INTERNATIONAL STANDARD

**ISO
10977**

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

Contents

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.

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.

International Standard ISO 10977 was prepared by Technical Committee ISO/TC 42, *Photography*.

Annexes A, B, C, D, E and F of this International Standard are for information only.

Introduction

This International Standard addresses the stability of colour photographic images and is divided into two sections. The first section covers the methods and procedures for predicting the long-term, dark storage stability of colour photographic images. The second section covers those 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 is not 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.

The images of most modern colour photogaphs are formed by organic cyan, magenta and yellow dyes that are dispersed in transparent binder layers coated onto transparent or white opaque supports. 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 can form and physical degradation can 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, can 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.

The stability of colour photographs when displayed indoors or outdoors is influenced primarily by the intensity of the illumination, the duration of exposure to light, the spectral distribution of the illumination and the

ambient environmental conditions. (However, the normally slower dark fading and staining reactions also proceed during display periods and will contribute to the total change in image quality.) Ultraviolet radiation is particularly harmful to some types of colour photographs and can cause rapid fading as well as degradation of plastic layers such as the pigmented polyethylene layer of 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 predict precisely 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 photo-graphs that have suffered varying degrees of fading and/or staining, no consensus has been achieved on how much change is acceptable for various image quality criteria. For this reason, this International Stan-dard 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 International Standard for predicting changes in image density and in colour balance.

The actual determination of such changes is made with test strips that have been exposed and carefully processed according to the manufac-turer's recommendations to produce at least:

a) an area of minimum density, d_{min};

b) patches of uniform, neutral density of 1,0 above d_{min}; and

c) uniform density patches of cyan, magenta, or yellow dyes having red, green, or blue densities of 1,0 above d_{min}.

To simplify the preparation of test samples and the handling of data, a starting density of 1,0 above d_{min} is specified for both dark- and light-stability tests; although it is recognized that the two types of fading generally have dissimilar visual characteristics [1]. The effects of light fading, both visually and when expressed as a percentage density change, tend to be proportionally much greater in lower density portions of an image (e.g. in the range of 0,1 to 0,5 above d_{min}) than in high den-sity areas. Conversely, in dark fading the visual effects of fading are generally more noticeable in higher densities than in low densities. Density losses in dark fading, expressed as a percentage density change, tend to be more or less equal throughout the entire density range (see annex A). The user may adopt different end-points for light- and dark-stability tests to take into account the visual differences mani-fested by these two types of fading.

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

In dark storage at normal room temperatures, most modern colour films and papers have images that fade and stain too slowly to allow evalu-ation of their dark storage stability simply by measuring changes in the samples 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 behav-iour 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 samples and their moisture content are controlled throughout the test period and the types of light sources are 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 can 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 stains, equally when irradiated with high-intensity versus low-intensity light, even though the total light exposure (intensity × time) is kept constant through appropriate adjustments in exposure duration [2]. 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, on the kind of dye dispersion, on the nature of the binder material and on other variables. For example, the supply of oxygen that can diffuse into a photograph's image-containing emulsion layers from the surrounding atmosphere can be restricted in an accelerated test (dry gelatin is an excellent oxygen barrier). This can change the rate of dye fading relative to that which would occur under normal display conditions. The magnitude of reciprocity failure is also influenced by the temperature and moisture content of the test sample. Furthermore, light fading is influenced by the pattern of irradiation (continuous versus intermittent) as well as by light/dark cycling rates.

For all of these reasons, long-term changes in image density, colour balance and stain level can be estimated reasonably closely 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.

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 are included in a particular product. With most materials, however, the major changes occur in the dye image layers.

This International Standard is based on American National Standard IT9.9[1] which was the result of 11 years of testing activity in the United States in which there was active participation from Canada, Germany, Japan, Switzerland and the United Kingdom.

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1) ANSI IT9.9:1990, *Imaging media — Stability of Color Photographic Images — Methods for Measuring*.

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

1 Scope

1.1 General

This International Standard describes test equipment, test procedures and analytic methods for predicting the long-term dark storage stability of colour photographic images and measuring the colour stability of such products when subjected to certain illuminants at specified temperatures and humidities.

Because of the problems outlined in the Introduction, this International Standard does not specify limits of acceptability for the stability of colour products. Instead, it provides means for measuring image changes that takes place during the ageing of colour photographs and indicates the critical image-change parameters that should be calculated. This International Standard does not specify which of the several light-stability tests is the most important.

Throughout this International Standard, densities are expressed in dimensionless units.

