temperature and relative humidity highs, lows, and means[7]. Often, this is published as a newsletter that is routinely sent to customers of the testing service. It is also recommended that the testing service provide ozone level data as well, if possible. Several manufacturers of accelerated weathering equipment offer testing services and outdoor exposure facilities.

7 Interferences

It is recognized that the fade of images on digital printing media will vary significantly because of factors such as initial colour density, the area printed (solid versus half-tone), the substrate, the colorant type (dye versus pigment inks), the number of passes (in multipass printing modes), ink load, print resolution, and the receiver coating type and thickness. Consequently, test results shall be determined individually for each print.

The rate of colorant degradation with light is often strongly dependent on humidity and air pollutants. Separating the environmental factors will not be possible in a real environment. This has to be taken into consideration when extrapolating to other display conditions. Guidance on the interference of environmental factors other than light, their importance in image degradation, and references to methods for measurement can be found in Reference [23].

Some outdoor environments are characterized by strong temperature and humidity fluctuations between day and night or sunny and overcast conditions. In cold weather, the presence of the sunlight creates strong temperature differences, especially in dark colours, that can lead to cracking and mechanical distortions. When samples are set out in the weather, another component for consideration is environmental materials: both polluting gases and materials left by fauna and flora. Information about the levels of common pollutants is available, e.g. on the web sites of local environmental offices, meteorological or climatological web sites, or from the testing services. Unless measurement of resistance to these environmental effects is desired, many of these materials can be removed from samples by request, thus assuring a more controlled test. Effects of polluting gases can be examined or eliminated based on the weathering site location. Other possible sources of degradation to consider are acid rain, salt corrosion from the sea, haze due to pollution or fires, and bird droppings. For removal of unwanted environmental materials, a gentle water rinse is recommended, but without scrubbing that can mar or abrade the surface. The use of mild soap solutions is permitted for laminated samples and for other materials that will not be damaged by this exposure.

Accelerated image stability tests for predicting the behaviour of colour images under normal outdoor conditions can be complicated by “reciprocity failure”. When applied to digital printing media, reciprocity failure refers to the failure of many types of colour images to degrade equally when irradiated to the same total light exposure (intensity × time) by both high-intensity light for a short period and low-intensity light for a long period. The magnitude of any reciprocity failure can also be influenced by the test temperature, the moisture content of the test specimen, and light/dark cycling rates. Also note that apparent reciprocity failures have been observed in some materials due to the presence of ozone or other pollutants in accelerated weathering test chambers[24].

8 Testing time consideration

8.1 Accelerated laboratory weathering tests

Testing is to be conducted until the printed image reaches an end-point that represents the condition at which the image changes may be considered unacceptable. Thus, the end-point of the tests depends on the envisaged application. However, there is no general consensus about the choice of end-points (see References [25] and [26]), so the full set of end-point criteria needs to be reported with the test report. It is to be understood that different end-points might be appropriate for different applications such as banners, billboards, vehicle graphics, industrial graphics, and signs. Annex B shows an example of the use of a possible end-point to determine specimen failure time.

8.2 Outdoor weathering tests

Care should be taken to observe the time of year in which the samples were initially submitted for weathering. Some materials originally weathered in the summer can give different results than those originally weathered in the winter for the same length of time. Weathering should extend at least over a whole year, particularly in areas with strong seasonal variations of light and climate, and tests should conclude at whole number multiples of a calendar year.

Most weathering testing is real-time weathering in which the samples are placed at a fixed angle to the ground and samples remain that way for fixed periods of time, or until a certain integrated light intensity has struck the samples.

There are other ways of treating samples in a more accelerated fashion, e.g. through the use of movable racks that track the path of the sun so the samples always remain normal to the sun, or use of concentrator mirrors or lenses that impart the optimal angle at increased intensity of radiation (ISO 877-3 provides a description of this practice). These tests provide results more quickly, but might be invalid due to reciprocity law failure, which is known to happen with gelatine binder systems and might happen in other systems. They are not recommended for testing of digital imaging media or traditional silver halide imaging materials.

