POPULAR PHOTOGRAPHY

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Color Preservation Update

How long will your color prints and slides last? Here's a comprehensive report on the most recent findings

By Bob Schwalberg

The mooted mortality of the photographic image is a controversy that has come out of the cold. No longer is the very existence of a problem denied by major manufacturers, and the biggest of them all, Eastman Kodak Co., now provides extensive literature explaining the potential performance of its black-and-white and color negatives, slides, and prints.

The old attitude that b&w is lasting because it is silver, and color is transitory because it is not, is giving way to a recognition that neither statement is completely accurate, and that there are options and trade-offs. People are now talking permanence, and even doing something about it.

Two effective forces are largely responsible for launching and floating this new movement for photographic image permanence. One of these forces consists of the army of library and curatorial staff who maintain picture collections and archives for schools and universities, museums of every description, commercial publications and picture agencies, and government departments. The other force is a 38-year-old former Virginian named Henry Wilhelm, now famously, if peripatetically resident in Grinnell, Ia. Conferences on photographic conservation are largely attended by the former, and star the latter as principal speaker. We are indebted to Wilhelm for sharing his latest information with us here in the accompanying charts. (Henry Wilhelm has just been awarded the Guggenheim Fellowship for Research in Color Stability, and is a member of the American National Standards Institute and the Task Group on Color Stability.)

One particularly important conference, on the "Production and Preservation of Color Slides and Transparencies," was held some months ago at the University of Texas at Austin. Organized and run by Susan Hoover of the School of Architecture, Nancy Schuller of the Department of Art, and Lynn Cooksey, a Continuing Education Specialist, this was—with a two-day program, nine scheduled speakers, and more than 110 attendees—the largest and probably the best symposium on photographic conservation yet staged. If the title forgot color prints, the program didn't, and this conference gave us a chance to summarize latest facts and findings in this field.

The expected permanence of a b&w negative or positive print is based upon the fact that the image is made of metallic silver, and is therefore unaffected by light or heat. But silver images are sensitive to certain air pollutants, sulfur being a major offender, and the assumption of metallic stability ignores the possibility of imperfect fixing and/or washing, or of defects in the paper or plastic support.

If you're using a two-bath paper fixer, you're saving pennies but maybe spoiling permanence. The newest fiber-based-paper wisdom—originated by Ilford researchers during Britain's 1976 drought, and later introduced as a Galerie paper procedure—is to fix as swiftly as possible, then give a short wash interrupted by an intermediate "washing aid." Short, speedy paper fixing calls for an ammonium thiosulfate hypo without any hardener, the print being sloshed about vigorously for about 30 seconds. Then comes five minutes in running water, 10 minutes in the washing aid whose principal constituent is sodium sulfite in a two-percent solution, and finally, another five-minute running-water wash.

Additional image permanence in the form of protection against air pollutants can be obtained by a final selenium-toner protective treatment. Half a minute in a nonhardening ammonium thiosulfate fixer plus the very short wash-sulfite-wash cycle combines excellent archival photographic protection with a decent regard for humanity and water-short municipalities.

Plastic or RC (resin-coated) papers introduce even shorter running-water wash times, and in many cases more than four minutes in running water is not recommended because this may lead to edge frilling. As reported by Wilhelm, some paper experts are concerned about residuals trapped at the edges of the prints, and recommend trimming off at least $\frac{1}{8}$-inch borders after the prints have been dried.

Other b&w RC paper problems are image discoloration and surface cracking due to prolonged light exposure and air pollution. Cracking is popularly supposed to be caused only by ultraviolet radiation, but the experts are now doubtful that these short wavelengths (which are usually present in only very small amounts in typical indoor display conditions) are really any more significantly guilty than other parts of the spectrum. The damage appears to be done by light in general, not specifically by the ultraviolet border region. Unlike conventional fiber-base b&w papers, RC types are also subject to image discoloration by long-term light exposure, particularly when mounted behind glass.