1.2 Dark stability

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*. [3] [4] and earlier references by Steiger and others [5] [6] [7]. Although this method is derived from well-understood and proven theoretical precepts of chemistry, the validity of its application to 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 [2].

1.3 Light stability

The methods of testing light stability in this International Standard 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 were discussed previously, this assumption does not always apply. Thus, the accelerated light-stability test methods described in this International Standard are valid at the specified accelerated test conditions but it is possible that they do not reliably predict the behaviour of a given product in long-term display under normal conditions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards in-

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2) 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 % relative humidity can cause loss of incorporated high-boiling-point 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 [8]. 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.

dicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5-2:1991, *Photography — Density measurements — Part 2: Geometric conditions for transmission density*.

ISO 5-3:1984, *Photography — Density measurements — Part 3: Spectral conditions*.

ISO 5-4:1983, *Photography — Density measurements — Part 4: Geometric conditions for reflection density*.

3 Test methods — General

3.1 Sensitometric exposure

The photographic material shall be exposed and processed in accordance with the manufacturer's recommendations to obtain areas (patches) of uniform density of at least 5 mm × 5 mm. The changes in colour densities shall be measured in areas of minimum density, d_{min}, and in areas with a density of $1,0 \pm 0,05$ above d_{min}. These changes are to be monitored in neutral areas, i.e. where the initial red, green and blue densities are all approximately equal (above their respective values of d_{min}), as well as in areas selectively exposed to produce the purest possible cyan, magenta and yellow dye scales. 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 B).

Table 1 — Suitable filters for exposing test samples

Type of material[1]	Filters to generate[2]		
	Cyan dye	Magenta dye	Yellow dye
Reversal and direct positive	Minus red 44	Minus green 32	Minus blue 12
Negative working	Red 29	Green 99	Blue 47 B

1) If materials to be tested have unusual spectral sensitivity characteristics, consult the manufacturer for recommendations.

2) Numbers in table refer to Kodak Wratten Filters, described in *Kodak Filters for Scientific and Technical Uses*, Kodak Publication No. B-3, Eastman Kodak Company, Rochester, New York (1985).

3.2 Processing

The sensitometrically-exposed samples 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 "plumbingless" system with a stabilizer rinse bath instead of a water wash probably has different stability characteristics than 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; 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.

3.3 Densitometry

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

ISO standard transmission density, D_T (90°*opal*; S_H: $\leqslant$ 10°; *s*), shall be measured with an instrument complying with the geometric conditions as specified in ISO 5-2.

ISO standard reflection density, D_R (40° to 50°; S: 5°; *s*) shall be measured as specified in ISO 5-4.

One of the problems encountered in densitometry is the instability of the measuring device, 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 deteriorate with age and sometimes need to be replaced every 2 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

samples of each test product sealed in vapour-proof containers and stored at − 18 °C or lower. These samples 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).

3.4 Density values to be measured

The following densities of the samples prepared as described in 3.1 shall be measured before and after the treatment interval (refer to figure 1):

a) $d_{min}(R)_t$, $d_{min}(G)_t$ and $d_{min}(B)_t$ being the red, green and blue minimum densities, respectively, of samples that have been treated for time t;

b) $d_N(R)_t$, $d_N(G)_t$ and $d_N(B)_t$ being the red, green and blue densities, respectively, of neutral patches that initially had densities of 1,0 above d_{min} and that have been treated for time t;

c) $d_C(R)_t$, $d_M(G)_t$ and $d_Y(B)_t$ being the red, green and blue densities of cyan, magenta and yellow colour patches, respectively, that initially had densities of 1,0 above d_{min} and that have been treated for time t.

3.5 Correction of density for d_{min} changes

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, can exhibit a loss in minimum density e.g. colour negatives in dark storage.

For the purposes of this International Standard, changes in d_{min}, as measured in the minimum density 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 the change in d_{min} into account.

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 [9] [10]. 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 by the working group that half the change in the measured value of

d_{min} for reflection materials provides a reasonable approximation of the actual d_{min} contribution to dye densities in the range of 0,7 to 1,0 above d_{min}. The above information is summarized in table 2.

Two examples are described in 3.7.1.1 and 3.7.1.2 (illustrated in figures 1 and 2) to help clarify the d_{min} correction procedures.

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

Type of material	Correction
Transmission	d_{min}
Reflection	0,5 d_{min}

NOTES

1 The correction applies for a starting density of 1,0 above d_{min} and for both dark and light stability tests.

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

3.6 Symbols

For the purposes of the following calculations, d is used to represent the measured density and D to represent the density corrected for d_{min}.