Testing may be conducted for a predetermined number of years, or may be continued until a certain end-point is reached. End-points are discussed at the end of 8.1 and in Annex B.

9 Safety precautions

Natural daylight, as well as unfiltered simulated daylight, contain high amounts of ultraviolet (UV) light. Unprotected skin and eyes should not be exposed to high levels of UV light. The laboratory weathering device shall be equipped with safety locks that prevent accidental exposure. The use of UV-protective safety glasses is detailed in ANSI Z87.1 and EN 166. Protective clothing is described in ASTM D6603-07 and EN 13758-2.

10 Test specimens

10.1 Substrate, method of printing, ink and post-treatment

The substrate, method of printing, ink, and post-treatment of printed specimens shall be consistent with the anticipated end use of the specimens. For example, self-adhesive vinyl media intended for vehicle graphics should be applied to a rigid metal sheet. Potential variables such as temperature and relative humidity during printing of the samples shall be monitored and controlled to guard against sample-induced changes.

10.2 Test image

The test image may be generated with drawing/graphics or page layout software. It may be saved as a print file for each printer or method of printing (contributing its unique ink and ink/receiver interactions that might impact on the image light stability), and trial-printed. Each print file should have its filename, type, and version identified in the image area, and should have a place for experimental notes, e.g. time, printer, environmental conditions, operator. The printer settings and a trial print of each print file version should be archived.

The recommended test image should consist of colour patches printed using files containing the appropriate printer set-up specific for each application. The colour patches should be printed at 0,5, 1,0, 1,5, and d_{max} densities, and should include each of the primary colours (cyan, magenta, yellow, and true black), secondary colours (red, green, and blue), and composite black (cyan plus magenta plus yellow). A minimum density (unprinted) patch should also be present on the test image. Since it might not be possible in RGB space to control whether black patches are printed using true black or composite black, the test image should be created in CMYK space to allow this aspect of the target to be controlled.

For instrumental evaluation, the colour patch shall be large enough to cover the specimen port. As outdoor samples might have areas with mechanical damage, dirt, dust, and other blemishes, the sample size should be significantly larger than the measurement instrument aperture. For many densitometers, a minimum sample size of 7 mm × 7 mm is practicable.

A test target should be used that can generate all of the aforementioned colour patches for this test method. If necessary, data for 0,5, 1,0, and 1,5 densities may be obtained by selection of the nearest patch or by interpolation between two or four patches of a colour target that are near to the target density. Annex B shows an example of the use of a possible end-point to determine specimen failure time.

10.3 Number of replicates

Three or more identical replicates are recommended for the outdoor tests. Two or more identical replicates are recommended for accelerated laboratory weathering tests. In order to compare the exposed samples to unexposed samples, reference control samples should be prepared at the same time and should be preserved in the standard condition prescribed by ISO 291.

It is suggested that additional tests with more replicates be repeated at staggered intervals to provide an indication of the repeatability of the test procedures and test equipment.

It is recommended that internal reference samples be included in every exposure test to track consistency of the test procedure as well as unintended changes of test conditions. If possible, internal references should be made of materials similar to the test samples. Their properties and behaviour in the exposure test should be well-known and predictable. The test results should be rejected if the reference results deviate by more than the tolerance limit of the test (see Reference [17]).

10.4 Laminates and encapsulation

Another important consideration is the type and method of application of laminates. If the material is on a paper base, it probably needs to be laminated for protection of the paper support and any water-soluble coated materials. Gelatine-containing materials also do not hold up well in outdoor tests without lamination. A product intended for outdoor use without lamination should be tested without lamination. Different fading results can occur between simple lamination, where the edges of the material are not sealed, and encapsulation, where a tight seal is applied all around the sample. For encapsulated samples, staple holes, etc., should not pierce the capsule, but should be made outside the sealed edges. For some products, a single staple hole can have the same effect on an encapsulated sample as cutting off the overlapping laminate, thus destroying the capsule. Care should be taken that the application of hot laminates does not destroy the integrity of the sample.