This RC problem is the only mark against Cibachrome which, in its non-RC forms, is far and away the most stable of all commercial color-print materials. (Please note that although all Cibachrome papers have a plastic base, only the semimatte "Pearl"-surfaced paper is resin-coated; glossy Cibachrome is not an RC paper. Instead, it is coated onto a white "voided polyester" base.)

Combining the reports of Henry Wilhelm and of Peter Krause, former president of Ilford Inc. who is now an independent consultant, the permanence of Cibachrome derives from the silver dye-bleach principle that uses preformed image dyes. The important point is that very stable layers of yellow, magenta, and cyan dyes are built into the paper. Then, after exposure, the unwanted parts of each layer are bleached out in processing. To get a red bit, for example, the cyan layer is completely bleached out, leaving yellow and magenta to form the wanted red.

All other noninstant color processes today (with the exception of the Kodak Dye Transfer print process that scores just behind the Cibachrome dye-bleach system for image permanence) are *chromogenic.* This means that development of a temporary silver image releases developer oxidation products that combine with color couplers to form the final image dye colors right in the three-emulsion layers. Since unreacted color couplers remain in all parts of the image that aren't a deep black, the couplers themselves must be colorless and transparent (except in color negatives, but that's another story). The colors that they form by chemical combination with developer oxidation products have in general not been nearly so stable as the preformed sorts of image dyes used in the dye-bleach and dye-transfer methods. This brings us to the question of instability itself.

Eastman Kodak, and the concerned conservationists led by Wilhelm, measure the fading rate of a color image in terms of the time needed to cause a 10-percent loss of the least stable of the three image dyes. In Kodaspeak, a "0.1 density loss from D = 1.0" means the same just-noticeable loss. But color fading is not as simple as it sounds, because there are two sorts: dark-fading and light-fading.

COLOR PRINTS

Relative Stability of Common Color-Print Materials

Rated on a scale from 1 (most stable) to 5 (least stable)

Dark Keeping

1 Ilford Cibachrome prints (glossy non-RC types only)*
Kodak Dye Transfer prints

2 Kodak Ektaflex PCT prints
Kodak Instant Color Film PR10 (improved)

3 Kodak Ektacolor 78 and 74 RC papers
Kodak Kodacolor prints (same as 78 and 74 RC)
Kodak Ektachrome 2203 paper
Kodak Ektachrome RC paper, Type 1993
Kodak Instant Print Film PR10
Polaroid Polacolor 2 Film**

4 Polaroid 600 High Speed Color Film***
Polaroid SX-70 Time-Zero Supercolor Film***
Polaroid SX-70 Film***

Light Fading on Display

1 Ilford Cibachrome print (glossy non-RC types only)*

2 Kodak Ektaflex PTC prints
Kodak Dye Transfer prints
Kodak Ektacolor 78 and 74 RC papers
Kodak Kodacolor prints (same as 78 and 74 RC)
Kodak Ektachrome 2203 paper

3 Polaroid SX-70 Film***
Polaroid Polacolor 2 Film
Kodak Ektachrome RC paper, Type 1993

4 Kodak Instant Color Film PR10 (improved)
Polaroid SX-70 Time-Zero Supercolor Film***
Polaroid 600 High Speed Color Film***

5 Kodak Instant Print Film PR10

Notes:
Relative stability rankings for the Kodak and Ilford Cibachrome materials listed are for prints processed according to instructions in chemicals supplied by the respective manufacturers. Use of processing chemicals supplied by other manufacturers may have an adverse effect on the stability of the prints.

At this writing, Ektachrome 2203 paper is being replaced by a new Kodak product, Ektachrome 14 paper, Type 5262. Recently released Kodak stability data for this new paper indicate that its light-fading and dark-keeping stability characteristics are very similar to current 2203 paper.

*Cibachrome prints are available on two distinctly different supports; the high-gloss, solid-white film-base supports are recommended. The lower-cost semigloss (Pearl) RC versions should be avoided when long-term keeping is concerned, as they may be subject to surface cracking and loss of flexibility. Film base Cibachrome and Kodak Dye Transfer prints may be considered to be essentially permanent in dark-keeping and should last considerably longer than 100 years under normal conditions without serious change. *In dark-keeping, these two materials are many times more stable than the other materials listed.*

**The image dyes used in Polaroid Polacolor 2 Film are quite stable in dark-keeping; however, the prints are subject to objectionable yellow stain in dark-keeping.

