3. Light Fading Stability of Displayed Color Prints

Light-Induced Cracking of RC Papers: Is It Still a Problem with Color Prints?

. . . part of the reason the Cabinet project was done with photographs instead of the traditional oil paintings was that Smith was able to convince White House officials that the photographic papers such as Kodak Ektacolor Professional Paper offer improved image stability. In addition, photography offers quick results at a fraction of the cost of oil painting. So a 30" x 40" photograph taken by Smith and printed on Kodak Ektacolor Professional Paper now hangs at the entry of every Cabinet member's office on Capitol Hill.[1]

From an interview with Merrett T. Smith
in *Kodak Studio Light* magazine,
Issue No. 1, 1986

A Gregory Heisler photo of New York City Mayor Edward I. Koch may wind up as Koch's official portrait in City Hall. Unlike the Mayor's predecessors, whose portraits are both painted and formal, Koch is looking rather relaxed and candid in this color photo. The photo, taken for the June 11, 1989, *New York Times Sunday Magazine*, was Heisler's first assignment to shoot Koch. The Art Commission, which decides on all art works in city buildings, still must approve the photo. "I'm excited," says Heisler, who thinks the concern of the Art Commission is that of archival quality — whether a photograph will last as long as a painting.[2]

"PDNews" by Susan Roman
Photo District News
New York City
December 1989

Shooting a portrait on color negative film and making prints with Ektacolor paper may indeed offer quick results at a fraction of the expense of an oil painting (a 30x40-inch sheet of Ektacolor paper costs only about $6.00), but there are other reasons that most people prefer a color photograph to a painting. The realism of a good color photograph — an authentic frozen moment of history — is something that a painting can never achieve. People love color photographs! But one thing an oil painting *does* have, and an Ektacolor print does not, is permanence on long-term display.

How long do prints made with the many different types of color negative papers last on display? How much longer will Fuji's precedent-setting Fujicolor SFA3 papers last than Kodak's Ektacolor papers? How does the light fading stability of Kodak Ektatherm thermal dye transfer prints compare with that of Fujicolor and Ektacolor prints? What is the best color negative paper for valuable portraits and wedding photographs? What are the longest-lasting materials for printing color transparencies? Has the light fading stability of Ektacolor or Fujicolor prints improved much over the past 20 years?

Is tungsten illumination less harmful to color prints than fluorescent? Does UV protection help? Compared with "conventional" color print materials, how much longer will a more costly UltraStable Permanent Color print, Polaroid Permanent-Color print, or EverColor Pigment color print last? The answers to these and other light fading stability questions are the subject of this chapter.

Recommendations

See Chapter 1 for a comprehensive list of the longest-lasting color films and print materials, based on overall light fading, dark fading, and dark staining performance.

Light Fading Is Now a More Serious Problem Than Dark Fading

In the 1970's and early 1980's, it could be debated which was the more serious problem with color papers: poor dark fading stability or poor light fading stability (yellowish stain formation in dark storage was not much of a worry then because the most pressing problem was poor dye stability). Some color negative papers had very poor dark fading stability indeed, and one paper, the previously mentioned Agfacolor Type 4 paper (sold worldwide from 1974 until 1982), had such astonishingly poor cyan dye dark storage stability that by the time this chapter was written in 1992, all known examples of Type 4 prints had faded to an ugly reddish shadow of their originally colorful images.

Although the Ektacolor papers of the same era were much more stable than Agfacolor Type 4 paper, in dark storage the cyan dye was also the least stable of the three image dyes in Ektacolor prints (and most other EP-3 and EP-2 papers during this period), and it was the inadequate stability of the cyan dye that effectively limited the life of Ektacolor prints in dark storage.

That situation changed with the historic introduction of Konica Color PC Paper Type SR in April 1984. (Type SR paper, which was still on the market when this book went to press in 1992, is also called Konica "Century Paper" and Konica "Long Life 100 Paper.") Type SR paper was the

Carol Brower – October 1990

Wedding portraits printed on Fujicolor Professional Paper Super FA Type P being inspected at H&H Color Lab by printing department supervisor Steve Tuggle. H&H, a leading professional portrait and wedding lab located near Kansas City in Raytown, Missouri, switched from Ektacolor Portra paper to Fujicolor paper in 1990 because of the superior light fading stability of the Fuji product. The change in color paper was made after a poll mailed to more than 700 H&H customers showed that the great majority wanted their wedding photographs and portraits printed on the longest-lasting color paper available, even if that meant changing from Kodak to Fuji as the paper supplier (see Chapter 8).

first of a new generation of color negative papers to feature an improved cyan coupler which, during processing, produced a new high-stability cyan dye. This improved cyan dye made the overall dark storage dye stability of the new Konica paper far better than that of any previous color negative paper. In August 1984 Kodak followed with Ektacolor Plus paper, which, like Konica Type SR paper, employed a new high-stability cyan dye. A few months later Agfa and Fuji announced their own similarly improved color negative papers, and these new products (which included Ektacolor Professional Paper as a replacement for Ektacolor 74 RC Paper in portrait and wedding markets) became generally available in 1985.

In addition to heralding greatly improved dark storage dye stability, the introduction of Konica Type SR paper accomplished three important breakthroughs:

1. For the first time in the history of color photography, image stability became an important competitive consideration. Konica's advertisements for Type SR paper, which claimed a 100-year album storage life for the prints, marked the first time that a color negative paper had *ever* been promoted on the basis of image stability. Kodak, Agfa, and Fuji all were forced to respond. Before the introduction of Konica Type SR paper, image stability data were for the most part kept secret by Kodak and the other manufacturers, and most purchasers of color paper were totally ignorant of the stability characteristics of the products they bought.

2. The improved dark storage dye stability of Konica Type SR paper and similar chromogenic papers made by Kodak, Agfa, and Fuji shifted the emphasis from dark storage *dye stability* to the problem of gradual formation of *yellowish stain* in prints kept in the dark. Not only is the stain objectionable in its own right, but it also contributes to a change in color balance toward yellow. It became a question of what is the most objectionable visual change when these papers are stored in the dark for long periods (with most color print materials, light-induced stain formation during long-term display is less severe than stain that occurs in dark storage).

Yellowish stain formation in dark storage has been a clearly recognized but little-discussed problem with in-

March 1990

An exhibition of Tina Barney's large Ektacolor prints at the Museum of Modern Art in New York City in 1990. Barney uses a view camera with large-format color negative film. Represented by the Janet Borden Gallery in New York, some of Barney's prints have sold for over $10,000.

corporated-coupler chromogenic materials ever since the first Kodacolor prints appeared in 1942. However, it was not until Fuji introduced Fujichrome Paper Type 34, a low-stain paper for printing transparencies, in 1986 (replaced with Type 35 paper in 1992) and Fujicolor Super FA low-stain papers for printing color negatives in 1989 (replaced with Fuji's advanced Fujicolor SFA3 papers in 1992) that concern about dark-storage stain problems really came into the open. Konica introduced its first low-stain paper, Konica QA Color Paper Type A5, in Japanese markets in 1990. Compared with Kodak Ektacolor and most other papers currently on the market, these new Fuji and Konica papers have greatly reduced rates of stain formation. Fuji has emphasized this advantage in promoting the papers, and the company has also discussed the topic in a number of technical papers (see Chapter 5).