10.5 Identification of samples

It is necessary to identify samples in such a way that the identification will not become unreadable when the samples fade. Identification exposed in the actual samples may fade during weathering. Certain marking inks can spread, especially under very humid conditions, and, in time, become unreadable. Another problem with inks is that they can bleed through the back of some samples and affect the images.

Typing of information onto adhesive labels and placing them on the back of the samples is acceptable for opaque samples[3]. With label applications, exercise appropriate care with regard to solvents found in the adhesive as solvent migration can cause sample damage.

Codes punched into the actual specimen might be necessary for translucent or transparent materials, since a label on the back would change the pattern of light transmission through the sample.

Another option is to affix a tag with a cable tie. A hole is punched through the backing material, the cable tie is threaded through the hole in the backing material and the identification tag, and the cable tie is then closed. The identification tag may be printed, engraved, or stamped with indicia.

10.6 Backing of test specimens during accelerated laboratory weathering tests

Prints shall 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 enamelled or unpainted aluminium panels, or stainless steel plate). Specimen positions in a light stability apparatus that are not occupied with actual test prints shall be filled with dummy specimens that have a reflectance approximately equal to that of the test specimens. Note that prints mounted onto aluminium with a pressure-sensitive adhesive shall be construed as a manifestation of “self-backing”, as per ISO 5 and ISO 13655. Take care to place and fix the samples so that water does not seep into any space between the samples and the backings.

10.7 Specimen preparation for outdoor weathering tests

Many sites have pre-built racks in which to install the samples. It should be determined whether samples need to be mounted on an additional substrate in order to fit the rack size requirements, e.g. one testing service uses racks in which one dimension of the sample shall be 33 cm.

Considerable thought should be given to the way in which the samples will actually be used in the trade. Of particular importance are the mounting and backing materials resistant to the effects of outdoor tests. When fastening images to plastic, consideration shall be given to the nature of the fasteners. Mild steel staples might hold up well in high desert environments, but they rust very quickly in semi-tropical locations and are thus not suitable. Alternatives include sewing the samples to the plastic or fastening with plastic button fasteners. Also used are pressure sensitive tapes, especially those with films made from poly(vinyl fluoride) resin and other similar polymers that are highly weatherable. These tapes may also be used around the border of the sample to securely affix it to the backing material. The border shall be at least 3 mm from the edge of the image so as not to interfere with the test exposure. If the method of fastening is the same as that in actual use, it might be important to note failures such as cracks and tears in the material around the fastening points.

Care shall also be taken to choose the appropriate backing material. The darker the material, the warmer the samples will be during daylight hours. For most non-billboard uses, clear polyester sheeting or aluminium panels are suitable backing materials. In no case should the backing interfere with the sample weathering. For billboard use, plywood or metal backings are appropriate.

11 Conditioning

It is recommended that samples be conditioned at (23 ± 2) °C and (50 ± 10) %RH for at least 24 h and a maximum of 14 days prior to testing[14]. Specimens should be visually inspected for colour uniformity and surface irregularities, which could adversely affect colour measurement.

12 Exposure program and settings

12.1 Accelerated laboratory weathering tests

Cycled tests with light and dark phases simulating day and night have been shown to represent natural fading more faithfully in certain imaging media[18]. These cycled tests are therefore recommended for such media. If the display condition involves exposure to rain, then water spray cycles shall be included in the test. A ratio of washed periods to dry periods of 1 to 5 is often used, but the actual ratio selected should depend on the intended use. For this International Standard, the water spray rate during spray cycles should be sufficient to wet the entire surface of the printing media. Increased water spray rates might be appropriate in some cases, depending upon the intended use. The water sprayed onto the specimen surfaces shall have conductivity below 5 µS/cm, contain less than 1 µg/g dissolved solids and leave no observable stains or deposits on these specimens. Care shall be taken to keep silica levels below 0,2 µg/g. A combination of deionization and reverse osmosis can be used to produce water of the desired quality.