3.7 Calculation of image-stability parameters

From the measured density values, the following parameters are calculated (see figures 1 and 2).

3.7.1 Densities corrected for d_{min}

3.7.1.1 Transmission density

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

EXAMPLE

See figure 1.

A colour transparency material tested for dark stability had a neutral patch with a starting blue density, $D_N(B)_0$, of 1,0, calculated as follows:

$d_N(B)_0 = 1,1$

$d_{min}(B)_0 = 0,1$

and so

$D_N(B)_0 = d_N(B)_0 - d_{min}(B)_0 = 1,1 - 0,1 = 1,0$

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 so

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

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 by 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 changes in d_{min}.

3.7.1.2 Reflection density[3]

a) $D_N(R)_t = d_N(R)_t - d_{min}(R)_t + 0,5[d_{min}(R)_t - d_{min}(R)_0]$

b) $D_N(G)_t = d_N(G)_t - d_{min}(G)_t + 0,5[d_{min}(G)_t - d_{min}(G)_0]$

c) $D_N(B)_t = d_N(B)_t - d_{min}(B)_t + 0,5[d_{min}(B)_t - d_{min}(B)_0]$

d) $D_C(R)_t = d_C(R)_t - d_{min}(R)_t + 0,5[d_{min}(R)_t - d_{min}(R)_0]$

e) $D_M(G)_t = d_M(G)_t - d_{min}(G)_t + 0,5[d_{min}(G)_t - d_{min}(G)_0]$

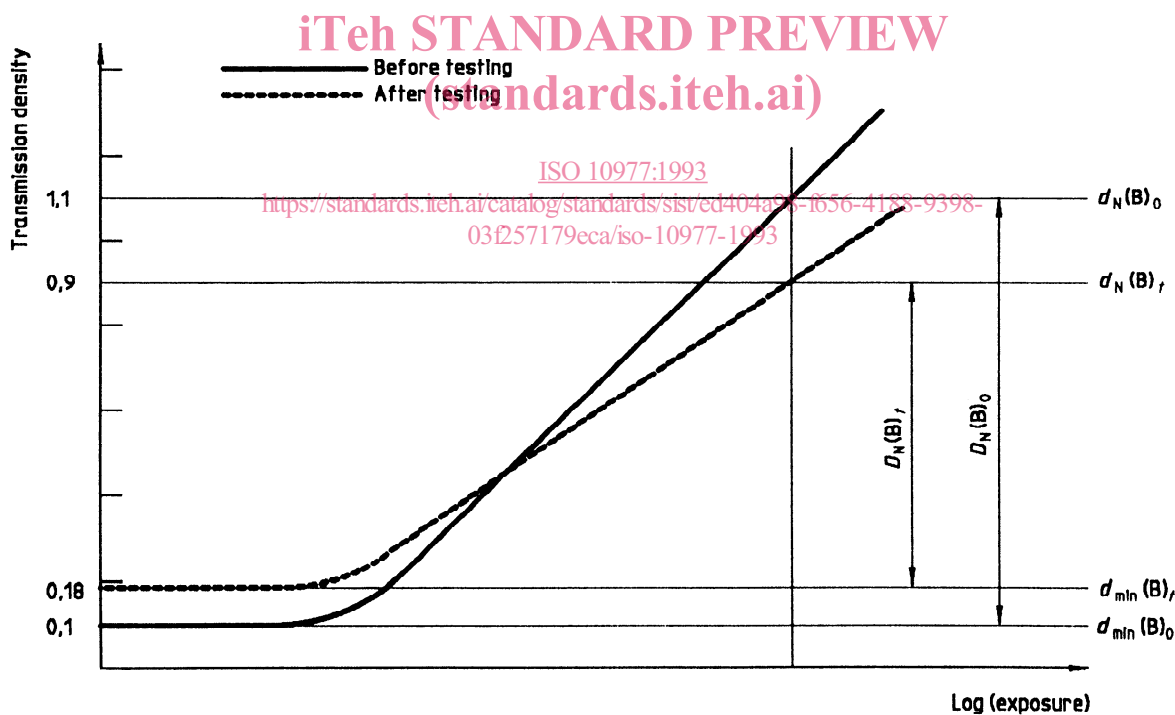f) $D_Y(B)_t = d_Y(B)_t - d_{min}(B)_t + 0,5[d_{min}(B)_t - d_{min}(B)_0]$