With the current generation of color prints, dark-storage stain formation is finally being acknowledged as a significant problem — a problem that in many cases is even more serious than dye fading itself. The new *ANSI IT9.9-1990* color stability test methods standard published by the American National Standards Institute[3] requires that d-min stain and d-min color balance changes be reported along with dye stability and color balance data, and this should focus much greater attention on the subject of dark-storage stain behavior.

3. Almost all current color papers feature high-stability cyan dyes (at the time this book went to press in 1992, the only exceptions were several of Kodak's Ektachrome papers which still have a cyan dye with poor dark-storage stability of the type abandoned by Fuji, Konica, and Agfa by the mid-1980's), so the principal image stability concern now is the light fading stability of color papers on display. As Klaus Gerlach of Agfa said in 1985, following the introduction of Agfacolor Paper Type 8, "In terms of dye or image stability, we consider the dark fading issue as resolved; improvements in light stability are in progress."[4] Color prints now last *much* longer when stored in the dark than they do when exposed to light on display.

On Display, Some Types of Color Prints Last Far Longer Than Others

The deterioration of displayed color print images is characterized by shifts in color balance caused by unequal fading of the cyan, magenta, and yellow image dyes; loss of color and detail (especially in highlight areas); changes in

1979

Fluorescent illumination is used in most offices, schools, and other public places. Illumination intensities of 500 to 2,000 lux are common; in display cases, where photographs are often displayed for extended periods, much higher intensities can be found. Because of their high energy-efficiency and low cost, single-phosphor "Cool White" lamps are by far the most popular type of fluorescent lamp. In some fluorescent-illuminated offices, photographs are exposed to the bright light for only short periods; for example, **LIFE** magazine photographer Alfred Eisenstaedt is shown here in his office at Time Warner Inc. in New York City selecting images for an exhibition of his photographs. When color prints are displayed under such lights for many years, however, severe fading eventually will result.

image contrast; and overall low-level yellowish stain formation. Light-faded color prints characteristically have a washed-out, off-color appearance. Such prints have lost their original richness, brilliance, and sparkle.

The light-fading of a color print is a slow but steady process that begins immediately when the print is hung on the wall or placed in a frame on a desk. Other considerations being equal, the rate of light fading of a particular type of color print is determined by the *inherent* dye stability characteristics of the paper, i.e., those built into the material by the manufacturer.

Even though all types of color prints are subject to light fading, grouping every type of color print together and stating simply that "all colors fade" ignores the very large differences in dye stability among currently available products. Some materials are *much* more stable than others. As shown by UltraStable Permanent Color prints and Polaroid Permanent-Color prints, it is possible to make color prints with high-stability color pigments that, in a practical sense, do not fade at all: that is, under normal conditions of display, the prints will probably retain excellent quality color images for five hundred years or more.

Image Fading and Discoloration Caused by Print Lacquers, Retouching, and Other Post-Processing Treatments

Color prints often are lacquered after processing. Treatment with lacquers obscures surface defects caused by corrective spotting and retouching; helps protect the surface from abrasion, scratches, and fingerprints; modifies emulsion surface gloss characteristics; and, probably most importantly, allows prints to be framed directly against glass without danger of the emulsion sticking or "ferrotyping" to the glass under humid conditions. Lacquering is especially popular among portrait and wedding photographers and is often combined with various surface texturing treatments because many photographers believe this enhances the value of a print to the customer.

According to Kodak, depending on the particular type of lacquer and the manner in which it is applied, these products are capable of accelerating both light fading and dark fading of Ektacolor prints and can under some circumstances produce severe yellow staining.[5] At the time this book went to press in 1992, this author was not aware of

January 1982

Art galleries and museums are among the few places where tungsten lamps are the only source of illumination. In this exhibition of Ilford Cibachrome (Ilfochrome) prints by the late photographer Hans Namuth at Castelli Gallery in New York City, the lamps were mounted on the gallery's high ceiling at a steep angle to the framed prints to minimize surface reflections.

any commercial print lacquer that did not contain at least one ingredient identified by Kodak as potentially harmful. To date, Kodak's published information on print lacquers concerns only the effects of lacquers on Ektacolor prints and may not apply to other types of color prints. No other studies of the effects of lacquers on image stability have been published.

This author believes that some types of abnormally rapid dye fading in displayed prints are actually caused at least in part by RC base-associated fading (see Chapter 2) and cannot be attributed solely to lacquers. However, the use of currently available print lacquers adds a significant unknown element in attempting to determine the long-term dye stability of a print. Thus, when possible, print lacquers — including those containing UV absorbers — should be avoided. (Lacquers and other print coatings are discussed in more detail in Chapter 4.)

Retouching dyes can both accelerate localized image dye fading and make normal print fading more obvious because they may fade more slowly or more quickly than the print's image dyes. As a portrait fades during display, facial wrinkles and blemishes, skillfully smoothed over by retouching when the print was new, begin to stand out in stark relief because of these differences in fading rates, and the picture can assume a ghastly appearance. (Retouching materials and procedures are discussed in more detail in Chapter 11.)

It is an unfortunate fact that the more a customer pays for a print, the more likely it is to have been subjected to retouching, lacquering, canvas mounting, texturizing, or other post-processing treatments, any of which can reduce the dye stability of the print.

How to Interpret the Light Fading Stability Tables in This Chapter

The color print image-life predictions given in the tables at the end of this chapter were based on data obtained in accelerated light fading tests using Cool White fluorescent illumination, incandescent tungsten illumination, and north daylight illumination. For the fluorescent and tungsten illumination tests, color prints were subjected to three different tests: **(1)** "Bare-Bulb" tests in which there was no glass or plastic sheet between the light source and test prints, **(2)** "Glass-Covered" tests conducted with a sheet of glass placed on top of the test prints, and **(3)** "UV-Filtered" tests in which a sheet of Rohm and Haas Plexiglas UF-3, a sharp-cutting ultraviolet filter that absorbs virtually all UV radiation and even some short-wavelength blue light, was placed on top of the test prints.

Carol Brower – November 1986

Henry Wilhelm speaking with associate curator Matthew Postal (right) about the effect of illumination intensity on perceived color print quality at the 1986 exhibition of Ektacolor prints by Len Jenshel at the Laurence Miller Gallery in New York City.

The glass and UF-3 sheets were in direct contact with the surface of the prints. For the indirect north daylight tests, prints were covered with either glass or Plexiglas UF-3 sheets, spaced about 1/8-inch above the surface of the prints, with free air circulation between the glass or Plexiglas and the print.

In addition to illumination intensity and spectral distribution, a number of other factors can influence the life of a print on display. These include "framing effects" (also called "enclosure effects") with prints framed under glass or plastic, RC base-associated fading and staining, and dark fading and dark storage staining that may occur concurrently with light-induced changes during prolonged display under low-level illumination (see Chapter 2 for discussion of RC base-associated fading and "framing effects" with displayed prints).

Changes in dye stability and/or stain characteristics can also be brought about by application of print lacquers or other coatings, retouching effects, and other factors such as choice of processing chemicals and/or failure to adhere to recommended processing and washing procedures. Separately or in combination, all of these factors can have an effect — most often an adverse effect, and sometimes a catastrophic effect — on color image stability.

In the tables the products are listed in order of their "Glass-Covered" stability rankings, as determined by the tests. For the important group of current Process RA-4 compatible color negative papers (**Table 3.1a** on page 131) and current Process EP-2 compatible color negative papers (**Table 3.1b** on page 132), at least three replicate samples were tested in all three light exposure conditions, and the experimental error was estimated to be ± 5%. For the other tables, the experimental error is somewhat greater, especially in cases where the limiting image-life parameter was a color imbalance between two dyes, rather than a density loss of a single dye.

