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Imaging materials — Reflection colour photographic prints — Method for testing humidity fastness

Matériaux pour l'image — Tirages photographiques en couleurs par réflexion — Méthode d'essai de la solidité à l'humidité

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Foreword

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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 18946 was prepared by Technical Committee ISO/TC 42, *Photography*.

Introduction

This International Standard addresses the methods and procedures for testing the humidity fastness of reflection colour photographic prints. Low and high humidity exposure are covered. This is of particular relevance to dye-based ink-jet prints or dye diffusion process prints[10][11][12][13][14][15][16].

Some types of colour photographic print suffer from changes in image appearance when exposed to a high relative humidity environment. The observed changes relate to colour, tone and loss of sharpness caused by horizontal and vertical diffusion of colorants as a result of exposure to elevated humidity.

The elevated humidity can arise from:

a) exposure to high relative humidity of the environment of the display area or storage space;

b) trapped moisture as a result of stacking prints, or inserting them into albums, in a high relative humidity environment;

c) trapped moisture as a result of stacking prints, or inserting them into albums, before sufficient dry time has elapsed.

Therefore, humidity based on meteorological data and users' behaviour was considered in determining the appropriate test conditions for the humidity fastness test. The test method stipulated in this International Standard is validated for case a).

Image deterioration of dye-based prints caused by high humidity is often detectable by the following characteristics.

— Blur (sharpness loss), change of colour and/or tone is observed.

— The deterioration is observed in higher humidity, commonly over 80 %RH or over 90 %RH.

— The deterioration can occur in a relatively short time, even within one or two weeks.

— Higher density images, or images that contain more secondary or mixed colours, are generally more affected. The largest change is usually observed at the boundary of different colours, or with images that have contrasting background colours. The size of the higher density area also affects the deterioration because the solvent and water of the ink diffuses to the adjacent lower density area when the higher density area is small.

It is important to take into account these characteristics when determining the appropriate test chart and test conditions.

It has also been observed that low relative humidities can accelerate the yellowing of certain types of inkjet papers. Indoor low humidities are common in colder climates as a result of heating air drawn in from the outdoors with very low dew points, and also in hot, dry climates in combination with air conditioning. In addition to D_{min} yellowing, very low humidities have also been shown to cause physical degradation to image-receiving layers; this phenomenon is outside the scope of this International Standard.

This International Standard makes use of a checkerboard pattern that allows assessment of humidity-induced blur by means of a relatively simple colorimetric measurement[11].

Imaging materials — Reflection colour photographic prints — Method for testing humidity fastness

1 Scope

This International Standard describes test methods for evaluating reflection colour photographic prints with regard to changes in image appearance resulting from exposure to both low and high relative humidity.

The observed changes relate to colour, tone and loss of sharpness caused by horizontal and vertical diffusion of colorants from exposure to elevated humidity levels. Other humidity-related factors, such as mould and mildew growth, and physical damage, such as curl, cockle, cracking or delamination due to humidity cycling, are outside the scope of this test method.

Although the method and procedures described in this International Standard can be used to test any colour hardcopy technology, it is particularly appropriate to systems where the colorants are applied by a mechanism involving the diffusion of colorant into image-receiving layers, for example inkjet or dye diffusion processes, and to certain types of inkjet media that are susceptible to D_{min} yellowing.

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 18913, *Imaging materials — Permanence — Vocabulary*

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

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

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*

3 Terms and definitions

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

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

NOTE Adapted from ASTM G113.

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

NOTE 1 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.

NOTE 2 Adapted from ASTM G113.

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

NOTE Adapted from ASTM G113.

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 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 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 can also be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.

NOTE 3 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.

NOTE 4 Adapted from ISO/IEC 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 might 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 exercised when comparing test results for different materials. Comparisons shall be limited to test cases that use equipment with matching specifications and matching test conditions.

5 Outline of test procedure

The checkerboard pattern[11] shown in Figure 1 shall be printed at (23 ± 2) °C and in an environment of (50 ± 10) %RH.

The test samples shall be conditioned, positioned with unrestricted airflow, for (24 ± 2) h at (23 ± 2) °C and (50 ± 5) %RH.

