BS ISO 18909:2022

BSI Standards Publication

Photography — Processed photographic colour films and paper prints — Methods for measuring image stability

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National foreword

This British Standard is the UK implementation of ISO 18909:2022. It supersedes BS ISO 18909:2006, which is withdrawn.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 committee manager.

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Published by BSI Standards Limited 2022

ISBN 978 0 539 18465 5

ICS 37.040.20

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 August 2022.

Amendments/corrigenda issued since publication

Date	Text affected

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INTERNATIONAL STANDARD

ISO 18909

Second edition
2022-02

Photography — Processed photographic colour films and paper prints — Methods for measuring image stability

Photographie — Films et papiers photographiques couleur traités — Méthodes de mesure de la stabilité de l'image

Reference number
ISO 18909:2022(E)

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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 (see www.iso.org/directives).

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

This second edition cancels and replaces the first edition (ISO 18909:2006), of which it constitutes a minor revision. The changes are as follows:

— a corrigendum published in 2006 has been incorporated, and

— updates have been made to align and compliment test methods for digital print materials.

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Introduction

This document is divided into two parts. The first covers the methods and procedures for predicting the long-term, dark storage stability of colour photographic images; the second covers the methods and procedures for measuring the colour stability of such images when exposed to light of specified intensities and spectral distribution, at specified temperatures and relative humidities.

Today, the majority of continuous-tone photographs are made with colour photographic materials. The length of time that such photographs are to be kept can vary from a few days to many hundreds of years and the importance of image stability can be correspondingly small or great. Often the ultimate use of a particular photograph may not be known at the outset. Knowledge of the useful life of colour photographs is important to many users, especially since stability requirements often vary depending upon the application. For museums, archives, and others responsible for the care of colour photographic materials, an understanding of the behaviour of these materials under various storage and display conditions is essential if they are to be preserved in good condition for long periods of time.

Organic cyan, magenta and yellow dyes that are dispersed in transparent binder layers coated on to transparent or white opaque supports form the images of most modern colour photographs. Colour photographic dye images typically fade during storage and display; they will usually also change in colour balance because the three image dyes seldom fade at the same rate. In addition, a yellowish (or occasionally other colour) stain may form and physical degradation may occur, such as embrittlement and cracking of the support and image layers. The rate of fading and staining can vary appreciably and is governed principally by the intrinsic stability of the colour photographic material and by the conditions under which the photograph is stored and displayed. The quality of chemical processing is another important factor. Post-processing treatments, such as application of lacquers, plastic laminates and retouching colours, may also affect the stability of colour materials.

The two main factors that influence storage behaviour, or dark stability, are the temperature and relative humidity of the air that has access to the photograph. High temperature, particularly in combination with high relative humidity, will accelerate the chemical reactions that can lead to degradation of one or more of the image dyes. Low-temperature, low-humidity storage, on the other hand, can greatly prolong the life of photographic colour images. Other potential causes of image degradation are atmospheric pollutants (such as oxidizing and reducing gases), micro-organisms and insects.

Primarily the intensity of the illumination, the duration of exposure to light, the spectral distribution of the illumination, and the ambient environmental conditions influence the stability of colour photographs when displayed indoors or outdoors. (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 (UV) 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 resin-coated (RC) paper supports.

In practice, colour photographs are stored and displayed under varying combinations of temperature, relative humidity and illumination, and for different lengths of time. For this reason, it is not possible to precisely predict the useful life of a given type of photographic material unless the specific conditions of storage and display are known in advance. Furthermore, the amount of change that is acceptable differs greatly from viewer to viewer and is influenced by the type of scene and the tonal and colour qualities of the image.

After extensive examination of amateur and professional colour photographs that have suffered varying degrees of fading or staining, no consensus has been achieved on how much change is acceptable for various image quality criteria. For this reason, this document does not specify acceptable end-points for fading and changes in colour balance. Generally, however, the acceptable limits are twice as wide for changes in overall image density as for changes in colour balance. For this reason, different criteria have been used as examples in this document for predicting changes in image density and colour balance.

Pictorial tests can be helpful in assessing the visual changes that occur in light and dark stability tests, but are not included in this document because no single scene is representative of the wide variety of scenes actually encountered in photography.

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In dark storage at normal room temperatures, most modern colour films and papers have images that fade and stain too slowly to allow evaluation of the dark storage stability simply by measuring changes in the specimens over time. In such cases, too many years would be required to obtain meaningful stability data. It is possible, however, to assess in a relatively short time the probable long-term fading and staining behaviour at moderate or low temperatures by means of accelerated ageing tests carried out at high temperatures. The influence of relative humidity also can be evaluated by conducting the high-temperature tests at two or more humidity levels.

Similarly, 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 specimens and their moisture content shall be controlled throughout the test period, and the types of light sources shall be chosen to yield data that can be correlated satisfactorily with those obtained under conditions of normal use.