Table 1 shows the details of the four-segment xenon arc exposure test cycle A, which shall be used for this International Standard. The light source and filter combination shall match the spectral power distribution in Annex A, which is based upon the solar spectral power distribution specified in CIE 85:1989, Table 4. To match this spectral power distribution, a filter combination such as borosilicate inner and outer filters or a "daylight filter" is suggested. Adherence to this spectral power distribution will improve the correlation between the laboratory test and natural outdoor weathering. This test cycle incorporates light and dark, and wet and dry periods. The surface temperature of the specimen (as indicated by the uninsulated black panel temperature), the relative humidity in the chamber, and the dry bulb chamber temperature shall be controlled to the values in Table 1. The limits of operational fluctuations do not apply during the water spray segments of the cycle. The irradiance may be controlled either over a narrowband (340 nm) or a broadband (300 nm to 400 nm). Equivalent irradiance levels at 340 nm and 300 nm to 400 nm may vary slightly depending upon the instrument type and daylight filter used. While it is generally accepted that 60 W/m^2 (300 nm to 400 nm) is proportional to 0,55 W/m^2/340 nm for daylight filters, contacting the instrument manufacturer for precise equivalent irradiance values is recommended. Operational fluctuations shall be maintained at ±0,02 W/m^2 for 340 nm irradiance control and at ±2,0 W/m^2 for 300 nm to 400 nm control. The operational uniformity of the irradiance shall be such that all sample positions have irradiance of at least 90 % of the maximum value. Regions of the test chamber shall be selected for use to comply with this required operational uniformity condition[19]. Note that the term "operational uniformity" denotes changes in operating parameters with respect to sample position in the chamber rather than with respect to time.

Either a black panel thermometer or a black standard thermometer shall be used to measure the temperature in the plane of the test panels during the dry cycle segments.

If a black panel thermometer is used, it shall consist of a plane (flat) metal plate that is resistant to corrosion. Typical dimensions are about 150 mm long, 70 mm wide, and 1 mm thick. The surface of the plate facing the light source shall be coated with a black layer that is resistant to ageing. The coated surface shall absorb at least 90 % to 95 % of all incident radiation up to 2 500 nm. Firmly attached to the centre of the exposed surface shall be the thermally sensitive element of a stem-type black-coated bimetallic coil thermometer with a dial display or a resistance thermometer. The back of the metal panel shall be open to the atmosphere within the test chamber.

If a black standard thermometer is used, it shall consist of a plane (flat) stainless steel plate with a thickness of about 0,5 mm. Typical length and width dimensions are about 70 mm by 40 mm. The surface of this plate facing the light source shall be coated with a black layer that is resistant to ageing. The coated surface shall absorb at least 90 % to 95 % of all incident radiation up to 2 500 nm. A platinum resistance temperature sensor shall be attached to, and in good contact with, the centre of the plate on the side remote from the radiation source. This side of the plate shall be attached to a 5 mm thick backing plate made of poly(vinylidene fluoride) (PVDF). A small space sufficient to hold the platinum resistance temperature sensor shall be machined into the PVDF backing plate. The distance between the sensor and the edge of the recess in the PVDF plate shall be about 1 mm. The length and width of the PVDF plate shall be sufficiently large to ensure that no metal-to-metal thermal contact exists between the black-coated metal plate and the holder on which it is mounted. The metal parts of this holder shall be at least 4 mm from the edges of the metal plate. Black standard thermometers which differ in construction are permitted, as long as the temperature indicated by the alternative construction is within ±1,0 °C of that indicated by the specified construction at all steady-state temperature and irradiance settings that the exposure device is capable of attaining. In addition, the time necessary for the alternative black standard thermometer to reach the steady state shall be within 10 % of the time needed for the specified black standard thermometer to reach the steady state.