The printed samples shall be exposed to high humidity or low humidity as specified in Clause 7.

The colour patches shall be measured using CIELAB colorimetry before and after the humidity exposures. $\overline{\Delta E^*_{ab}}$ for the patches of the checkerboard pattern shall be calculated.

This International Standard stipulates three test methods: A, B, and C.

Method A demonstrates the degree of the deterioration ($\overline{\Delta E}$ of the printed image) quantitatively in a fixed humidity condition, i.e. 25 °C and 85 %RH, for a given period of time. Four weeks is the recommended duration. One, two or eight week durations can be used. Method A is most useful for research and development of printing systems or printing materials where the humidity fastness of many samples can be screened and closely compared.

Method B demonstrates the limitations of printing systems and materials by analysing data from tests at various levels of humidity, i.e. 25 °C for two weeks at three or more humidity levels chosen from 60, 65, 70, 75, 80, 85, 90 and 95 %RH, and showing where each sample starts to deteriorate. Method B is especially useful for communicating with end users who will be able to recognize the high humidity limitations for each product tested.

Method C demonstrates the propensity of the image-receiving layer or underlying substrate to yellow upon exposure to low relative humidities, i.e. 25 °C at 20 %RH for up to six months[18].

The test procedures are summarized in Table 1.

Table 1 — Summary of test procedures

Steps		Procedures and test conditions
Sample preparation	Test target	Checkerboard pattern shown in Figure 1
	Temperature and RH	(23 ± 2) °C and (50 ± 10) %RH
Sample conditioning	Temperature and RH	(23 ± 2) °C and (50 ± 5) %RH
	Duration	(24 ± 2) h, unrestricted airflow
Measurement	Method	CIE colorimetry conforming to measurement condition M0 of ISO 13655
	Parameter	$\overline{\Delta E^*_{ab}}$ of 84 patches in Figure 1 before and after the humidity exposure
Humidity exposure	Method A	25 °C and 85 %RH Recommended duration of 4 weeks One, two or eight week durations can be used
	Method B	25 °C for two weeks at three or more humidity levels chosen from 60, 65, 70, 75, 80, 85, 90 and 95 %RH
	Method C	25 °C at 20 %RH for up to six months
Measurement	Method	CIE colorimetry conforming to measurement condition M0 of ISO 13655
	Parameter	$\overline{\Delta E^*_{ab}}$ of 84 patches in Figure 1 before and after the humidity exposure
Report	Methods A and C	Measured deterioration at a fixed humidity
	Method B	Highest limit humidity without significant deterioration

6 Sample preparation

6.1 General

The checkerboard pattern shown in Figure 1 shall be printed at (23 ± 2) °C and (50 ± 10) %RH.

The test samples shall be conditioned for (24 ± 2) h at (23 ± 2) °C and (50 ± 5) %RH before humidity exposure, positioned with unrestricted airflow.

The sample holding environment shall be ozone-free [≤2 nl/l[1)] average ozone concentration over any 24 h period] for ozone-sensitive samples, as determined in accordance with ISO 18941. A material that is not sensitive to ozone shall have demonstrated no measurable D_{min} or printed patch colour change at ambient

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

ozone exposure levels and measurement condition temperature and humidity, over time periods consistent with measurement and test-staging time periods.

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.

It is recommended that reference samples be included in every exposure test to track consistency of the test procedures as well as unintended changes of test conditions[9].

6.2 Test target

The checkerboard test pattern (see Figure 1) shall be used as the test target. This test file is contained in the Humidity Print Stability Digital Test File collection and is available at http://www.i3a.org/resources/#iso. The standard Humidity Print Stability Digital Test File shall be downloaded and maintained in the tiff file format. No lossy image or file compression shall be applied to the target file. The digital file resolution shall be maintained as 600 dpi. The Humidity Print Stability Digital Test File is encoded in sRGB, defined as per IEC 61966-2-1, and uses the tiff format with the sRGB ICC profile embedded. After downloading, the Humidity Print Stability Digital Test File shall be retained in that format and encoding with the ICC profile retained.

NOTE Other file formats that retain the state of exactly unchanged pixel encoding values, no lossy compression, embedded sRGB ICC profile, and 600 dpi, can be treated as equivalent to the tiff format for internal use in a test environment.