Accelerated light stability tests for predicting the behaviour of photographic colour images under normal display conditions may be complicated by reciprocity failure. When applied to light-induced fading and staining of colour images, reciprocity failure refers to the failure of many dyes to fade, or to form stain, equally when dyes are 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 (see Reference [1]). The extent of dye fading and stain formation can be greater or smaller under accelerated conditions, depending on the photochemical reactions involved in the dye degradation, the kind of dye dispersion, the nature of the binder material, and other variables. For example, the supply of oxygen that can diffuse from the surrounding atmosphere into a photograph's image-containing emulsion layers may be restricted in an accelerated test (dry gelatin is an excellent oxygen barrier). This may change the rate of dye-fading relative to that which would occur under normal display conditions. The temperature and moisture content of the test specimen also influence the magnitude of reciprocity failure. Furthermore, light fading is influenced by the pattern of irradiation (continuous versus intermittent) as well as by light/dark cycling rates.

For all these reasons, long-term changes in image density, colour balance and stain level can be reasonably estimated only for conditions similar to those employed in the accelerated tests, or when good correlation has been confirmed between accelerated tests and actual conditions of use.

In order to establish the validity of the test methods for evaluating the dark and light stability of different types of photographic colour films and papers, the following product types were selected for the tests:

a) colour negative film with incorporated oil-soluble couplers;

b) colour negative motion picture pre-print and negative films with incorporated oil-soluble couplers;

c) colour reversal film with incorporated oil-soluble couplers;

d) colour reversal film with incorporated Fischer-type couplers;

e) colour reversal film with couplers in the developers;

f) silver dye-bleach film and prints;

g) colour prints with incorporated oil-soluble couplers;

h) colour motion picture print films with incorporated oil-soluble couplers;

i) colour dye imbibition (dye transfer) prints;

j) integral colour instant print film with dye developers;

k) peel-apart colour instant print film with dye developers;

l) integral colour instant print film with dye releasers.

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The results of extensive tests with these materials showed that the methods and procedures of this document can be used to obtain meaningful information about the long-term dark stability and the light stability of colour photographs made with a specific product. They also can be used to compare the stability of colour photographs made with different products and to access the effects of processing variations or post-processing treatments. The accuracy of predictions made on the basis of such accelerated ageing tests will depend greatly upon the actual storage or display conditions.

It should also be remembered that density changes induced by the test conditions and measured during and after the tests include those in the film or paper support and in the various auxiliary layers that may be included in a particular product. With most materials, however, the major changes occur in the dye image layers.

Stability when stored in the dark

The tests for predicting the stability of colour photographic images in dark storage are based on an adaptation of the Arrhenius method described by Bard *et al.*[2][3]) and earlier references by Arrhenius, Steiger and others (see References [4], [5] and [6]). Although this method is derived from well-understood and proven theoretical precepts of chemistry, the validity of its application for predicting changes of photographic images rests on empirical confirmation. Although many chromogenic-type colour products yield image-fading and staining data in both accelerated and non-accelerated dark ageing tests that are in good agreement with the Arrhenius relationship, some other types of products do not.

NOTE For example, integral-type instant colour print materials often exhibit atypical staining at elevated temperatures; treatment of some chromogenic materials at temperatures above 80 °C and 60 % RH can cause loss of incorporated high-boiling solvents and abnormal image degradation; and the dyes of silver dye-bleach images deaggregate at combinations of very high temperature and high relative humidity, causing abnormal changes in colour balance and saturation (see Reference [7]). In general, photographic materials tend to undergo dramatic changes at relative humidities above 60 % (especially at the high temperatures employed in accelerated tests) owing to changes in the physical properties of gelatin.

Stability when exposed to light

The methods of testing light stability in this document are based on the concept that increasing the light intensity without changing the spectral distribution of the illuminant or the ambient temperature and relative humidity should produce a proportional increase in the photochemical reactions that occur at typical viewing or display conditions, without introducing any undesirable side effects.

However, because of reciprocity failures that are discussed in this Introduction, this assumption does not always apply. Thus, the accelerated light stability test methods described in this document are valid at the specified accelerated test conditions, but may not reliably predict the behaviours of a given product in long-term display under normal conditions.

Translucent print materials, designed for viewing by either reflected or transmitted light (or a combination of reflected and transmitted light), shall be evaluated as transparencies or as reflection prints, depending on how they will be used. Data shall be reported for each condition of intended use.

This document does not specify which of the several light stability tests is the most important for any particular product.

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Photography — Processed photographic colour films and paper prints — Methods for measuring image stability

1 Scope

This document describes test methods for determining the long-term dark storage stability of colour photographic images and the colour stability of such images when subjected to certain illuminants at specified temperatures and relative humidities.

