American National Standard

for Imaging Materials –

Stability of Color Photographic Images – Methods for Measuring

ANSI/NAPM IT9.9-1996

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Stability of Color Photographic Images – Methods for Measuring

Secretariat

National Association of Photographic Manufacturers, Inc.

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American National Standard

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Foreword

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This standard deals with measuring the image stability of color photographic materials. The standard is divided into two parts. The first covers the methods and procedures for predicting the long-term, dark storage stability of color photographic images; the second covers the methods and procedures for measuring the color 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 color 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 color 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 color photographic materials, an understanding of the behavior 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 color photographs are formed by organic cyan, magenta, and yellow dyes that are dispersed in transparent binder layers coated onto transparent or white opaque supports. Color photographic dye images typically fade during storage and display; they will usually also change in color balance because the three image dyes seldom fade at the same rate. In addition, a yellowish (or occasionally other color) 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 color 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 colors, also may affect the stability of color materials.

The two main factors that influence storage behavior, 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 color images. Other potential causes of image degradation are atmospheric pollutants (such as oxidizing and reducing gases), microorganisms, and insects.

The stability of color 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 color photographs and can cause rapid fading as well as degradation of plastic layers such as the pigmented polyethylene layer of RC (resin-coated) paper supports.

In practice, color 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 color qualities of the image.

After extensive examination of amateur and professional color 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 standard does not specify "acceptable" end-points for fading and changes in color balance. Generally, however, the acceptable limits are twice as wide for changes in overall image density as for changes in color balance. For this reason, different criteria have been used as examples in this standard for predicting changes in image density and in color balance.

The actual determination of such changes is made with test strips that have been exposed and carefully processed according to the manufacturer's recommendations to produce at least (1) an area of minimum density (d_{min}), (2) patches of uniform, neutral density of 1.0 above d_{min}, and (3) 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 specimens 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 percent density change, tend to be proportionally much greater in lower-density portions of an image (e.g., in the range of 0.1–0.5 above d_{min}) than in high-density areas. Conversely, in dark fading, the visual effects of fading generally are more noticeable in higher densities than in low densities. Density losses in dark fading, expressed as a percent density change, tend to be more or less equal throughout the entire density range (see annex A). The user may wish to adopt different end-points for light and dark stability tests to take into account the visual differences manifested 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 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 color films and papers have images that fade and stain too slowly to allow evaluation of their 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 behavior at moderate or low temperatures by means of accelerated aging 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.

[1] Wilhelm, H. G., Monitoring the Fading and Staining of Color Photographic Prints, *Journal of the American Institute for Conservation*, 21(1):49–64; 1981.

Similarly, information about the light stability of color 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 must be controlled throughout the test period, and the types of light sources must 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 behavior of photographic color images under normal display conditions may be complicated by "reciprocity failure." When applied to light-induced fading and staining of color images, reciprocity failure refers to the failure of many dyes to fade, or to form stain, equally when irradiated with high-intensity versus low-intensity light, even though the total light exposure (intensity x 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 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 magnitude of reciprocity failure is also influenced by the temperature and moisture content of the test specimen. 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, color 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.

In order to establish the validity of the new standard methods for evaluating the dark and light stability of different types of photographic color films and papers, the following product types were selected for the tests by the subcommittee that produced this standard:

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

b) Color reversal film with incorporated oil-soluble couplers;

c) Color reversal film with incorporated Fischer-type couplers;

d) Color reversal film with couplers in the developers;

e) Silver dye-bleach film and prints;

f) Color prints with incorporated oil-soluble couplers;

g) Color dye imbibition (dye transfer) prints;

h) Integral color instant print film with dye developers;

i) Peel-apart color instant print film with dye developers;

j) Integral color instant print film with dye releasers.

[2)] Wilhelm, H. and Brower, C. (contributing author), *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*, pp. 67–76, Preservation Publishing Company, Grinnell, Iowa; 1993.

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

It must be remembered also that the 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.

There are seven annexes in this standard. They are informative and are not considered part of the standard.

Suggestions for the improvement of this standard are welcome. They should be sent to the National Association of Photographic Manufacturers, Inc., 550 Mamaroneck Avenue, Suite 307, Harrison, New York 10528-1612 (telephone: 914-698-7603; fax: 914-698-7609).

This standard was processed and approved for submittal to ANSI by NAPM Technical Committee on the Physical Properties and Permanence of Imaging Materials, NAPM IT9. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, NAPM Technical Committee IT9 had the following members:

Peter Z. Adelstein, Chairman
A. Tulsi Ram, Secretary

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Association for Information and Image Management (Liaison)	Marilyn Wright
Canadian Conservation Institute	Klaus B. Hendriks
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Image Permanence Institute	James M. Reilly
	Douglas Nishimura (Alt.)
International Society of Photogrammetry and Remote Sensing	Francis J. Parrish
Light Impressions Corporation	Dennis Inch
Motion Picture Studio Preservation	Rami Mina
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National Association of Photographic Manufacturers, Inc.	Kenneth M. Smith
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NAPM Subcommittee IT9-3, on Methods for Measuring the Stability of Color Pictorial Images, which was responsible for the development of this standard, had the following members:

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Henry Wilhelm, Secretary
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1 Introduction

1.1 General

This standard describes test equipment, test procedures, and analytic methods for:

– predicting the long-term dark storage stability of color photographic images; and

– measuring the color stability of such products when subjected to certain illuminants at specified temperatures and humidities.

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

1.2 Scope

This standard is applicable to color 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 color 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 color imaging systems.

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

1.3 Stability when stored in the dark

The tests for predicting the stability of color photographic images in dark storage are based on an adaptation of the Arrhenius method described by Bard et al. [1–2] [3)] and earlier references by Arrhenius, Steiger, and others [3–5]. 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 color products yield image fading and staining data in both accelerated and non-accelerated dark aging tests that are in good agreement with the Arrhenius relationship, some other types of products do not.

NOTE – For example, integral-type instant color print materials often exhibit atypical staining at elevated temperatures; treatment of some chromogenic materials at temperatures above 80°C and 60% RH may 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 color balance and saturation [6]. 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.

1.4 Stability when exposed to light

The methods of testing light stability in this 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.

[3)] Numbers in brackets refer to corresponding numbers used in annex G, Bibliography.