This test pattern contains all of the cyclic combinations of Y, M, C, R, G, B, white and black as a checkerboard pattern. Rows 1, 7, 13 and 14 consist of solid-fill colour patches, which are used to evaluate changes in colour quality. Rows 2 to 6 and 8 to 12 consist of colour patches with a fine checkerboard pattern of interleaved colour squares which manifest colour changes that correlate well with loss of line quality caused by lateral migration of colorants.

This test target was created to measure both colour and tone change and blur of the checkerboard pattern. The change in the CIELAB colorimetric value of each patch in Figure 1 caused by humidity exposure shall be measured as specified in Clause 8.

It is recommended that a printed reference be kept in a freezer after conditioning and that it be used for the additional visual evaluation, comparing it to the humidity-exposed samples. The freezer should comply with the cold storage conditions given in ISO 18920, ensuring in particular that the humidity is less than 50 %RH. The measurement of the colorimetric value of CIELAB of the checkerboard pattern is not always accurate in detecting line profile change as it cannot detect image sharpness loss if there is no colorimetric change in the checkerboard pattern.

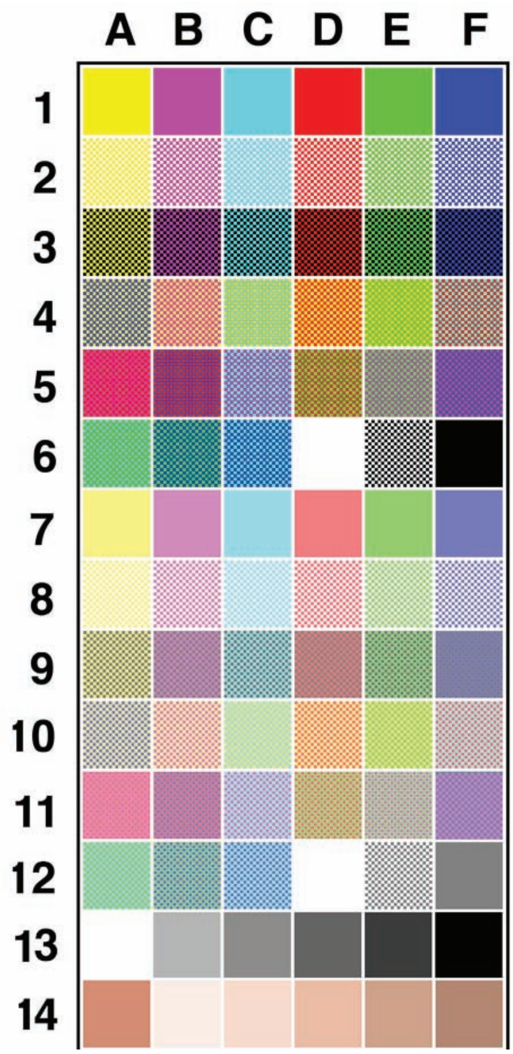


Figure 1 — Test target for humidity fastness test

6.3 Printer driver setting

When making prints for the humidity test, the manufacturer's recommended printer driver settings for each applicable medium should be used. Other printer driver settings may be used depending on the objectives of the test. The driver setting used shall be reported.

The standard target file shall be used, with no density or colour adjustment, when preparing the test samples.

6.4 Printing conditions

The test samples shall be printed in accordance with the manufacturer's recommended procedures for each printing system. The temperature and humidity for printing shall be (23 ± 2) °C and (50 ± 10) %RH.

6.5 Sample conditioning

The printed samples shall be conditioned for (24 ± 2) h at (23 ± 2) °C and (50 ± 5) %RH before humidity exposure, positioned with unrestricted airflow. This is not mandatory for traditional chromogenic prints and electrophotographic prints. These prints shall be prepared within one month of the starting time of the test.

Although it is common to condition printed samples for two weeks before the image stability test, this test method stipulates a shorter conditioning time. This better replicates actual user practice and accounts for the fact that most inkjet manufacturers recommend drying prints for 24 h or overnight before framing or placing in an album. In some systems, prolonged conditioning can improve humidity fastness by removing not only water from the media, but also organic solvents in the ink, both of which can contribute to the diffusion of colorants.