This document is applicable to colour photographic images made with traditional, continuous-tone photographic materials with images formed with dyes. These images are generated with chromogenic, silver dye-bleach, dye transfer, and dye-diffusion-transfer instant systems. The tests have not been verified for evaluating the stability of colour images produced with dry- and liquid-toner electrophotography, thermal dye transfer (sometimes called dye sublimation), ink jet, pigment-gelatin systems, offset lithography, gravure and related colour imaging systems. If these reflection print materials, including silver halide (chromogenic), are digitally printed, refer to ISO 18936, ISO 18941, ISO 18946, and ISO 18949 for dark stability tests, and the ISO 18937 series for light stability tests.

This document does not include test procedures for the physical stability of images, supports or binder materials. However, it is recognized that in some instances, physical degradation such as support embrittlement, emulsion cracking or delamination of an image layer from its support, rather than image stability, will determine the useful life of a colour film or print material.

2 Normative references

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

ISO 5-2, *Photography and graphic technology — Density measurements — Part 2: Geometric conditions for transmittance density*

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 18911, *Imaging materials — Processed safety photographic films — Storage practices*

ISO 18913, *Imaging materials — Permanence — Vocabulary*

3 Terms and definitions

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

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

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

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

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4 Test methods — General

4.1 Sensitometric exposure

The photographic material shall be exposed and processed in accordance with the manufacturer's recommendations to obtain areas (patches) of uniform density at least 5 mm × 5 mm. This document requires measuring the changes in colour densities in minimum density areas, d_{min}, and at a density of 1,0 ± 0,05 above d_{min}. These changes are to be monitored in neutral areas, i.e. where the initial red, green and blue densities are approximately equal (above their respective d_{min}, as well as in areas selectively exposed to produce the purest possible cyan, magenta and yellow dye scales[1)]. These shall be made with the aid of appropriate filters (see Table 1).

The desired density may be obtained from a single precise exposure or from a continuous wedge exposure. Alternatively, if it is more convenient (e.g. with automated densitometry), the starting densities of 1,0 above d_{min} may be interpolated from other densities (one way to do this is described in Annex A).

Table 1 — Suitable filters for exposing test specimens

Type of material[a]	Filters to generate (e.g. Kodak Wratten filters[b] or Fuji filters[c])		
	Cyan dye	**Magenta dye**	**Yellow dye**
Reversal and direct positive	Minus red	Minus green	Minus blue
	Wratten 44 Fuji SP-5	Wratten 32 Fuji SP-4 or SP-12	Wratten 12 Fuji SC-50 or SC-52
Negative working	Red	Green	Blue
	Wratten 29 Fuji SC-62	Wratten 99 Fuji BPN-55	Wratten 47B Fuji BPB-42

[a] If materials to be tested have unusual spectral sensitivity characteristics, consult the manufacturer for filter recommendations.

[b] *Kodak Filters for Scientific and Technical Uses,* Kodak Publication No. B-3, Eastman Kodak Company, Rochester, New York, USA; 1985. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

[c] *Fujifilm Filter "Optical,"* Fuji Photo Film Co., Ltd., Tokyo, Japan; 1993. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

4.2 Processing

The sensitometrically exposed specimens shall be processed using the processing system of primary interest.

The processing chemicals and processing procedure can have a significant effect on the dark-keeping and/or light-keeping stability of a colour photographic material. For example, a chromogenic colour negative print paper processed in a washless or non-plumbed system with a stabilizer rinse bath instead of a water wash probably has stability characteristics that are different from the same colour paper processed in a conventional 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.

1) Because of optical or chemical interactions, a neutral patch or a patch with a colour composed of a mixture of two dyes, e.g. red, green or blue, often exhibit stability effects that are different from pure cyan, magenta or yellow dye patches. This situation is particularly likely to occur when images are subjected to light fading.

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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. Likewise, data obtained from test specimens shall not be applied to colour materials that have been subjected to post-processing treatments (e.g. application of lacquers, plastic laminates or retouching colours) that differ from the treatments given to the test specimens.

4.3 Densitometry

Image density shall be measured with the spectral conditions specified for Status A densitometry (transparencies and reflection prints) and for Status M densitometry (negatives) as described in ISO 5-3.

Transmission density, D_T, (90° opal; S: < 10°; s) shall be measured with an instrument complying with the geometric conditions described in ISO 5-2. Reflection density, D_R, (40° to 50°; S: 5°; s) shall be measured as described in ISO 5-4.

One of the problems encountered in densitometry is the instability of the measuring devices, especially during the course of long-term tests. Some of the components of densitometers that can change appreciably with age, as well as from one unit or batch to another, are the optical filters, the light sensors and the lamps. For example, the filters in many modern densitometers will deteriorate with age and shall be replaced periodically, often within 2 years to 3 years. However, replacement filters of the same type frequently do not exactly match the original filters in spectral transmittance characteristics. Such changes in transmittance will cause unequal changes in the measured density values of dyes having different spectral absorption properties.

One way of dealing with such problems in a densitometer system is to keep standard reference specimens of each test product sealed in vapour-proof containers and stored at –18 °C or lower. These specimens can be used to check the performance of the system periodically and to derive correction factors for different products as required (the calibration standards supplied with a densitometer are not adequate for this purpose).