***The image dyes used in Polaroid SX-70 and Polaroid 600 Films are quite stable in dark-keeping. However, the prints are subject to serious yellow-stain formation in dark-keeping, and under some conditions may develop large image cracks in either dark-keeping or on display. The new magenta dye used in Polaroid SX-70 Time-Zero Supercolor Film and the recently released Polaroid 600 High Speed Color Film is significantly less stable in light-fading than the magenta dye used in previous types of SX-70 films. The stability characteristics listed for Polaroid 600 High Speed Color Film are based on preliminary tests.

Dark-fading is what happens when a color image (negative or positive, opaque print or transparent slide) is stored in darkness. Dark-fading is an especially acute problem with current chromogenic color negatives and color papers. Light-fading occurs when slides are projected, or when prints are hung on home, office, or museum walls. And this is the worst sort of fading damage because light-fading bleaches out the lighter (highlight) areas of a positive print or transparency, thereby destroying highlight picture detail. Because of these washed-out highlights, the early stages of light-fading actually result in a slight *increase* in overall image contrast (usually accompanied by a slight color shift).

> "Henry Wilhelm's most important and surprising discovery is that there is an effect similar to film-exposure 'reciprocity failure' in the light-fading of color prints and transparencies"

Dark-fading seems to affect the bright and dark parts of the picture fairly evenly, instead of producing a disproportionate loss of highlight detail. With most chromogenic color-print and transparency materials there are markedly different dark-fading rates for the yellow, magenta, and cyan color layers. The ultimate result of dark-fading is therefore an extreme color shift accompanied by a loss of contrast. Mi-

COLOR FILMS

Relative Stability of Common Color Films

Rated on a scale from 1 (most stable) to 5 (least stable)

Dark Keeping*

1 Kodak Kodachrome 25 (K-14)
Kodak Kodachrome 64 (K-14)
Kodak Kodachrome 40 Type A (K-14)

2 Kodak Kodachrome II (K-12)
Kodak Kodachrome-X (K-12)
Kodak Kodachrome Type A (K-12)
Kodak Ektachrome 50 Tungsten (E-6)
Kodak Ektachrome 64 (E-6)
Kodak Ektachrome 160 Tungsten (E-6)
Kodak Ektachrome 200 (E-6)
Kodak Ektachrome 400 (E-6)
Fuji Fujichrome 100 (E-6)
Kodak Ektachrome Duplicating Film (E-6)

3 Kodak Ektachrome-X (E-4)
Kodak High Speed Ektachrome (E-4)
Fuji Fujichrome R-100 (E-4)

4 Agfa Agfachrome 64**
Agfa Agfachrome 100**
GAF 64 Color Slide Film**
GAF 200 Color Slide Film**
GAF 500 Color Slide Film**
Kodak Kodacolor II (C-41)
Kodak Kodacolor 400 (C-41)
Kodak Vericolor II (C-41)
Kodak Kodacolor-X (C-22)
Kodak Ektacolor (C-22)
Fuji Fujicolor F-II (C-41)
Fuji Fujicolor 400 (C-41)

5 Kodak Ektachrome Professional Films (E-3)
Kodak Ektachrome Film (E-2)
Kodak Ektachrome Film (E-1)
Kodak Ektachrome Duplicating Film (E-4)
Kodak Ektachrome Duplicating Film (E-3)

Light Fading During Projection***

1 Kodak Ektachrome 50 Tungsten (E-6)
Kodak Ektachrome 64 (E-6)
Kodak Ektachrome 160 Tungsten (E-6)
Kodak Ektachrome 200 (E-6)
Kodak Ektachrome 400 (E-6)
Fuji Fujichrome 100 (E-6)
Fuji Fujichrome R-100 (E-4)
Kodak Ektachrome-X (E-4)
Kodak High Speed Ektachrome (E-4)
Kodak Ektachrome Duplicating Film (E-6)