The black panel and chamber air temperatures during the test cycle shall be those designated in Table 1. These temperatures shall be maintained and controlled throughout testing with an operational fluctuation within ±2,0 °C of aim, and a running average, sampled at least every 15 min, of the operational fluctuations within ±1,0 °C of aim. The running average shall not include the transition time of 1 h after door closing. If the average does not meet the set point, this shall be documented and explained. The air temperature sensing element shall be shielded from the light source and water spray as stipulated in ISO 4892-1. Practically, air temperature can be measured at the exit of the test chamber. Through historical testing and observation, at 0,55 W/m^2 at 340 nm (or 60 W/m^2 at 300-400 nm) the insulated black standard (BST) is normally 3 °C higher than the black panel temperature (BPT). Table 1 takes this difference into consideration for the BPT and BST set points.

The levels of relative humidity during the test cycle shall be those designated in Table 1. The relative humidity shall be maintained and controlled throughout testing with an operational fluctuation within ±6,0 %RH of aim, and a running average of the operational fluctuation within ±2,0 %RH of aim, at a constant temperature. The running average shall not include the transition time (typically around 10 min) after door closing or the start of a new test cycle segment. If the average does not meet the set point, this shall be documented and explained.

Each test chamber shall be calibrated for humidity control and measurement accuracy using a calibration with a chilled mirror hygrometer or a device calibrated and traceable to a national standards authority. A check of 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. Measurement system to monitor and control irradiance and temperature should be calibrated with a process and frequency as recommended by the test instrument manufacturer.

Several types of printing media are sensitive to the presence of ozone. In order to avoid confounding of the accelerated weathering results due to fade generated by ozone exposure, it is good laboratory practice to eliminate or control the ozone levels in the test chamber during the course of the test.

Table 1 — Xenon arc exposure test cycle A

Cycle segment	**Time** min	**Irradiance-narrowband** (340 nm) W/m^2	**Irradiance-broadband** (300 to 400 nm) W/m^2	**Black panel temperature** °C	**Black standard temperature** °C	**Chamber temperature** °C	**Relative humidity** %	**Water spray**
1	40	0,55 ± 0,02	60 ± 2	63 ± 2	66 ± 2	40 ± 2	50 ± 6	None
2	20	0,55 ± 0,02	60 ± 2	—	—	40 ± 2	—	Front
3	60	0,55 ± 0,02	60 ± 2	63 ± 2	66 ± 2	40 ± 2	50 ± 6	None
4	60	0,00	0	—	—	38 ± 2	—	Front

For accelerated testing of image fade in outdoor sunlight without the presence of water, which is out of the scope of this International Standard, it is recommended that a dry version of the test cycle described above, a dry version of ASTM G155, Cycle 1, or the test cycle described in ISO 18909:2006, 5.9, be used.

12.2 Outdoor weathering tests

Samples may be submitted to an outdoor weathering service or mounted at another selected outdoor test location. If more than one sample is on a panel, then the panel should be rotated periodically to randomize the effects of water that collects at the bottom of the panel. Repositioning of specimens during an exposure test will generally decrease the variability of the results.

Sample irradiance will change with the angle of inclination. Testing at an angle of inclination of either 45° or 90° (vertical orientation), south facing (for the northern hemisphere) or 90° (vertical orientation) north or south facing shall be required. Additional testing at other additional angles of inclination set by the latitude of the test site is permitted.

13 Procedure

13.1 Steps for laboratory accelerated weathering tests and outdoor weathering tests

The following steps shall be performed for laboratory accelerated weathering tests and outdoor weathering tests.

a) Prepare samples in accordance with Clause 10.

b) Take initial readings of reflected optical densities and/or colour coordinates in L*a*b space.

c) Mount the samples as described in Clause 10.

d) Run the test program or submit the samples to the testing service.

e) Tests should be done at pre-determined intervals at which the test specimens are measured and compared to the reference sample. It is recommended that one interval cover less than or equal to one fifth of the expected total exposure time, so that there are five or more data points.