4.4 Definition of density terms

d is the symbol for measured density;

D is the symbol for density corrected for $d_{\min}$.

4.5 Density values to be measured

The following densities of the specimens, prepared as described in 4.1, shall be measured before and after the treatment interval (see Figure 1):

a) $d_{\min}(\mathrm{R})_t$, $d_{\min}(\mathrm{G})_t$, $d_{\min}(\mathrm{B})_t$

the red, green and blue minimum densities of specimens that have been treated for time t, where t takes on values from 0 to the end of the test;

b) $d_{\mathrm{N}}(\mathrm{R})_t$, $d_{\mathrm{N}}(\mathrm{G})_t$, $d_{\mathrm{N}}(\mathrm{B})_t$

the red, green and blue densities of neutral patches that initially had densities of 1,0 above $d_{\min}$ and that have been treated for time t, where t takes on values from 0 to the end of the test;

c) $d_{\mathrm{C}}(\mathrm{R})_t$, $d_{\mathrm{M}}(\mathrm{G})_t$, $d_{\mathrm{Y}}(\mathrm{B})_t$

the red, green and blue densities of cyan, magenta and yellow colour patches that initially had densities of 1,0 above $d_{\min}$ and that have been treated for time t, where t takes on values from 0 to the end of the test.

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4.6 Method of correction of density measurements for d_{min} changes

4.6.1 General

The areas of minimum density of many types of colour photographs change with time during dark storage, and generally to a lesser extent also change on prolonged exposure to light during display or projection. Such changes most commonly take the form of density (stain) increases, usually yellowish in colour. However, some materials, under certain conditions, may exhibit a loss in minimum density; e.g. colour negatives in dark storage.

For the purposes of this document, changes in minimum density as measured in d_{min} patches, whether increases or losses, are assumed to have occurred equally at all density levels. Therefore, in order to determine accurately the amount of dye-fading that has taken place during testing or during storage and display, it is necessary to take into account the change in the d_{min} value (see Table 2).

Table 2 — Correction of density measurements for d_{min} changes[a]

Type of material and test	Correction
Transmission materials in dark and light stability tests	Full d_{min} correction (for starting density of 1,0 above d_{min})
Reflection materials in dark and light stability tests	1/2 d_{min} correction (for starting densities of 0,7 to 1,0 above d_{min})
Reflection materials in dark and light stability tests (alternative method – see Annex B)	d_{min} correction by power formula

[a] No correction is made for d_{min} changes when determining colour balance changes of neutral patches.

Different methods of d_{min} correction are specified for transmission and reflection materials because multiple internal reflections affect the d_{min} density values obtained with reflection materials, but not those of transmission materials (see References [8] and [9]). Specifically, the multiple reflections within the image and auxiliary layers of a reflection material cause an increase in the measured value of the stain density, but have much less effect on the measured values of reflection densities in the range of 0,7 to 1,0 above d_{min}. It was determined empirically that one-half the change measured in the d_{min} value of reflection materials provides a reasonable approximation of the actual d_{min} contribution to measured reflection densities in the range of 0,7 to 1,0 above d_{min}.

For translucent materials the most common method of density measurement is transmission; however, these materials shall be measured by reflection if that is their intended use. Translucent materials with very high initial transmission d_{min} may show a loss of d_{min} with light or dark treatment. In these cases, the use of half d_{min} correction may confound the measurements and caution shall be used.

An alternative method for d_{min} correction using a multi-power relationship among stain, dye and measured densities is described in Annex B. This method is particularly useful for the correction of measured densities when relatively high stain levels are present and/or when measuring low-density levels below 0,7.

Two examples are described in a) and b) to help clarity the d_{min} correction procedures (illustrated in Figure 1 for transmission materials and Figure 2 for reflection materials).