2 Kodak Kodachrome 25 (K-14)
Kodak Kodachrome 64 (K-14)
Kodak Kodachrome 40 Type A (K-14)
Kodak Kodachrome II (K-12)
Kodak Kodachrome-X (K-12)
Kodak Kodachrome Type A (K-12)
Agfa Agfachrome 64
Agfa Agfachrome 100

3 GAF 64 Color Slide Film
GAF 200 Color Slide Film
GAF 500 Color Slide Film

Notes:
*Dark-keeping rankings are based on results from tests performed as outlined in *ANSI PH1.42-1969 Method For Comparing The Color Stabilities Of Photographs*, modified to use 45% and 76% relative humidity with the results averaged. Kodak and Fuji color-negative-stability rankings are based on estimated printability; light-fading is not normally a factor with color negatives as they are usually stored in the dark.

**Agfa Agfachrome and GAF Color Slide Films are particularly sensitive to high relative humidity during storage; the dark-keeping stability of these films can be greatly improved by storing them in a low-relative-humidity (25-40%) environment.

****For the typical amateur photographer, the light-fading stability of most 35-mm color-slide films is adequate for the usually limited total times of projection (projection times longer than one minute at a time and a total of 20 minutes for Kodachrome and Agfachrome—45 minutes for Ektachrome and Fujichrome—should be avoided).* Dark-keeping stability is generally the most important consideration for a color-transparency film. If prolonged projection of a slide is anticipated, duplicate slides should be made for projection purposes, and the original should be kept in the dark.

nor damage caused by dark-fading can often be compensated for by filtering in duplicating or reprinting, but a similar degree of light-fading damage renders such remedies much less effective.

Another way of looking at this is to say that dark-fading is what goes on at all times, whether or not the color image is being exposed to light. For Wilhelm and the scientists studying color stability through accelerated light-fading tests, this is an important fact whose True Value eludes me. Isn't this a bit like pointing out that troops advancing under fire are also aging?

Henry Wilhelm's most important and surprising research discovery is that there is an effect similar to film-exposure "reciprocity failure" in the light-fading of color prints and transparencies. (*The reciprocity law defines film exposure as the effect of light intensity multiplied by time. "Reciprocity failure" occurs when unusually short or long exposure times produce less than the expected exposure density. Because of this, extra exposure time must often be added to long time exposures, and some very fast electronic-flash exposures need larger f-stop compensation.*)

Wilhelm found something quite similar when studying the light-fading of color prints and slides. For the same total light exposure, high-intensity illumination used for short periods of time in accelerated tests does not usually cause as much fading damage as does normal indoor household illumination used for much longer periods of time.

When the film-manufacturing industry felt its first pangs of conservationism some years ago, this reciprocity effect was generally ignored in making accelerated light-fading tests. For example, by exposing Polaroid SX-70 instant-color prints to short blasts of high-intensity illumination, and by noting very little effect, Polaroid was able to state that SX-70 and Polacolor 2 color dyes were "among the most stable known in photography." Actually, they are no such thing, as some months of exposure to normal indoor room lighting will reveal to anyone patient enough to conduct this scientific experiment.

It is a fact that SX-70 and Polacolor 2 prints exhibited outdoors in very bright sunlight will outlast Ektacolor (or Kodacolor) prints made from color negatives. Put them together on an ordinarily illuminated *indoor* wall, however, and Wilhelm's tests reveal light-fading in about one-third of the time required for an equivalent loss from an Ektacolor print.

Two additional factors limit the longevity of Polaroid SX-70 prints. One is a cracking of the image layer underneath the clear plastic top surface, which appears to be related to changes between high and low relative humidity over a long period of time. The other problem is yellow staining, caused not by fading but by dye accretion. The SX-70 system uses the preferable sort of preformed dyes, but these must physically move through a white interlayer to form the color picture. The yellow dye layer is located just below this white interlayer, and some yellow dye continues to migrate, albeit very slowly, through this layer and into the image. Once a print is stained, it matters little what the cause.