Illumination Intensity Is Generally Much More Important Than the Spectral Distribution of the Light Source

In reviewing the data presented in this chapter, it will become apparent that for most modern color print materials, the spectral distribution of the illumination source has relatively little effect on fading rates. Far more important is the *intensity* of the illumination. There are some exceptions to this — Kodak Ektatherm thermal dye transfer prints being a notable example — but in general, for a given illumination intensity, no great differences in fading rates will be noted when prints are illuminated with different types of commonly encountered indoor light sources (e.g., fluorescent lamps and incandescent tungsten lamps).

1977

George Eastman House in Rochester, New York is an example of an older museum where some areas are illuminated with both daylight through window glass and tungsten lamps. To maintain the architectural integrity of the historic building, the windows cannot be covered. When this photograph was taken in 1977, this upstairs room was used to exhibit photographs from the Eastman House collection. After the completion of the adjacent Eastman House Archives Building in 1988, Eastman House was renovated and this room is no longer used to exhibit photographs from the permanent collection.

The Most Important Conclusions: Which Color Print Materials Last Longest

The color print image-life predictions presented in this chapter are based on accelerated test data with non-lacquered, correctly processed prints. Because of the previously mentioned factors, prints on actual long-term display under typical home and office conditions may fade more rapidly than predicted by these tests. Because of the reciprocity failure trends noted with two-intensity testing, RC base-associated fading, and "framing effects" during long-term display (see Chapter 2), there appears to be little chance that prints would last longer than predicted under the specified illumination conditions. To the extent that these image-life predictions could be in error, it is most likely that they somewhat *overestimate* the stability of the various types of color prints.

These uncertainties aside, the most important conclusions from these tests are, within each class of color print material (e.g., color negative paper, color reversal paper, instant color prints, etc.), which type of color print likely will last the longest when displayed. For professional wedding and portrait photographers, or commercial photographers who sell prints for long-term display as wall decor, it is only good ethics — and certainly good business — to give customers the longest-lasting color prints possible.

For operators of color labs, the choice of color papers will matter a great deal to at least some customers. For competitive reasons, and to minimize the chance of clients eventually bringing faded prints back and demanding free replacement prints, the most economical strategy is to use the most stable materials available. Otherwise a lab's business image will suffer, long-standing customers may leave, and potential new clients will never walk in the door.

What Are "Normal" Display Conditions?

The illumination intensity, spectral distribution, and duration; the temperature and relative humidity in the display area; and the method of framing or mounting that constitute "normal" display practice cover such a wide range (see **Table 17.1** in Chapter 17) that the concept of "normal display conditions" should be approached with caution.

The three most common indoor illumination sources are: **(1)** indirect daylight that has passed through window glass; **(2)** fluorescent lamps — most commonly "Cool White" lamps — that may or may not be covered with a UV-absorbing glass or plastic diffuser; and **(3)** incandescent tungsten

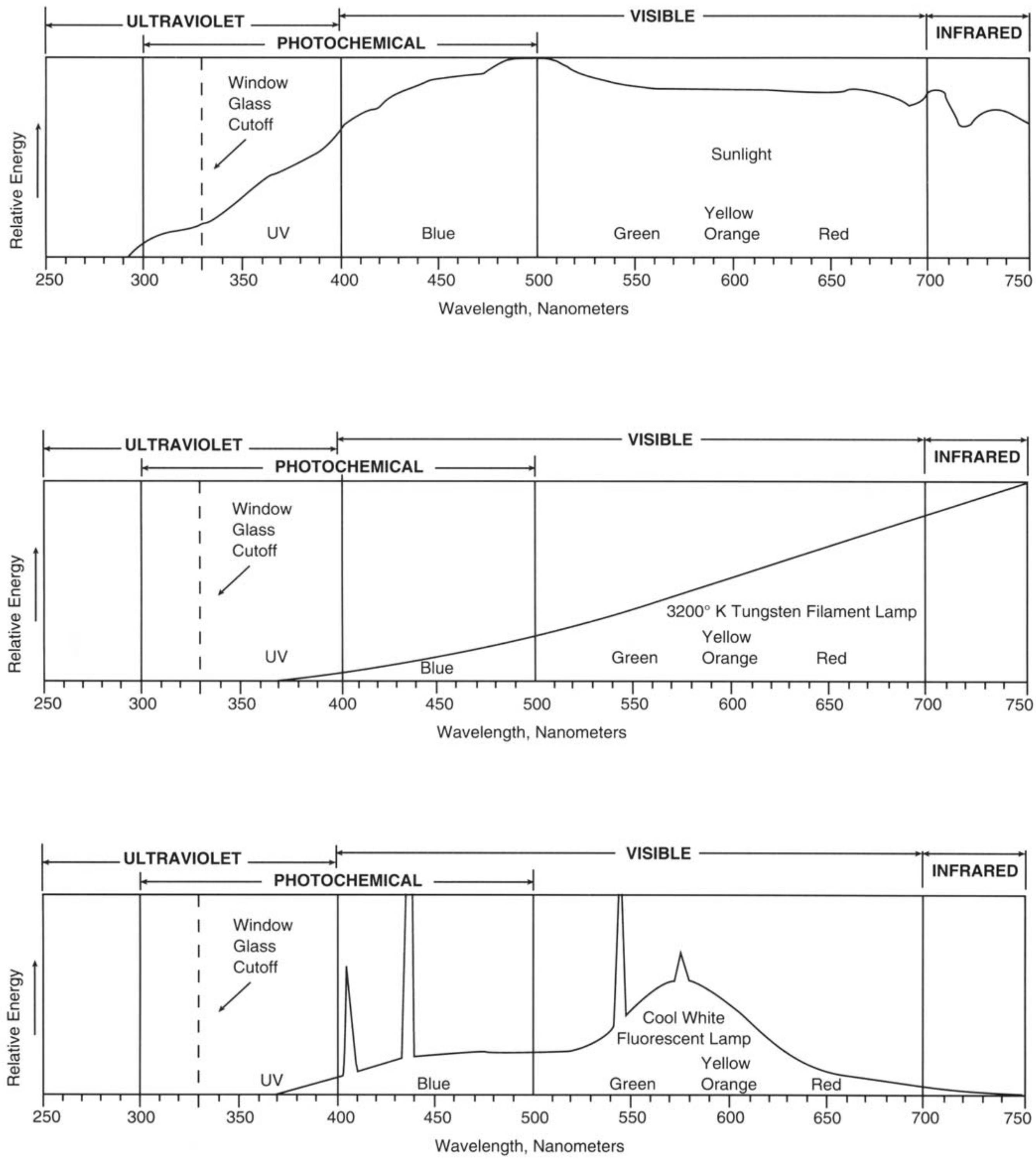


Figure 3.1 The spectral energy distribution of sunlight illumination, incandescent tungsten lamps, and Cool White fluorescent lamps. Mercury vapor line emissions from the low-pressure mercury arc in fluorescent lamps produce the irregular energy peaks characteristic of these lamps. At a given illumination intensity (measured in lux units), the very different spectral distributions of these three light sources produce surprisingly similar fading rates with Ektacolor, Fujicolor, and other types of modern chromogenic color papers, all of which have effective UV-absorbing emulsion overcoats. (Sources: Rohm & Haas Publication PL-612c and General Electric Company)

Back-illuminated color transparencies and translucencies (e.g., Kodak Duratrans, Fuji Fujitrans, and Ilfochrome Translucent Display Film) are a popular form of advertisement for hotels, rental car agencies, and other services catering to travelers at airports. In this example at the Tampa, Florida airport, the intense 24-hour-a-day fluorescent illumination caused severe fading of those images which had been displayed for extended periods.