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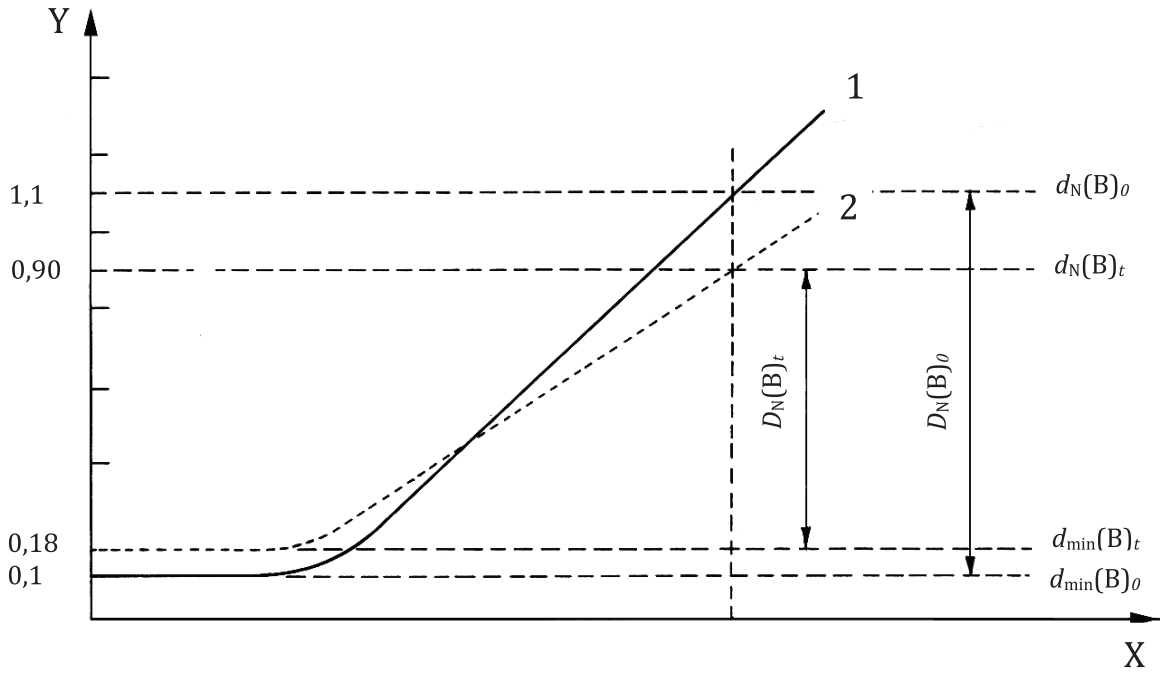

Key

X log of exposure

Y transmission density

1 before testing

2 after testing

Figure 1 — Illustration of the blue transmission density of a neutral patch of a transparency-type colour material (as defined by formulae in 4.6.2)

a) A colour transparency material tested for dark stability had a neutral patch with a starting blue density $D_N(B)_o$ of 1,0 since:

$d_N(B)_o = 1{,}1$

$d_{min}(B)_o = 0{,}1$, and therefore

$D_N(B)_o = [d_N(B)_o - d_{min}(B)_o] = 1{,}1 - 0{,}1 = 1{,}0$

After incubation for time t, the blue density $D_N(B)_t$ was 0,72 because the measured density values had changed as follows:

$d_N(B)_t = 0{,}90$

$d_{min}(B)_t = 0{,}18$, and therefore

$D_N(B)_t = [d_N(B)_t - d_{min}(B)_t] = 0{,}90 - 0{,}18 = 0{,}72$

Hence, the blue density of the neutral patch decreased by 0,28, whereas that of the minimum density patch increased (due to formation of yellowish stain) by 0,08. If the d_{min} value had increased less, or even decreased (as can occur with colour negative films, for example), the value of $d_N(B)_t$ would have changed by a different, commensurate amount. However, by subtracting the d_{min} density from the density of the neutral patch, both before and after incubation, the actual change in density of the neutral patch is determined. Similar procedures are employed to correct the cyan, magenta and yellow patches for d_{min} changes.

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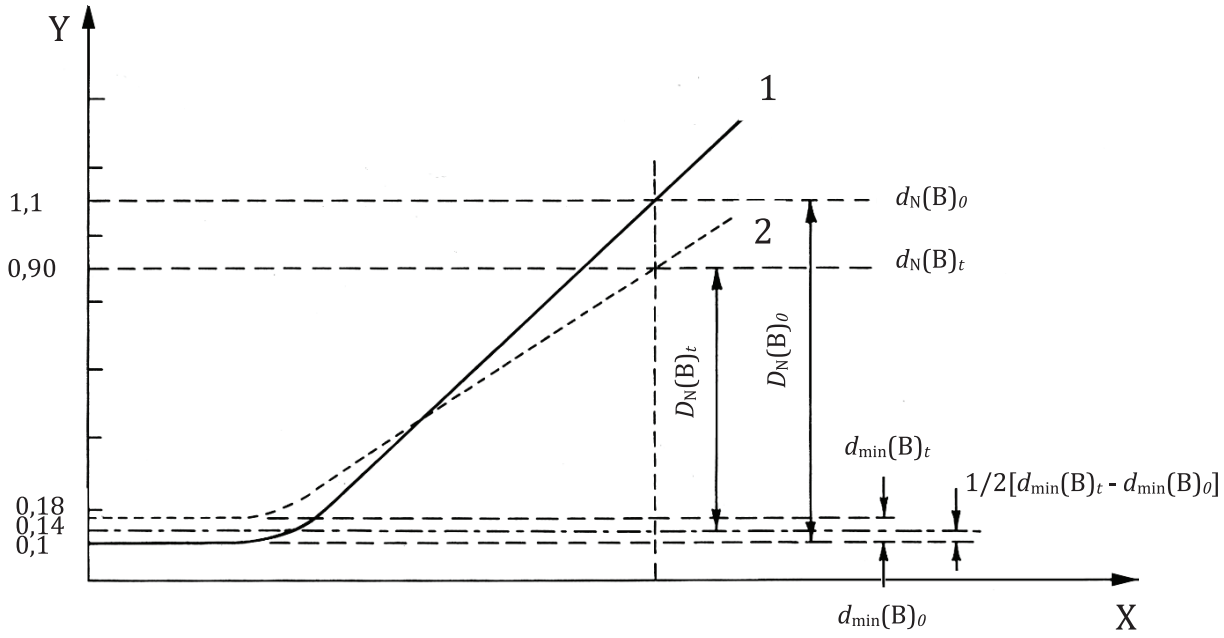