f) Measure reflected optical densities and/or colour coordinates in L*a*b space. UV filters shall not be used in the colour measurement devices. Colorimetry of the d_{min} patch shall be measured using ISO 13655 measurement condition M0 for the relative spectral power distribution of the flux incident on the specimen surface. Measurement conditions shall be consistent throughout the test process. For colour coordinates in L*a*b space, calculate the colour changes of the samples at every interval. Colour change, ΔE^*_{ab}, shall be calculated as described in ISO 11664-4. Reflected optical densities shall be measured as described in ISO 5-3, with the relative spectral power distribution of the flux incident on the specimen surface conforming to CIE Illuminant A, ISO 13655 measurement condition M0, and spectral products conforming to Status A or Status T density as appropriate for the material under test. In addition to receiving weathered samples back for observation, consideration should be given to having the testing service make periodic measurements of optical density change, and physical change or gloss change if such inputs are desired. Sometimes it is easier to have the testing service make these measurements at specified intervals rather than shipping the samples back to the submitter's laboratory to perform this work. Another alternative is to send many replicates to the test site, with one or more of the replicates sent back at specified intervals.

g) Terminate the test when the predetermined colour change end-point is achieved, or stop after significant material damage. The duration of the test and the magnitude of the predetermined colour change might differ significantly, depending on the ink/media combination and the intended usage.

13.2 End-point

Failure criteria might be the loss of a certain percentage of the optical density of a particular colorant, a certain value for the colour change, ΔE, in L*a*b* space, loss of adhesion of the printable coating to the substrate, etc. Illustrative numerical end-points for colour or density change are given in ISO 18909, although the end-points given there are illustrative only. Each user of this International Standard shall select end-points for the listed parameters which, in that user's judgment, are appropriate for the specific product and intended application. For illustration, the use of an end-point to determine the point of failure of a test specimen is demonstrated in Annex B.

13.3 Reporting of accelerated laboratory weathering test data

The report for accelerated laboratory weathering tests shall include the following details.

a) Specimen identification, including the method of printing, and substrate. The printer model, printer driver version, printer driver settings, number of passes (in multipass printing modes), ink load, print resolution, the name of the host application used in generating the print and the colour controls selected in that application, the cartridge configuration/ink or colorant used (manufacturer's name and part number), the media 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.

b) Exposure apparatus type and model, light source, filter combination, irradiance levels, wavelength at which the irradiance is monitored, and the light or water spray cycles used.

c) Time of each light and dark period and the dry and water spray cycles.

d) Description of method used to mount specimens in exposure frame, including a description of any material used as backing for test specimens. For backed samples, the material, thickness, and reflectance factor should be specified.

e) Description of any specimen repositioning during the test.

f) The black panel temperature, chamber air temperature, and relative humidity in the chamber during the different test cycle segments.

g) The starting densities (i.e. 0,5, 1,0, 1,5 and d_{max}) of the colour and neutral patches in the test specimen; the particular end-point values chosen and the time required for the specimen to reach the limiting end-point.

h) Total exposure time, in hours.

i) Test results from the instrumental colour change evaluation (density loss and ΔE) of the colour patches and the support, and the initial and final density or L*a*b values.

j) The type of equipment used for making colour measurements and the test method. For densitometers, the filter type (e.g. ANSI Status A, ANSI Status T) and measurement geometry (e.g. 45°/0°, 0°/45°, spherical) should be reported. For spectrophotometric density measurements, the instrument model, measurement conditions and computation procedure are to be reported as in ISO 5-3. For colorimeters, the illuminant type (e.g. D50, D65), the field of view (e.g. 2°, 10°), and the colour difference equation used shall be stated.

k) Ozone level during the test, if measured.