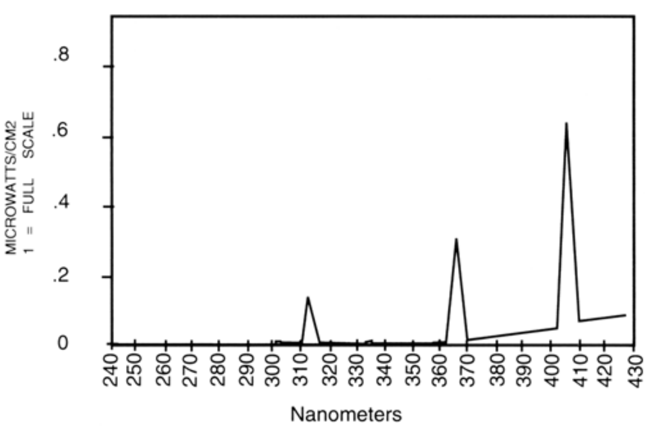


Figure 3.2 The 313 nanometer mercury vapor emission of bare-bulb fluorescent lamps may appear to be of relatively low energy, but it can have a devastating effect on the dye images of Kodak Ektatherm prints and other color print materials that lack a UV-absorbing overcoat. A sheet of ordinary window glass or framing glass placed between a fluorescent lamp and a color print will protect the image from the harmful 313 nm emission — glass and most types of plastics effectively absorb UV radiation below 330 nm. (Source: General Electric Company)

lamps. Typical spectral distributions for these three illumination sources are given in **Figure 3.1**. These and other illumination sources are described in detail in *ANSI IT9.9-1990, American National Standard for Imaging Media – Stability of Photographic Images – Methods for Measuring.*[6]

Of particular importance with fluorescent lamps is the ultraviolet mercury vapor line emission at 313 nanometers, shown in **Figure 3.2**. Although in terms of relative power distribution the energy of this UV emission may appear to be low, it has a devastating effect on color prints that lack an effective UV-absorbing emulsion overcoat. The effect of ultraviolet radiation on color print fading is discussed in more detail below.

The "years of display" image-life predictions given in **Tables 3.1a** through **3.6** (pages 131 through 144) are based on two "standard" display conditions, as determined by this author. One display condition is for homes, offices, and commercial locations, and the other is for tungsten-illuminated museum and archive display areas.

For homes, offices, and commercial locations, an intensity of 450 lux (42 fc) for 12 hours a day has been adopted by this author.[7] This illumination level is not greatly different from the 500 lux (46.5 fc), also for 12 hours a day, adopted by Fuji for reporting "years of display" image-life predictions for Fujicolor Paper Super FA Type 3, one of Fuji's

November 14, 1989

The United States Declaration of Independence, which is housed at the National Archives in Washington, D.C., is displayed with extremely low intensity tungsten illumination in an effort to minimize further fading. The Declaration (1776), the Constitution (1787), and the Bill of Rights (written in 1789 and ratified in 1791), which are displayed in the main rotunda of the National Archives, are protected with bullet-proof glass and a yellow filter material that absorbs UV radiation and most blue light. (See page 244 in Chapter 7 for discussion of the computer-based monitoring system employed by the National Archives to detect further ink fading, flaking, or other changes in the 200-year-old documents.)

family of Fujicolor SFA3 papers introduced in 1992. (Fuji's "years of display" extrapolations were based on data obtained from very high-intensity, 85-klux xenon arc tests.) According to Fuji:

> Since in common domestic situations sunlit areas may be as bright as 1000 lux or more during the day and drop to 300 lux in the evening and at night, storage conditions are usually designated to be at an average of 500 lux of light exposure for a period of 12 hours per day.[8]

Fuji selected an even higher illumination level on which to base "years of display" predictions for Fujichrome Paper Type 35, a reversal paper for printing color transparencies, introduced in 1992: "Type 35 paper is designed for indoor display under high average illumination conditions of 1000 lux for a period of 12 hours a day."[9]

Employing data obtained from very high intensity (100 klux) cycling xenon arc tests, Ilford has chosen three illumination conditions for "years of display" image-life predictions for Ilfochrome prints (called Cibachrome prints, 1963–91) displayed indoors:[10]

Indoors/1 Normal conditions, protected from direct sunlight at least 7 feet from a window (i.e., living rooms, offices, and museums: 45–55% RH, light intensity approximately 500 lux for 12 hours per day).

Indoors/2 Medium conditions, protected from direct sunlight (i.e., under spotlights in galleries and exhibits. Averaging 1000 lux for 12 hours per day).

Indoors/3 Extreme conditions, high humidity and direct sunlight for half the day (i.e., near indoor swimming pools and aquariums. Averaging 2500 lux for 12 hours per day).

To date, Eastman Kodak has, for the most part, avoided making predictive "years of display" image-life estimates for color prints based on specified illumination conditions. In 1988, in the first such instance, Kodak published an article in the *Journal of Imaging Technology* which included a small graph showing the predicted fading of Kodak Ektacolor Plus Paper expressed in "years of display" based on an illumination level of 100 lux for 12 hours per day.[11] In a general discussion of accelerated test methods, the 100-lux level was adopted by Kodak in *Image-Stability Data: Kodachrome Films,* "Reference Information from Kodak," Kodak Publication E-105 (March 1988).[12] This publication has not been widely distributed and this author is not aware of any other Kodak publications making an image-life prediction, expressed in "years of display," based on data from accelerated light fading tests.

In the display of color prints in homes, offices, and museums, lighting conditions similar to this author's standard display conditions are commonly encountered; however, display situations frequently have much more intense illumination and/or are illuminated for longer than 12 hours per day — either or both of which would correspondingly shorten the image life of a color print. In other cases, prints are displayed under much lower light levels and/or are illuminated for fewer hours each day than specified in this author's "standard display condition" of 450 lux for 12 hours per day.

It is a simple matter to convert the color print image-life predictions given in this chapter to other display conditions by measuring the light intensity in the display area with an illuminance meter (the Minolta Illuminance Meter is a good instrument for this purpose), determining the average number of hours of illumination each day, and then making the appropriate calculations.

Fluorescent Illumination for Accelerated Light Fading Tests

For a variety of reasons, fluorescent illumination has become the "standard" light source for accelerated light fading tests. Fluorescent lamps provide fairly high-intensity illumination with relatively little heat; this makes it easier to maintain the proper temperature and relative humidity in accelerated test equipment. Compared with daylight-simulating xenon arc light sources, fluorescent lamps provide stable, energy-efficient, evenly distributed, and low-cost illumination. More importantly, fluorescent lamps are by far the most common light source in offices, educational institutions, stores, and public buildings. Fluorescent lamps are increasingly found in homes, especially in Japan and in other countries that stress energy conservation.

All current chromogenic color papers are made with UV-absorbing emulsion overcoats and are little affected by the UV radiation present in even bare-bulb fluorescent illumination (**Figure 3.3**) or indoor daylight that has passed through window glass (**Figure 3.4**).