Key

X log of exposure

Y refection density

1 before testing

2 after testing

Figure 2 — Illustration of the blue reflection density of a neutral patch of a reflection-type colour material (as defined by formulae in 4.6.3)

b) A colour reflection print material tested for dark stability had a neutral patch with a starting blue density $D_N(B)_o$ of 1,0 since:

$d_N(B)_o = 1{,}1$

$d_{min}(B)_o = 0{,}1$, and therefore

$D_N(B)_o = [d_N(B)_o - d_{min}(B)_o] = 1{,}1 - 0{,}1 = 1{,}0$

After incubation for time t, the blue density $D_N(B)_t$ was 0,76 because the measured density values had changed as follows:

$d_N(B)_t = 0{,}90$

$d_{min}(B)_t = 0{,}18$, and therefore

$D_N(B)_t = d_N(B)_t - d_{min}(B)_t + ½\,[d_{min}(B)_t - d_{min}(B)_o] = 0{,}90 - 0{,}18 + ½\,(0{,}18 - 0{,}10) = 0{,}72 + 0{,}04 = 0{,}76$

Hence, the blue density of the neutral patch decreased by 0,24, whereas that of the minimum density patch increased (due to formation of yellowish stain) by 0,08. However, this increase in the measured d_{min} value was due in part to the effects of multiple internal reflections, as explained in 4.5. Therefore, a correction was made equal to + ½ the measured change of 0,08. Such a correction of + ½ d_{min} change would also have to be made if the d_{min} value had decreased rather than increased. Similar procedures are employed to correct the cyan, magenta and yellow patches for d_{min} changes.

NOTE The gradient of the two curves of Figure 2 was deliberately lowered in order to provide a clearer view of the density relations defined in the formula.

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4.6.2 Transmission density corrected for d_{min}

a) $D_N(R)_t = d_N(R)_t - d_{min}(R)_t$

b) $D_N(G)_t = d_N(G)_t - d_{min}(G)_t$

c) $D_N(B)_t = d_N(B)_t - d_{min}(B)_t$

d) $D_C(R)_t = d_C(R)_t - d_{min}(R)_t$

e) $D_M(G)_t = d_M(G)_t - d_{min}(G)_t$

f) $D_Y(B)_t = d_Y(B)_t - d_{min}(B)_t$

4.6.3 Reflection density corrected for d_{min}

a) $D_N(R)_t = d_N(R)_t - d_{min}(R)_t + 1/2\ [d_{min}(R)_t - d_{min}(R)_o]$

b) $D_N(G)_t = d_N(G)_t - d_{min}(G)_t + 1/2\ [d_{min}(G)_t - d_{min}(G)_o]$

c) $D_N(B)_t = d_N(B)_t - d_{min}(B)_t + 1/2\ [d_{min}(B)_t - d_{min}(B)_o]$

d) $D_C(R)_t = d_C(R)_t - d_{min}(R)_t + 1/2[d_{min}(R)_t - d_{min}(R)_o]$

e) $D_M(G)_t = d_M(G)_t - d_{min}(G)_t + 1/2\ [d_{min}(G)_t - d_{min}(G)_o]$

f) $D_Y(B)_t = d_Y(B)_t - d_{min}(B)_t + 1/2\ [d_{min}(B)_t - d_{min}(B)_o]$

NOTE The d_{min} correction for reflection density is identical to that for transmission density, except that it includes a back correction equal to one half the d_{min} gain.

4.6.4 Colour balance in a neutral density patch

These are calculated as the percent of the average density.

a) $$d_N(R-G)_t = \frac{d_N(R)_t - d_N(G)_t}{0{,}5[d_N(R)_t + d_N(G)_t]} \times 100\ \%$$

b) $$d_N(R-B)_t = \frac{d_N(R)_t - d_N(B)_t}{0{,}5[d_N(R)_t + d_N(B)_t]} \times 100\ \%$$

c) $$d_N(G-B)_t = \frac{d_N(G)_t - d_N(B)_t}{0{,}5[d_N(G)_t + d_N(B)_t]} \times 100\ \%$$

4.6.5 d_{min} changes

a) $d_{min}(R)_t - d_{min}(R)_o$

b) $d_{min}(G)_t - d_{min}(G)_o$

c) $d_{min}(B)_t - d_{min}(B)_o$

4.6.6 d_{min} colour balance

a) $d_{min}(R - G)_t = d_{min}(R)_t - d_{min}(G)_t$

b) $d_{min}(R - B)_t = d_{min}(R)_t - d_{min}(B)_t$

c) $d_{min}(G - B)_t = d_{min}(G)_t - d_{min}(B)_t$

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4.7 Computation of image-life parameters

From the measured density values, five image-life parameters can be computed (see Figure 1 for transmission materials and Figure 2 for reflection materials). These image-life parameters and illustrative end-points are listed in Table 3.