The sample holding environment shall be ozone-free [≤2 nl/l average ozone concentration over any 24 h period] for ozone-sensitive samples, as determined in accordance with ISO 18941. A material that is not sensitive to ozone shall have demonstrated no measurable D_{min} or printed patch colour change at ambient ozone exposure levels and measurement condition temperature and humidity, over time periods consistent with measurement and test-staging time periods.

7 Humidity exposure

7.1 Equipment and calibration

A test chamber which can control temperature and humidity to within the specifications described below shall be used.

Each test chamber shall be calibrated for relative humidity control and measurement accuracy by using a chilled mirror hygrometer or other type of measurement device as stipulated in ISO 18931. 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.

7.2 Test environment control

The relative humidity shall be maintained and controlled throughout testing with an operational fluctuation of within ±3 %RH of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±1 %RH of aim. The running average shall not include the test condition transition time (of not more than 1 h) after operation at the test condition has been initiated. Operational uniformity of the equipment at the test conditions shall be evaluated prior to the start of the test and shall be within ±3 %RH of aim, at a constant 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.

The air temperature shall be maintained and controlled throughout testing with an operational fluctuation of within ±2,0 °C of aim. The 24 h running average of the operational fluctuation, sampled at least every 15 min, shall be within ±1,0 °C of aim. The running average shall not include the test condition transition time (of not more than 1 h) after operation at the test condition has been initiated. Operational uniformity of the equipment at the test conditions shall be evaluated prior to the start of the test and shall be within ±2,0 °C of aim. Regions of the test chamber shall be selected 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.

The airflow shall be sufficiently high to produce uniform temperature and humidity conditions in the chamber.

The test chamber design shall be such that it eliminates the possibility of light exposure on the print surface.

Because of the potential sensitivity to air pollution for some imaging materials, the tests described in this International Standard shall be run in as near to pollutant-free conditions as possible. One way to comply with the requirement for pollutant-free conditions is to use humidified environmental chambers in a laboratory with an average ozone concentration of <2 nl/l over any 24 h test period.

Recent work has shown that, for those materials studied (and especially so for the porous inkjet media), the effects once thought to be light-fade reciprocity failure are actually dark interactions of atmospheric pollutants with the prints[19]. Separate testing for sensitivity to atmospheric pollutants shall be conducted following the methods specified in ISO 18941.

7.3 Method A — Fixed humidity condition

The print samples shall be held at 25 °C and 85 %RH for a given period of time. Four weeks is the recommended duration. One, two or eight week durations can be used. The test duration used shall be reported. Other test conditions for the temperature and humidity may be also applied depending on the purpose of the test, e.g. 30 °C or 40 °C for the temperature and 70 %RH, 80 %RH or 90 %RH for the humidity. Colorimetric measurements shall be done before and after the humidity exposures.

7.4 Method B — Multiple humidity conditions

The print samples shall be held at 25 °C for two weeks at three or more humidity levels chosen from 60, 65, 70, 75, 80, 85, 90 and 95 %RH.

Colorimetric measurements shall be done before and after the two-week humidity exposures. It is recommended that measurements also be done at one week.

7.5 Method C — Fixed low-humidity condition

The print samples shall be held at 25 °C at 20 %RH for up to six months. Colorimetric measurements shall be done before and after the humidity exposures for up to six months. Although low humidities have been shown to primarily affect the colorimetry of the D_{min} (white) patches, the colour patches on lines 1, 7, 13 and 14 of the test target should also be measured.

8 Colorimetric measurement

Patches A1 to F14 shall be measured as follows.

Measurements, and the holding of samples for measurement and next test phase preparation, shall be conducted either in a controlled environment with no time constraint [see list item a)] or in a less controlled environment with a time constraint [see list item b)]. The measurement environment and sample holding environment can influence measured densities.

a) The controlled environment with no time constraint shall meet the following conditions.

   1) Samples shall be kept in dark conditions of (23 ± 2) °C and (50 ± 10) %RH while waiting for measurements to be taken and while holding between test stages. The sample holding environment shall be ozone-free (≤2 nl/l average ozone concentration over any 24 h period) for ozone-sensitive samples, as determined in accordance with ISO 18941. A material that is not sensitive to ozone shall have demonstrated no measurable D_{min} or printed patch colour change at ambient ozone exposure levels and measurement condition temperature and humidity, over time periods consistent with measurement and test-staging time periods.