For testing current chromogenic papers, glass-filtered fluorescent illumination provides

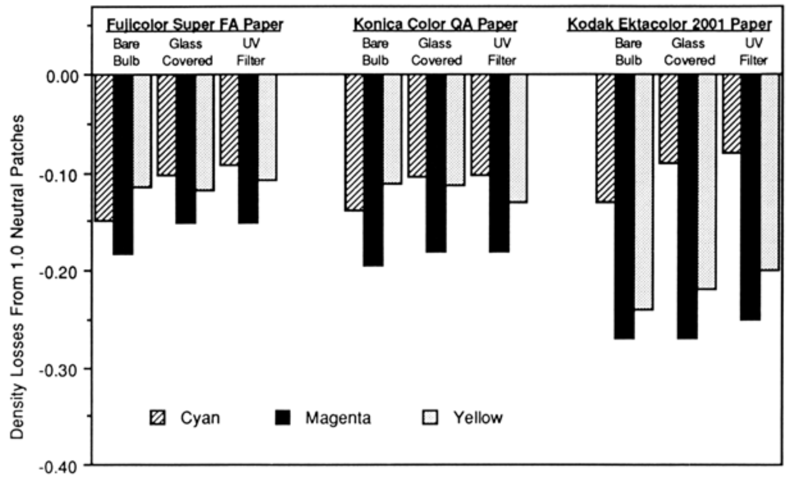


Figure 3.3 All modern color negative papers are manufactured with a UV-absorbing emulsion overcoat that protects the image dyes from damaging ultraviolet radiation present in fluorescent lamps, daylight, and some other sources of illumination. The fading that occurs in displayed prints is caused almost entirely by visible light, and additional UV protection is of little if any benefit. Prints are effectively protected even from the UV radiation of bare-bulb fluorescent lamps, most of which have a high-energy UV emission at 313 nm that produced rapid fading in earlier color negative papers without a UV-absorbing overcoat. In this graph, the Fuji, Konica, and Kodak color papers were exposed to Cool White fluorescent illumination in an accelerated test at 21.5 klux for 100 days; the temperature at the sample plane was maintained at 75°F (24°C) and the relative humidity at 60%.

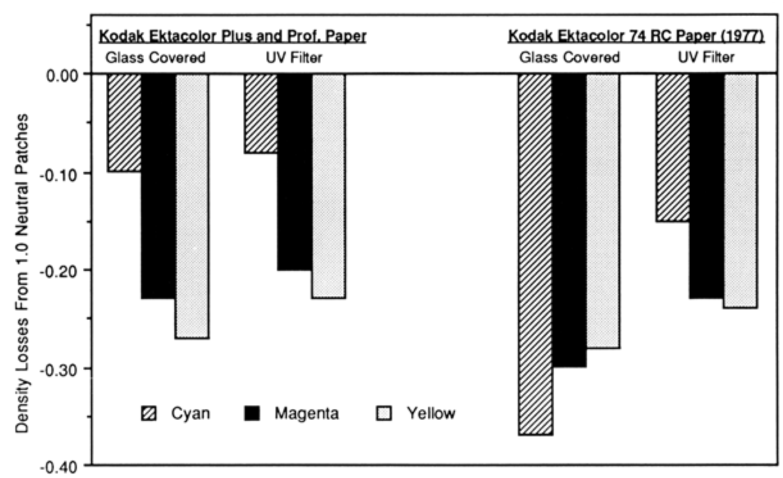


Figure 3.4 Two generations of Kodak Ektacolor paper exposed to north daylight through window glass. The illumination intensity, averaged over a 24-hour period, was 0.78 klux. The temperature was 75°F (24°C) and the relative humidity 60%. Because the print samples were close to a north-facing window, with almost no light reflected from walls or ceilings (which tend to absorb UV radiation), this is a "worst-case" indoor display situation in terms of UV radiation and short-wavelength blue light. With Ektacolor Plus and Professional papers (1984—), which are made with an effective UV-absorbing overcoat, a sharp-cutting UV filter (Rohm & Haas Plexiglas UF-3) afforded little more protection than ordinary window glass. With Ektacolor 74 RC paper (initial type: 1977–82), which did not have a UV-absorbing overcoat, the fading of the cyan dye was reduced by more than 50% when protected by UF-3. This paper, like most other color negative papers of the era, has a UV-absorbing interlayer that protects the magenta and yellow dye layers. Unannounced, Kodak added a UV-absorbing overcoat to Ektacolor 74 RC paper in early 1982; Konica, Fuji, and Agfa incorporated this feature in their color papers by 1984–85.

a reasonable approximation — in terms of dye fading and light-induced yellowish stain formation — of the indirect, glass-filtered daylight illumination found in homes.

In 1990, Stanton Anderson and Richard Anderson of Eastman Kodak reported that the "typical" daytime indoor illumination in homes (away from windows) was very different from what had been expected: "The characteristic curve contains most of its energy at the longer wavelengths. . . . In direct contrast to sunlight, there is little content at the shorter wavelengths (UV radiation and blue light) but much yellow and red light of lower energy."[13] They found that the shorter-wavelength radiation was largely absorbed by floor coverings, paint on walls and ceilings, furniture, and draperies. They suggested that glass-filtered fluorescent or tungsten illumination provides a closer match to typical indoor illumination than do the filtered xenon arc light sources that have often been used in the past for testing the light fading stability of color prints.

There are many types of fluorescent lamps (e.g., Cool White, Warm White, Cool White Deluxe, Daylight, etc.), all of which have different spectral energy distributions. However, according to the General Electric Company, more than 70% of the fluorescent lamps in the U.S. are of the "Cool White" type, and for this reason Cool White lamps were used in the tests reported here. The *ANSI IT9.9-1990* Standard also specifies Cool White lamps for the 6.0 klux accelerated fluorescent light fading test (the now-obsolete *ANSI 1.42-1969* color stability test methods Standard called for Cool White Deluxe lamps).

To date, nearly all of the light fading stability data reported by Eastman Kodak have been based on 5.4 klux (500 fc) accelerated tests[14] employing fluorescent illumination filtered with acrylic plastic panels to absorb the potentially damaging 313 nm UV emission of fluorescent lamps (ordinary window or framing glass also absorbs this wavelength).

The 313 nm wavelength emitted by bare-bulb fluorescent lamps caused rapid cyan dye fading in pre-1982 Ektacolor papers, which, like most other color papers of the time, were manufactured without UV-absorbing emulsion overcoats. The bare-bulb 313 nm emission also causes rapid fading of the cyan dye in Kodak Dye Transfer prints, and it greatly increases the fading rate of Ilfochrome prints (called Cibachrome prints, 1963–91). Neither Ilfochrome nor Dye Transfer prints have a UV-absorbing overcoat.

Kodak Ektatherm prints and other types of thermal dye transfer prints tested by this author also do not have effective UV protection of the image dyes, and bare-bulb fluorescent illumination has a devastating effect on these prints (see **Figure 3.5**). When the Kodak Photo CD system was commercially introduced in the summer of 1992, Ektatherm prints were the only type of print initially available for reproducing images from the Photo CD's. The Photo CD Index Prints supplied with each Kodak Photo CD as "contact sheets" for visual reference to the images recorded on the Photo CD are also Ektatherm prints.