Table 3 — Image-life parameters for which times shall be reported

Parameters	Illustrative end-points for positive colour transparencies and reflection colour images	Illustrative end-points for colour negative materials
Change in neutral patches of D_N(R), D_N(G), and D_N(B) (d_{min} corrected)	30 %	15 %
Change in colour patches of D_C(R), D_M(G), and D_Y(B) (d_{min} corrected)	30 %	15 %
Change in colour balance of neutral patch: % D_N(R − G), % D_N(R − B), and % D_N(G − B) (not d_{min} corrected)	15 %	15 %
Change in d_{min}(R), d_{min}(G), and d_{min}(B) in the d_{min} patch	0,10	0,05
Change in colour balance: d_{min}(R − G), d_{min}(R − B) and d_{min}(G − B) in the d_{min} patch	0,06	0,05
NOTE The image-life parameters listed are the critical characteristics that have practical significance for the visual degradation of colour images; however, the numerical end-points given here are only illustrative. Each user of this document shall select end-points for the listed parameters, which, in that user's judgement, are appropriate for the specific product and intended application. Selected end-points may be different for light and dark stability tests.		

4.8 Effects of dye fading and stain formation on the printing quality of colour negative images

The printing quality of colour negative images is mainly governed by three factors:

— the colour printing densities of its image dyes;

— the overall contrast and the contrast balance of these images;

— the colour printing density of the masking dyes and the stain.

Any change in these properties, whether due to dye fading, changes in dye morphology or discolouration of residual substances, has a greatly amplified effect on the final image because most colour print materials have high inherent contrast. The most damaging change tends to be contrast balance distortions brought about by differential fading of the three image dyes. 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 light-fading of the negative's magenta image dye, or from yellow to blue (colour negatives) or cyan to red (recent generations of colour negatives) due to dark-fading of the yellow or cyan dye. Generally, the acceptable deviation from essentially equal contrast values of all three dye images varies from 0,10 to 0,15, depending on the scene content, on the inherent contrast values of the negative and associated positive material, and on the conditions under which the print image is viewed. For instance, the tolerance of colour shifts is much smaller with reflection prints viewed in normal surround conditions than with projected images viewed in a dark room.

The second most consequential change is that caused by an increase in stain (discolouration of residual colour couplers and/or residual processing chemicals, etc.) and/or fading of masking dyes. This is so because the combined colour density of the stain and masking dyes governs the colour and density of low-density image areas and non-image areas of the negative and, thereby, its printing filter balance. They also affect the colour balance in high-density image areas. Changes in the d_{min} colour balance of colour negatives of more than 0,05 result in appreciable changes in the colour balance of prints unless compensating adjustments are made in the ratios of blue, green and red exposure of the print materials. The required compensation usually is determined with colour analysers as part of the overall evaluation of the printing characteristics of individual or related sequences of images. The output of such colour

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analysis systems is used to control print exposures directly in automatic printers, and indirectly in manual or semi-automatic printers.

Depending on the magnitude of the d_{min} imbalance, the colour rendition in shadow areas of the print image may vary from acceptable to unacceptable. Usually a change of 15 % in d_{min} balance borders on the unacceptable.

The printing densities of colour negative image dyes usually change as a result of dark fading rather than light fading, because normally only a few prints are made from original camera negatives and this involves only modest aggregate exposure to light. This is true with most still-camera negative films and is also true with most motion picture camera colour negative films, because the latter serve only as masters for the generation of a small number of intermediate colour negative films. It is these motion picture intermediate films, which often are used to print large numbers of positive release prints, and the release prints themselves which may receive appreciable light exposure.

The dark-fading of image dyes typically results in a proportional loss of density at all density levels, without significant changes in spectral absorption. The practical effect of such change is a loss in image contrast. Contrast losses of up to 0,15 are tolerable with many scenes, provided that reasonable grey balance is maintained throughout the tone scale.

5 Test methods — Dark stability

5.1 Introduction

Long-term dark stability is evaluated by a series of tests carried out at several elevated temperatures at a particular relative humidity. Where practical, a useful relative humidity at which to test is 50 %.