Two years ago, Wilhelm reported that the original Kodak instant-color PR10 print film was even less stable than Polaroid SX-70. Today, his most recent findings give Kodak PR10 a higher dark-keeping rating, with the light-fading of the newest PR10 prints on approximate par with Polaroid SX-70 Time Zero and the latest Polaroid 600 prints. Wilhelm is impressed by the new Kodak PR10 dark-keeping, which is now actually several times better than that of Ektacolor/Kodacolor papers, creating a new category with Kodak Ektaflex prints.

These Kodak instant-color prints fall just below the dark-storage print champions, Ilford Cibachrome and Kodak Dye Transfer. (*See color-print stability chart on page 82, but please note that the Cibachrome and Dye Transfer standards of dark-storage stability are vastly greater than those of any of the materials listed below them in the table.*)

The tendency of Polaroid SX-70 to suffer image-layer cracking at low relative humidities is specially unfortunate because the dark-storage conditions for best permanence with all color materials tested to date require both low temperature and low humidity. Wilhelm's own recommendation is for cold storage at 1.5 C/35 F, or even colder, while maintaining an "ideal" relative humidity of 25 to 30 percent.

For the institutional user this means an extremely large, terribly costly room-like installation, but such are beginning to be built today. The John F. Kennedy Library in Boston was the first institution to build conservation-minded storage facilities with very low temperature and controlled humidity conditions. Similar facilities have been introduced by archivist and Texas panelist Dan Jones at the Peabody Museum of Harvard University. The Art Institute of Chicago will be the first art museum with such photographic storage facilities when its new installation is completed. The only commercial archival storage to date is at the New York headquarters of Time/Life, although others are at least in the talking stages. If Time/Life is there, can National Geographic be far behind?

Personal photographers, including

> " 'As cold as possible with 25-to-30-percent humidity' appears to be the best archival wisdom"

Tips on Preserving Your Color

If you have a color print you want to preserve, don't display it in light for prolonged periods of time. Have a good copy made for display purposes and store the original in the dark.

When buying prints from a professional studio or wedding photographer, order two: one for display, one for dark storage.

Remember that instant photographs are, like daguerreotypes, one-of-a-kind items. Have copies made of ones you really want to save and to display.

High-energy ultraviolet light is the most destructive to color photographs. Avoid hanging color prints in daylight. Tungsten illumination is less damaging.

The best place to dark-store color photographs in most homes is the top shelf of a first-floor closet. Avoid the basement (too damp) and the attic (too hot).

Humidity is an even worse enemy than heat. A warm, dry location is better than a cool, moist one. An air-conditioned and/or dehumidified environment is good for long-term storage.

many professionals, can turn the trick with properly functioning frost-free refrigerators or home-freezer units. Low temperature without low humidity won't protect adequately, and all of the experts (including Wilhelm) are convinced that one is as important as the other. "As cold as possible, with 25-to 30-percent humidity" appears the best archival wisdom.

Another side of the dark- and light-fading question is that the same film may be better in respect to one than the other. This is a new aspect of the sibling rivalry between Kodachrome and Ektachrome color-slide films. As shown in the color-film chart on page 83, Kodachrome has the best dark-storage prognosis, while Ektachrome suffers the perils of projection more bravely. You pays your money and takes your choice. If the photographer wants a high quality, long-lasting original from which an internegative can be made for printing (with no damage to the slide), Kodachrome is doubtlessly best. In fact, this is widespread professional practice today. You could also make a highly stable Cibachrome print directly from the Kodachrome original. On the other hand, if the end product is a slide presentation that must be projected over and over again, the vote would have to go to Ektachrome, and note that in respect to slide-projector light-fading, even the fast E-6 Ektachromes outpoint the Kodachromes.

Another report of original research presented at the Austin conference was Christine Sundt's study of slide-mounting systems. Sundt is Curator of Slides and Photographs in the Art History Department of the University of Wisconsin at Madison. Like other art historians, she administers huge collections of copy slides which are loaned to students. The average informed photographer's contemporary preference for leaving chromes in their open paper mounts just won't work because fingers are more destructive than any chemical or moisture phenomena. She is therefore forced to go to glass-mounting, which is exactly what we've been educated against for the past two decades. Her method is glass-contact binding, specially modifying existing commercial metal and plastic mounting frames so that the two glass pieces squeeze tightly against the front and back of the slide.