Light Fading Stability of Current Color Negative Print Papers

During 1990, according to estimates provided by *Photofinishing News,* amateur photographers in the United States alone took nearly 17 billion photographs; of these, about

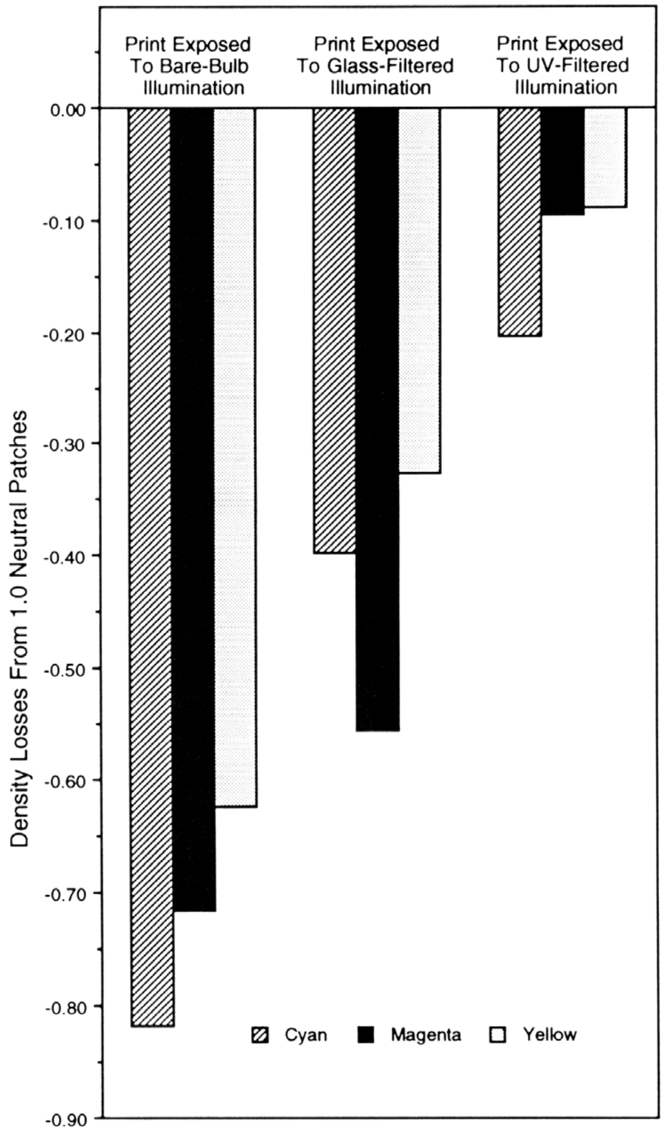


Figure 3.5 As shown in this 100-day 21.5 klux accelerated fluorescent light fading test, the image dyes of Kodak Ektatherm prints and other types of thermal dye-transfer (dye-sublimation) prints that lack a UV-absorbing overcoat are strongly affected by even the low-level ultraviolet radiation present in glass-filtered fluorescent illumination. The light fading stability of the prints is greatly increased by the use of Plexiglas UF-3 or other effective UV-absorbing filter.

98% were in color. Black-and-white photographs constituted just a little over 2% of the market.[15] Color slides accounted for only about 5% of the photographs taken by amateurs, and Polaroid instant color prints, which have steadily declined in popularity in recent years, had about 2% of the market.

With over 15 billion exposures in 1990, color negative films constituted the lion's share of the total amateur film market in the U.S. and accounted for 90% of all amateur photographs made. The popularity of ordering "twin prints" from each negative, along with sales of reprints and enlargements, pushed the total number of prints made from

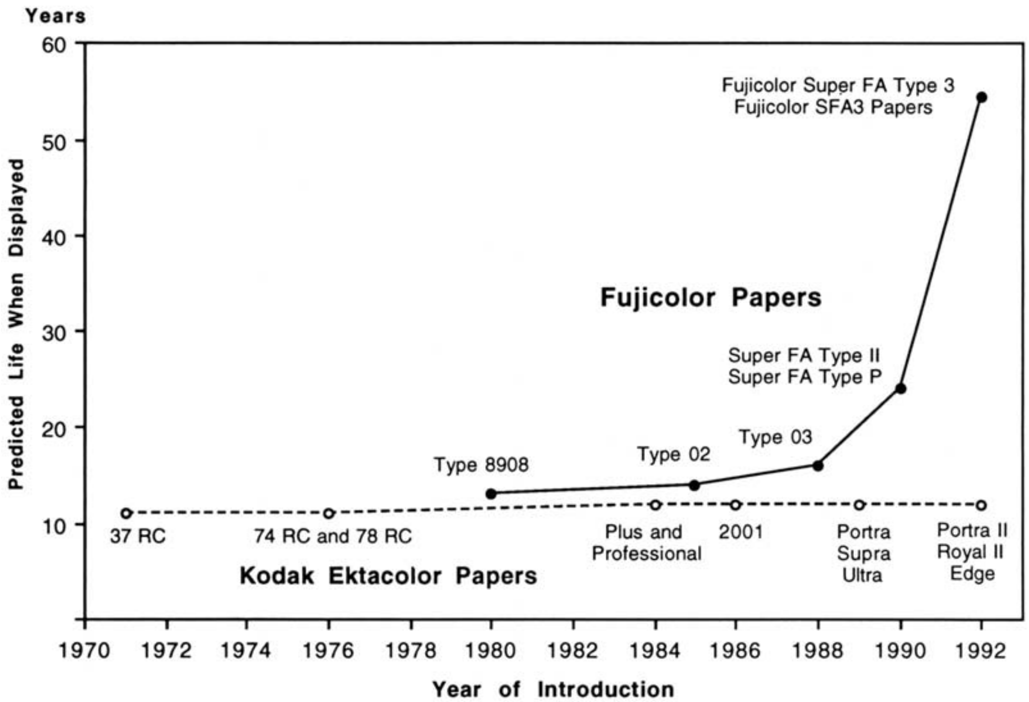


Figure 3.6 Beginning in 1980, successive generations of Fujicolor EP-2 and RA-4 compatible papers have exhibited steadily increasing light fading stability, with current Fujicolor SFA3 papers having an estimated display life of more than 50 years according to this author's tests. Kodak's Ektacolor papers, on the other hand, have shown negligible improvements in light fading stability since the introduction of Ektacolor 37 RC Paper more than 20 years ago in 1971. When exposed to light on display, Fujicolor SFA3 papers last more than **four times longer** than current Ektacolor papers (e.g., Ektacolor Portra II Paper).

amateur color negatives to 20 billion. (The amateur market for prints from slides was estimated to be only about 24 million prints — less than 1% of the total number of amateur color prints made in 1990.)

Not only are color negative papers the easiest and fastest to process and by far the lowest cost of all color print materials — every aspect of their design is dictated by the requirements of mass production snapshot photofinishing — but virtually all professional color portraits and wedding photographs, even the most expensive, are printed with these papers. So to the 20 billion prints made from amateur color negatives, one can add another billion or so prints made from color negatives in the professional market. In addition, most of the color photography for newspapers is now done with color negative films, with prints made on color negative papers (or with negatives scanned and entered directly into electronic prepress systems without making prints).

The majority of fine art color prints purchased by museums and private collectors are also made with color negative papers. Most photographers making fine art color photographs prefer the wide exposure latitude of color negative films, and the smooth tonality, often subtle color rendition, and the speed and simplicity of making prints from color negatives. Similar results are much more difficult to obtain with prints made from color transparencies. From all of this, it is easy to see why color negative papers are *by far* the most important part of the color print market.