Two test methods, known as the sealed-bag and the free-hanging methods, are available for accelerated dark stability testing. These test methods, which simulate two kinds of storage conditions, tend to give somewhat different results (see Reference [10]). In one, the photographic material is stored in a sealed container with very little air. Any substance released by the photographic material is trapped inside the container and can interact with the image or support. For example, with cellulose acetate base motion picture films stored in closed metal or plastic film cans, the fading of the dye images may be accelerated by the presence of acetic acid generated by the degradation of the acetate film base. This condition is best simulated by the sealed-bag method, in which preconditioned specimens are sealed in a moisture-proof bag from which most of the air has been expelled. An appropriate number of such bags is placed in ovens maintained at different test temperatures to permit specimen evaluation at periodic intervals until at least one predetermined end-point has been reached for the image-life parameters listed in Table 3.

The second storage condition is simulated by the free-hanging method, in which the specimens are suspended in a relatively large test chamber at a sufficient distance from each other to ensure free access of the circulating air to all surfaces.

The choice of test method shall be based on the known properties of the photographic materials being evaluated and the expected storage conditions of these materials. For example, motion picture films normally are stored in closed metal or plastic cans and, therefore, should be evaluated with the sealed-bag method. This method also provides a better simulation of the storage environment of still-camera colour films placed in plastic sleeves in strip or roll form as well as when the films are stored in roll form. However, the free-hanging method usually is more representative of the keeping conditions for mounted 35 mm and 6 cm × 6 cm colour slides and reflection colour prints.

5.2 Test conditions

At least four different temperatures shall be used at any one humidity level. The temperature range shall be at least 20 °C, preferably wider, and the temperature intervals shall be approximately equal, e.g. 55 °C, 65 °C, 75 °C, and 85 °C. The tolerance shall be ±0,5 °C. The lower the temperature, the closer

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the approximation to normal storage conditions but the longer the time required to reach the image-life parameter end-points chosen for the test.

In general, a relative humidity of 50 % is used for these tests. The relative humidity of the test shall be maintained within ±5 % RH of the aim value. Because the effects of humidity on image stability can differ markedly from one product to another, it is useful to evaluate its effect. This is done by means of a temperature test series carried out at different relative humidities.

If the relative humidity during storage is expected to be significantly lower than 50 % RH, such as when stored in accordance with ISO 18911 or in an arid climate, or significantly higher, as in a tropical climate, the relative humidity selected for the test shall correspond to the storage conditions. Such tests are often conducted at 30 % RH or 70 % RH.

At relative humidities above 50 %, misleading results may be obtained, especially at the high temperatures employed in accelerated tests, because of significant changes in the physical and/or chemical properties of some components of photographic imaging layers. For example, photographic gelatin changes from a solid to a gel state (glass transition temperature, T_g) at about 50 °C and 50 % RH. In the gel state, the structure and distribution of the image and masking dyes may change with consequent changes in spectral absorption and/or covering power. An example of this is the de-aggregation of the dyes in silver dye-bleach images which occurs at above 60 % RH and 70 °C. This causes changes in hue and colour density. Another example is the initial increase in density of some masking dyes in colour negative films due to physical changes, followed by a density decrease due to chemical transformation into colourless species (see Reference [11]). This multiple mechanism may come into play only in accelerated ageing tests and, if so, precludes accurate predictions of ageing behaviour under normal storage conditions. Furthermore, ferrotyping and other physical defects may be induced at elevated temperatures and humidities.

Disproportionate increases or decreases in density values and/or pronounced changes in the appearance of the test specimens usually indicate the deleterious effects of high temperature treatment. Data derived from such specimens shall be excluded from the computation of the test results.

The user of this document shall be aware that the moisture content (by weight) of the specimens would differ somewhat with the two test methods, especially at the highest oven temperatures (see Reference [12]). With the sealed-bag method, the moisture content of the specimens will remain essentially constant, irrespective of oven temperature (the relative humidity, however, generally will increase). With the free-hanging method, the actual moisture content of the specimens will generally decrease somewhat as the temperature of the ovens is increased (this is true even though the relative humidity of the air inside the ovens is maintained at the same level at all temperatures). The influence of these differences in specimen moisture content and the glass transition temperature of the gelatin emulsion on predictions of ageing behaviour may vary depending on the photographic material, the range of oven temperatures employed and the selected relative humidity value. If, with a particular photographic material, it is suspected that small differences in specimen moisture content could have a significant impact on fading and/or staining behaviour, it may be useful to conduct tests with both methods.

5.3 Number of specimens

The specimens shall be representative of the products and modes of processing to be evaluated.

For the free-hanging test method, two specimens are required for each of at least four temperatures at a single humidity level (i.e. a minimum of eight specimens). The optical densities of these specimens are measured before incubation and at predetermined intervals thereafter, as the specimens are withdrawn from the temperature/humidity-controlled ovens. The same specimens are used throughout the test period.

For the sealed-bag test method, two specimens are required for each bag. A separate bag is needed for each of the multiple density measurements to be made during the entire test period, because specimens that have been withdrawn from an oven and removed from a bag shall not be re-bagged and further incubated. The total number of specimens and bags required to evaluate a particular product will depend on the number of withdrawals from the ovens for measurement. This number will

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