Figure 1 — Blue transmission density of a neutral patch of a transparency-type colour material

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3) The d_{min} correction for reflection density includes an extra back correction equal to half of the d_{min} gain with respect to the d_{min} correction for transmission density.
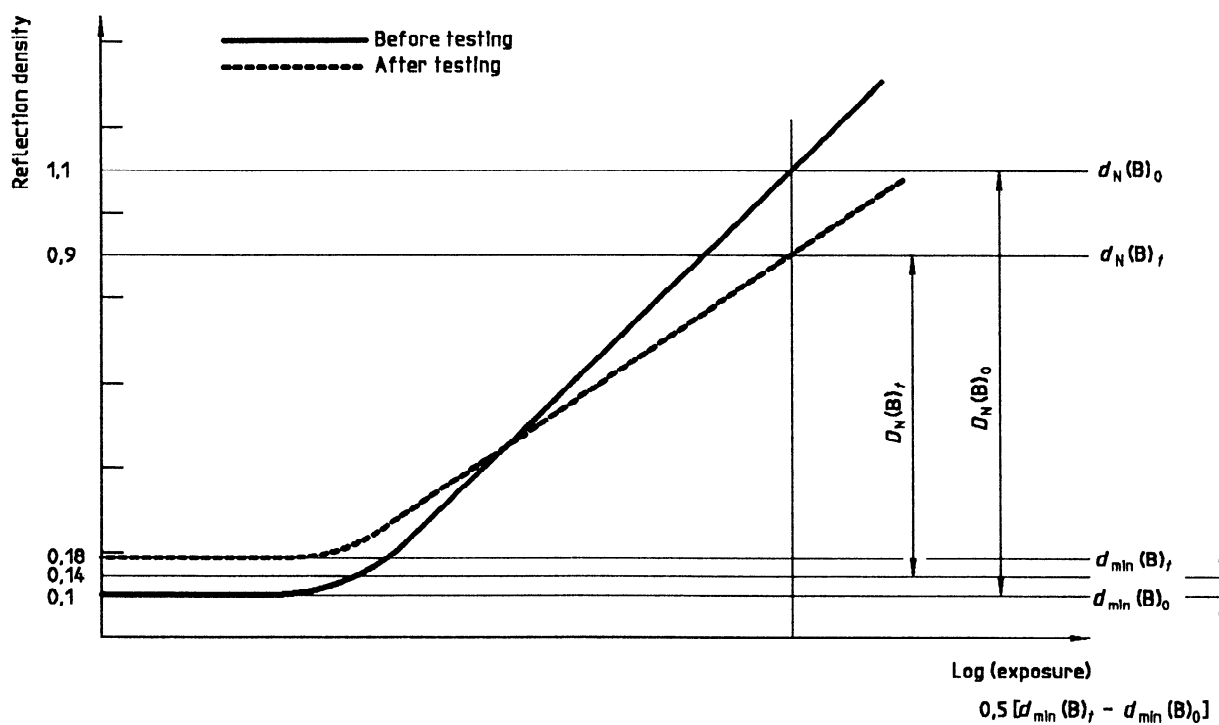
Figure 2 — Blue reflection density of a neutral patch of a reflection-type colour material

EXAMPLE

See figure 2.

A colour reflection print material tested for dark stability had a neutral patch with a starting blue density, $D_N(B)_0$, of 1,0, calculated as follows:

$$d_N(B)_0 = 1,1$$

$$d_{min}(B)_0 = 0,1$$

and so

$$D_N(B)_0 = d_N(B)_0 - d_{min}(B)_0 = 1,1 - 0,1 = 1,0$$

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 so

$$D_N(B)_t = d_N(B)_t - d_{min}(B)_t + 0,5[d_{min}(B)_t - d_{min}(B)_0]$$

$$= 0,90 - 0,18 + 0,5(0,18 - 0,10)$$

$$= 0,72 + 0,04 = 0,76$$

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 measured d_{min} value was due in part to the effects of multiple internal reflections, as explained in 3.5. Therefore, a correction was made equal to half of the measured change of 0,08. Such a correction of half of the change in d_{min} 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 changes in d_{min}.

3.7.2 Colour balance in the neutral density patch

These are calculated as percentages of average density.

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

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

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

3.7.3 d_{min} changes

a) $d_{min}(R)_t - d_{min}(R)_0$

b) $d_{min}(G)_t - d_{min}(G)_0$

c) $d_{min}(B)_t - d_{min}(B)_0$