The theory of "let-them-breathe-in-cardboard-readymounts" is that the small atmosphere trapped inside a conventional glass mount soon becomes polluted by stuff given off by the film, which isn't able to escape sufficiently swiftly. Now comes Christine Sundt with a compromise between this logic and the determining need for glassed-in slide protection. By reducing the trapped atmosphere to almost nothing, the well-known long-term chemical dangers and moisture-related problems should be greatly reduced, if not completely eliminated.

Another bit of archival nitty-gritty not totally uninteresting to the average photographer is the problem of "accessing" large slide collections. This means finding the slide that you know you've

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WHAT KODAK SAYS

Estimated time for "just-noticeable" fading to occur in Kodak films and prints stored in the dark at 75 F (24 C) and 40% relative humidity. (Compiled from data published by Kodak.)

Dye-transfer prints	300 years
Ektaflex PCT prints	60 years
Ektacolor 78 and 74 RC papers (Process EP-2)	8 years
Ektachrome 2203 paper (Process R-100)	8 years
Ektachrome 14 paper, Type 5262 (Process R-100)	10 years
Ektacolor 37 RC paper (previous Process EP-3)	8 years
Kodachrome films (Process K-14)	90 years
Kodachrome films (previous Process K-12)	50 years
Ektachrome films (Process E-6)	50 years
Ektachrome-X films (previous Process E-4)	20 years
High Speed Ektachrome films (previous Process E-4)	20 years
Ektachrome Professional films (previous Process E-3)	6 years
Vericolor II films (Process C-41)	6 years
Kodacolor II films (Process C-41)	6 years
Kodacolor 400 films (Process C-41)	10 years

Note:

"Just-noticeable" fading is defined as a 10% loss (0.1 from an original density of 1.0) of one or more of the cyan, magenta, and yellow image dyes. Such small color changes may not be noticed by the average individual except by direct visual comparison with an unfaded print or slide; color changes will be more obvious in photographs that have large areas of near-neutral colors than with images consisting of smaller areas of highly saturated colors. Small density changes can be significant in critical applications such as scientific and fine-art photography. Fading-rate data such as given here provides a meaningful way to compare the dark-keeping stability of one product with another; for example, current Kodachrome films are almost twice as stable as current Ektachrome films and Kodak dye-transfer prints are nearly *40 times* more stable than Ektacolor prints. While the amount of fading expected to take place in the times listed here is not large, deterioration will become ever more obvious in the years that follow; these 10%-loss figures give a good indication of what can be expected over longer periods of time. As an example, Ektacolor 78 and 74 RC prints, and Ektachrome 2203 reversal prints, which are estimated to have a 10% dye loss in about 8 years (cyan is the least stable dye in dark-keeping with these papers), will suffer an obvious loss of contrast and shift in color toward red in about 16 or 20 years; by the time 30 or 40 years pass, the image deterioration will be very serious and nearly half of the original cyan dye will have faded away.

This data is for films and prints processed in Kodak chemicals according to instructions; use of other manufacturers' processing chemicals may have an adverse effect on stability.

Storage of color materials at temperatures and/or relative humidities higher than 75 F and 40% relative humidity will decrease the storage times listed here. For example, storing color photographs at 86 F instead of 75 F will double the fading rate and cut these estimated storage times in half. An increase in relative humidity from 40% to 60% will approximately double the fading rates of some of these products. In many locations, the average indoor relative humidity will be significantly higher than the 40% RH used for these Kodak estimations.

Storage at lower temperatures will greatly increase the life of a color print or film. For information on the increase in potential stability that can be had by storing film and prints in humidity-controlled refrigerated facilities, see Kodak Publication E-30, *Storage and Care of Kodak Color Materials* (12/80 Revision) or Kodak Publication No. F-30, *Preservation of Photographs.*