13.4 Reporting of outdoor weathering test data

The report for outdoor weathering shall include the following details.

a) Specimen identification, including the method of printing, and substrate. 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 or colorant 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.

b) The starting densities (i.e. 0,5, 1,0, 1,5 and d_{max}) of the colour and neutral patches in the test specimen.

c) Any sample lamination or encapsulation, including the type and thickness of the laminate.

d) The type of equipment used for making colour measurements and the test method. For densitometers, the filter type (e.g. ANSI Status A, ANSI Status T) and measurement geometry (e.g. 45°/0°, 0°/45°, spherical) should be reported. For spectrophotometric density measurements, the instrument model, measurement conditions, and computation procedure are to be reported as in ISO 5-3. For colorimeters, the illuminant type (e.g. D50, D65), the field of view (e.g. 2°, 10°), and the colour difference equation used shall be stated.

e) Location at which the exposure was conducted.

f) Direction at which the exposure was oriented.

g) Angle to the sun at which the exposure was conducted.

h) Height above ground, and notes in regard to any ground cover.

i) Periodic cleaning of specimen (if used), and how it was cleansed.

j) Whether the sample was backed or unbacked. For backed samples, the material, thickness, and reflectance factor should be specified.

k) Exposure starting date, exposure intervals, and finishing date.

l) The particular end-point values chosen and the exposure time required to reach the end-point.

If available, the following test information should be reported:

— the percentage of total sunshine;

— the temperature range during weathering;

— the amount of rainfall, expressed in cm, including the number of hours of wetness;

— any relevant information about the level of pollutants and particulate matter;

— the amount of energy reaching the samples at the end-point in total solar UV irradiance and total solar irradiance.

Annex A
(normative)

Spectral power distribution for accelerated laboratory weathering tests

Table A.1 — Target irradiance and operating limits for accelerated testing with irradiance control at 340 nm

Wavelength band nm	**Target irradiance normalized to 0,55 W/m²/340 nm** W/m²	**Irradiance lower bound** W/m²	**Irradiance upper bound** W/m²
280 to 290	0,00	0,00	0,05
290 to 300	0,00	0,00	0,30
300 to 310	0,72	0,51	0,94
310 to 320	2,55	1,78	3,31
280 to 320	3,28	2,30	4,27
320 to 360	23,04	16,13	29,95
360 to 400	34,05	23,84	44,27
400 to 450	63,06	44,14	81,98
450 to 500	74,19	51,93	96,44
500 to 550	77,83	54,48	101,18
550 to 600	64,76	45,33	84,19
600 to 650	62,51	43,76	81,26

NOTE Target irradiance taken from CIE Publication 85, Table 4.

Table A.2 — Target irradiance and operating limits for accelerated testing with irradiance control at 300 to 400 nm

Wavelength band nm	**Target irradiance normalized to** 0,55 W/m²/340 nm W/m²	**Irradiance lower bound** W/m²	**Irradiance upper bound** W/m²
300 to 400	60,00	58,00	62,00

Annex B
(informative)

Use of an end-point to determine specimen failure time

The end-point given here is illustrative only, and is intended to serve as an example of the determination of the failure point of a printed sample.

In this example, a printed yellow colour patch is tested to failure in an accelerated laboratory weathering test. The failure criterion that will be employed is a 30 % fade from the initial optical density.

Table B.1 — Fade of a yellow ink to failure

Exposure time h	Yellow optical density	Fraction of retained optical density
0	1,04	1,000
108	1,04	1,000
194	1,03	0,990
291	1,02	0,981
417	1,00	0,962
520	0,98	0,942
603	0,96	0,923
711	0,93	0,894
798	0,90	0,865
904	0,86	0,827
1 008	0,81	0,779
1 106	0,75	0,721
1 219	0,66	0,635

The first measurement for which the fraction of retained optical density is less than 0,70 is 1 219 h, so failure occurs between 1 106 h and 1 219 h. By linear interpolation:

$$\begin{aligned} & 1\,106\text{ h} + \left[(0{,}721 - 0{,}700)/(0{,}721 - 0{,}635)\right] * (1\,219\text{ h} - 1\,106\text{ h}) \\ & = 1\,106\text{ h} + 28\text{ h} \\ & = 1\,134\text{ h failure time} \end{aligned} \quad \text{(B.1)}$$

Alternatively, the failure time could be obtained via a curve fitting procedure. The failure criterion shall be selected to be above the noise of the testing procedure.

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