Process RA-4 Papers Will Soon Replace Process EP-2 Materials

Kodak introduced fast-processing Ektacolor 2001 paper and Process RA-4 chemicals when the company entered the rapidly expanding minilab market in 1986. (In the face of intense competition from Japanese and European manufacturers, Kodak left the minilab equipment market at the end of 1989.) Ektacolor 2001 and other Process RA-4 compatible papers have a silver chloride emulsion that allows processing in approximately half the time required for Process EP-2 papers (such as Ektacolor Professional Paper), which have slower processing silver bromide emulsions. Until 1988, Ektacolor 2001 was restricted mainly to the minilab market, where the fastest possible processing is essential. Ektacolor 2001 Paper was replaced by Ektacolor Edge Paper in 1991.

In addition to reduced processing times, silver chloride papers and RA-4 chemicals offer a number of other advantages, including lower chemical replenishment rates, reduced water use, no benzyl alcohol in the color developer (which allows easier mixing, less tar formation, and reduced environmental impact), and greater process stability. In the case of the Ektacolor RA-4 papers, at least, less silver is required than with Kodak's EP-2 papers, and this lowers manufacturing costs (Kodak sells the two types of papers for the same price, however).

Outside of the minilab field, the conversion from EP-2 papers to RA-4 papers was at first slow, in part because photofinishing labs were reluctant to purchase all new processing machines or to get involved with expensive conversions of existing equipment (most labs did not want to deal with RA-4 and EP-2 chemical mixing and storage at the same time, and the conversion to RA-4 from EP-2 became sort of an all-or-nothing affair). Speed of processing generally is less important for large photofinishers than it is for minilab operators.

Commercial labs did not want to change until a full complement of RA-4 materials was available (labs supplying Duratrans translucent polyester-base display material did not want to maintain a separate EP-2 line for just one

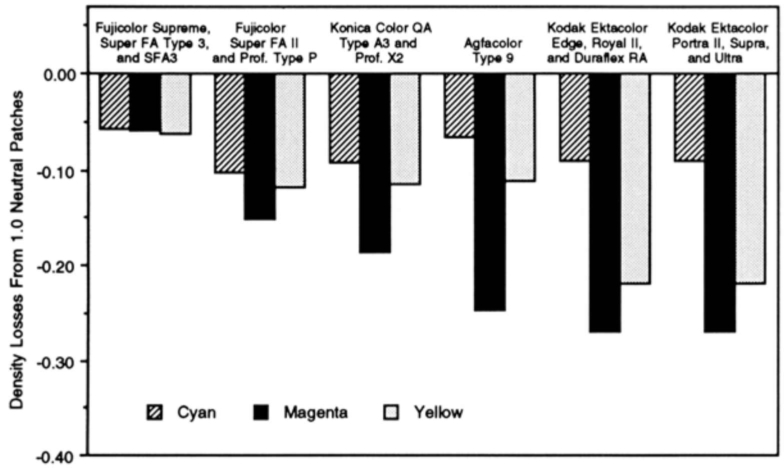


Figure 3.7 Process RA-4 compatible color negative papers compared by density losses from 1.0 neutral patches. Print samples were covered with glass and exposed to 21.5 klux fluorescent illumination in accelerated light fading tests conducted at 75°F (24°C) and 60% RH. Unless otherwise noted, all of the graphs in this chapter are based on this high-intensity, 100-day test. This light exposure is equivalent to 26 years of display under this author's "standard display condition" of 450 lux for 12 hours per day. The new type of high-stability magenta dye employed in the Fujicolor SFA3 papers faded much less than the magenta dyes in the other papers, and this in turn resulted in significantly less color balance shift to green or green/yellow as fading progressed. The new "low-stain" magenta coupler in Fujicolor SFA3 papers also has much lower rates of yellowish stain formation in dark storage than the magenta couplers used in Kodak, Agfa, and most Konica papers.

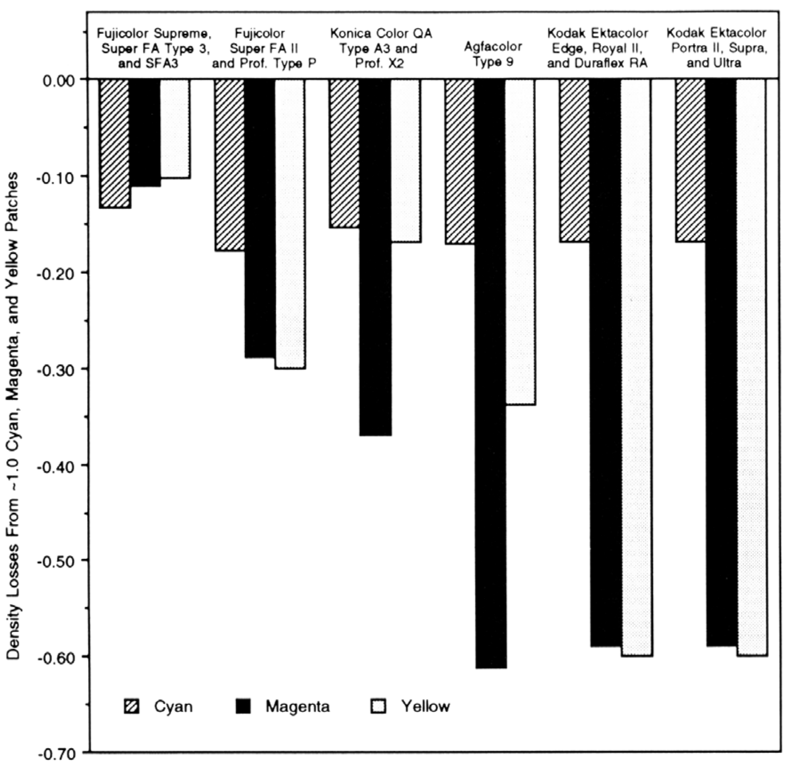


Figure 3.8 Process RA-4 compatible color negative papers compared by density losses from ~1.0 cyan, magenta, and yellow color patches. Note that while the light-fading stability of the cyan dyes of the various products is fairly similar, the stabilities of the magenta and yellow dyes differ significantly, with the Kodak Ektacolor papers being, overall, the worst of the group. Although not included here, the image stability of Mitsubishi RA-4 compatible papers is similar if not identical to that of the Konica papers (Konica supplies key emulsion components to Mitsubishi for use with its papers).

product). By early 1989 Fuji, Konica, and Agfa all had introduced RA-4 photofinishing papers, and early latent-image keeping problems with Ektacolor RA-4 papers had been adequately resolved. Outside of the minilab market, however, the move from EP-2 to RA-4 was still proceeding fairly slowly. With Kodak's introduction of a complete line of RA-4 materials in late 1989, and with lower-contrast RA-4 "professional" papers and translucent polyester-base display materials also available from Fuji and Konica, an industry-wide changeover to RA-4 began in earnest in 1990. By the end of 1994, it is likely that many of the EP-2 papers available when this book went to press in 1992 will have been discontinued.

For photofinishers wishing to continue using processing equipment designed for Process EP-2, Kodak introduced Process RA-4ECM, which allows Ektacolor Edge and other Kodak RA-4 papers to be processed with the longer EP-2 process cycle. In 1990, as part of the company's broad competitive policy of maximum market segmentation, Kodak introduced Ektacolor Royal Paper (later replaced by Royal II paper) into the general minilab and photofinishing markets (the paper was actually introduced in 1989, but at first it was used only in the Kodak Create-A-Print 35mm Enlargement Center). Ektacolor Royal II Paper has a thicker RC base and a somewhat higher-gloss surface than other Ektacolor papers; the image stability of Royal paper is the same as for the other Ektacolor RA-4 papers. In 1990, to compete directly with Ektacolor Royal Paper, Fuji introduced Fujicolor Supreme paper, a thick-base, high-gloss version of Fujicolor Paper Super FA paper.