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

b) When sample holding or measurement, or both, are conducted in the less controlled environment, samples 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 of 75 %RH and 30 °C, with an ambient illuminance on the sample surface of up to 1 000 lx.

NOTE 1 Stray light decreases the accuracy of measurements taken in less controlled lighting environments[20][21]. 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.

The colour difference shall be measured using the M0 measurement condition of ISO 13655 for the relative spectral power distribution of the flux incident on the specimen surface. White backing is recommended in accordance with ISO 13655. Report the backing used or report the material opacity, according to ISO 2471, such that the backing has no influence on the measurement. Measurement conditions shall be consistent throughout the testing process. In accordance with ISO 13655, calculated tristimulus values and corresponding CIELAB values shall be computed using CIE illuminant D50 and the CIE 1931 standard colorimetric observer (often referred to as the 2° standard observer).

NOTE 2 With completely opaque materials, such as the aluminium substrate used in outdoor testing, the backing has no relevance.

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 as 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 such as those currently under test, may be used when the original instrument is not available. In this case, all measurements shall be corrected with the known offset.

NOTE 3 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 BCRA (British Ceramic Research Association) tiles. Refer to ISO 18920 for cold storage methods.

9 Data analysis

Patches A1 to F14 shall be measured as described in Clause 8, before and after the humidity exposures.

L*a*b* values for each patch, measured after the humidity exposure test, are compared to values measured after sample conditioning prior to humidity exposure.

ΔE^*_{ab} is calculated using the following equation:

$$\Delta E^*_{\mathrm{ab}} = \sqrt{(L_t^* - L_0^*)^2 + (a_t^* - a_0^*)^2 + (b_t^* - b_0^*)^2} \quad (1)$$

where L*, a*, and b* are the colour coordinates at the initial time 0 and at time t, as defined in ISO 11664-4 (see also ISO 11664-1 and ISO 11664-2).

In this test method, the initial values thus refer to measurements made on each colour patch just after sample conditioning, and values at time t are the data for the corresponding patches re-measured after humidity incubation at time t.

$\overline{\Delta E}$ is the average of the ΔE values of the 84 patches (A1 to F14) shown in Figure 1. $\overline{\Delta E}$ shall be calculated as follows:

$$\overline{\Delta E} = \sum \frac{\Delta E^*_{\mathrm{ab}}(i)}{84} \quad (2)$$

where

i	is A1 to F14;
$\Delta E^*_{ab}(i)$	is the ΔE^*_{ab} value of the ith patch in the 84 patches of the test target shown in Figure 1.

10 Test report

10.1 General

Reporting based singly on this test method shall be restricted to reporting the specific humidity fastness test result and shall include reporting of the humidity (%RH) and temperature test conditions, and the test time duration.

Users are cautioned that results from this test method apply only to the specific system tested. For example, in inkjet systems, a specific ink used with a specific paper may have very different results from another. The test report shall include this disclaimer.

10.2 Samples information

The following sample information shall be reported:

— for digital output samples, 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 colorant used (manufacturer's name and part number);

— the paper used (manufacturer's name and model number) and any other necessary information;

— for silver-halide-based samples, the processing conditions (i.e. chemicals, procedures), such that the print file can be reproduced by another user of this International Standard.

10.3 Test conditions

The following test conditions shall be reported:

a) temperature, humidity, duration and airflow (if known) for humidity exposure;

b) type of colorimeter or spectrophotometer, light source and measuring parameter.

10.4 Results

10.4.1 General

The values of $\overline{\Delta E}$ shall be reported.

NOTE The colour difference, ΔE, which is measured on the checkerboard patches after humidity exposure, is used as an indirect measure of colour bleed. The standard interpretation of ΔE values in terms of "just noticeable" colour differences is thus not applicable. Instead, a specific correlation between ΔE and visual perception of blurriness (loss of sharpness) and tonal changes due to humidity-induced bleed has been determined for the purpose of this International Standard. According to a psychophysical study[11], the change which affects the value of the actual photograph corresponds to a $\overline{\Delta E}$ of 7. However, this International Standard does not refer to any criteria, because these vary depending on the scenes captured or the usage of the photographic prints.

An example of the correlation between psychophysical evaluation and $\overline{\Delta E}$ is demonstrated in Annex A.

10.4.2 Method A

The values of $\overline{\Delta E}$ for one, two, four or eight weeks' humidity exposure shall be reported.

10.4.3 Method B

The values of $\overline{\Delta E}$ for two weeks' humidity exposure at each relative-humidity level tested shall be reported.

10.4.4 Method C

The values of $\overline{\Delta E}$ for up to six months' test duration shall be reported.

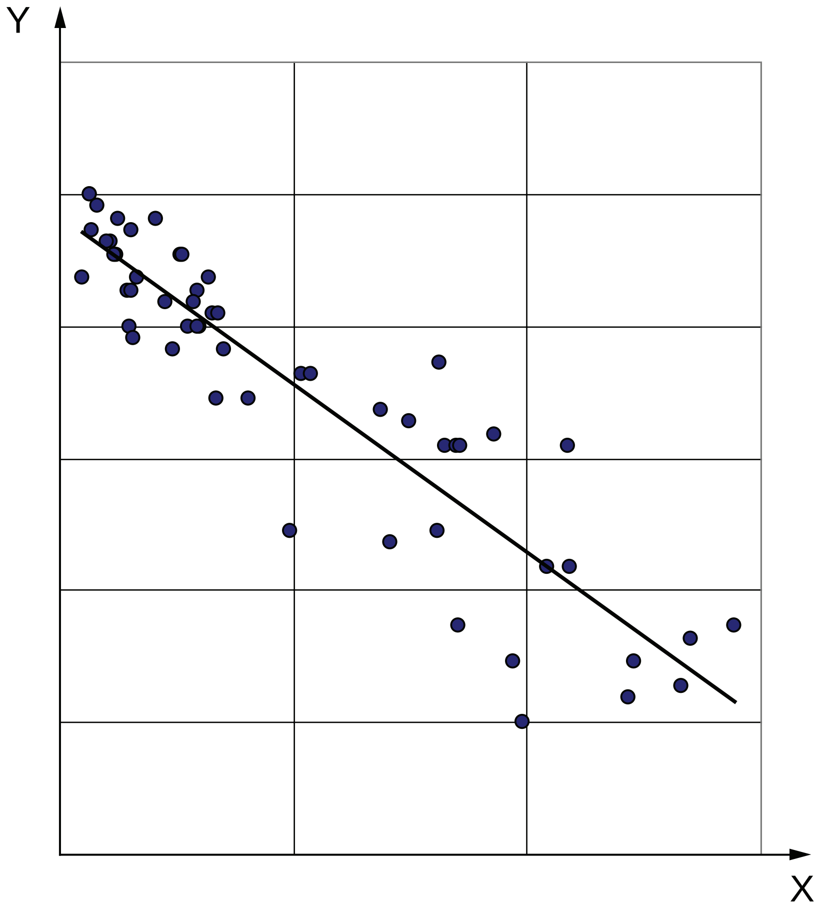
Annex A
(informative)

Correspondence to psychophysical evaluation

The test methods described in this International Standard provide $\overline{\Delta E}$ as the test results. The correlation between this value and the psychophysical evaluation is demonstrated in this annex.

The details of the test evaluation and the psychophysical evaluation demonstrated here are described in Reference [11]. The humidity test target and photographic images of a portrait, a landscape and a snapshot were printed with a total of 14 inkjet materials. Those prints were exposed to humidity in several different conditions. The psychophysical evaluation was performed by ten people with experience in evaluating printed images. The set of the exposed print and the fresh print was compared side by side and evaluated.

The correlation between the psychophysical evaluation to the measured and calculated $\overline{\Delta E}$ is shown in Figure A.1.



X $\overline{\Delta E}$ (left to right = small to large)

Y psychophysical score (bottom to top = low to high)

NOTE The scale used for the psychophysical evaluation and other details are described in Reference [11].

Figure A.1 — Correlation between psychophysical evaluation to $\overline{\Delta E}$

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