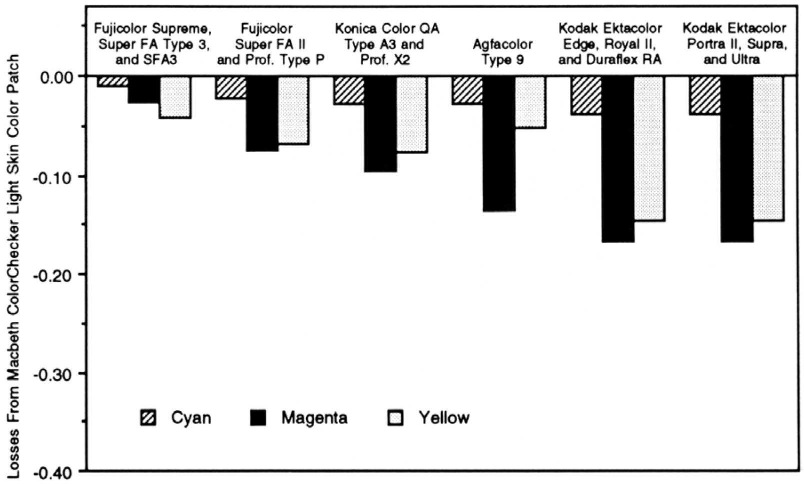


Figure 3.9 Process RA-4 compatible color negative papers compared by density losses from the Macbeth ColorChecker Light Skin Color patch. For portraits and wedding photographs, this is usually the most important indicator of a color paper's performance. As is the case in the other graphs and tables in this chapter, the Fujicolor SFA3 papers faded the least and had the least color balance change. The Konica QA Type A2 (and Mitsubishi SA) papers were the next best, with the Kodak Ektacolor papers fading the most and suffering the most objectionable color balance change. In the Ektacolor papers, the comparatively large losses of both the magenta and yellow dyes — the two most important dyes in skin tone reproduction — seriously degrade skin colors, resulting in a sickly, washed-out, greenish appearance. Because of the lower initial density of the ColorChecker Light Skin Color patch, a 60-day test period was used in this test (equivalent to 16 years of display under this author's "standard display condition").

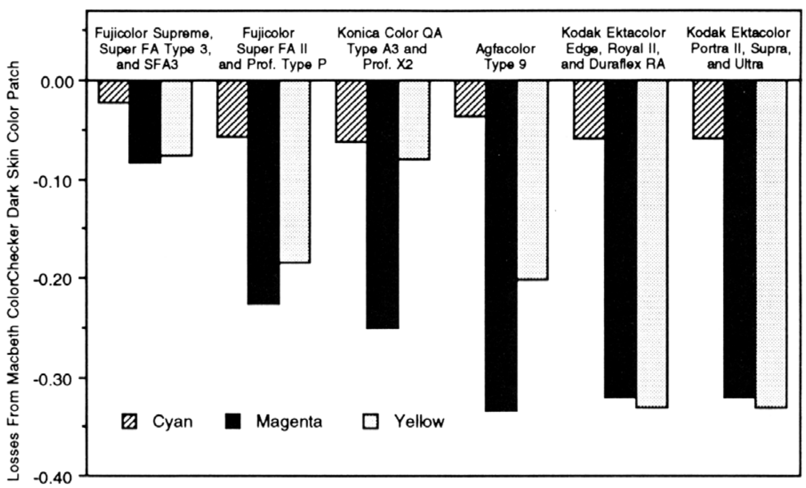


Figure 3.10 Process RA-4 compatible color negative papers compared by density losses from the Macbeth ColorChecker Dark Skin Color patch. This color is representative of the skin color of dark-skinned individuals. Most portraits, whether of light-skinned or dark-skinned people, have important areas of low-density highlights, and pictorial quality is adversely affected if these highlight areas fade or suffer significant color balance changes.

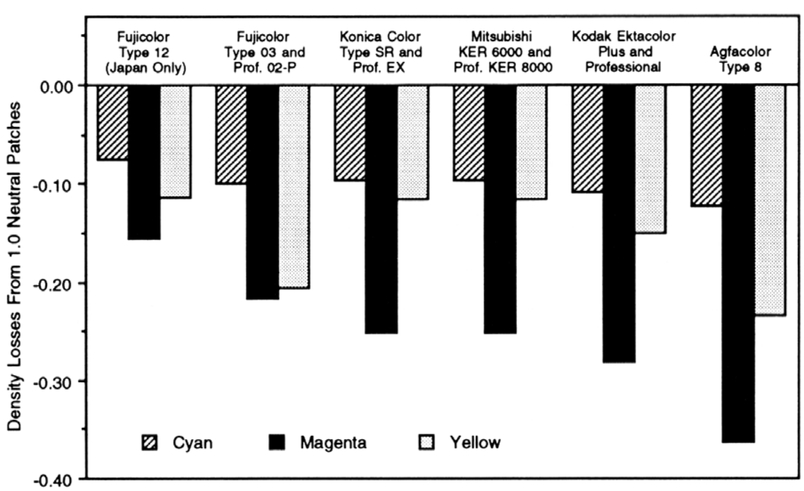


Figure 3.11 Process EP-2 compatible color negative papers compared by density losses from 1.0 neutral patches. As with the RA-4 compatible papers discussed previously, the print samples were covered with glass and exposed to 21.5 klux fluorescent illumination for 100 days in accelerated light fading tests conducted at 75°F (24°C) and 60% RH. This light exposure is equivalent to 26 years of display under this author's "standard display condition" of 450 lux for 12 hours per day. Fujicolor Type 12 paper (1985—) marked the first use of one of the high-stability, low-stain magenta couplers developed by Fuji for color papers.

Comparative Light Fading Stability of Current Process RA-4 Papers for Printing Color Negatives

Introduced in February 1992, Fujicolor Paper Super FA Type 3 and a higher-contrast version called Fujicolor SFA3 Type C for commercial labs are by far the best, longest-lasting RA-4 compatible color negative papers available. Fuji planned to introduce a lower-contrast "professional" version of the papers, tentatively named Fujicolor SFA3 Professional Portrait Paper, around the end of 1992. Fujicolor Supreme paper has also been upgraded to have the same precedent-setting image stability characteristics of the other SFA3 papers.

When exposed to light on display, the Fujicolor SFA3 papers will last *more than four times longer* than Ektacolor Edge, Ektacolor Portra II, Supra, Ultra, and the other Kodak RA-4 papers, as shown in **Figure 3.6** and in **Table 3.1a** (page 131). All of these papers proved to be magenta-dye-limited (with this author's visually-weighted fading limits, the magenta dye was considered to be the least stable of the three image dyes).

All of the RA-4 Ektacolor papers listed in **Table 3.1a** had essentially identical light fading stability; the image-life predictions given here were based on tests with Ektacolor Portra II Paper, which was introduced in 1992 as a replacement for Ektacolor Portra Paper. Portra II was the latest version of Ektacolor paper available to this author for testing at the time this book went to press in late 1992.

The major advance in light fading stability of the Fujicolor SFA3 papers was made possible by a new type of high-stability, low-stain coupler that forms a magenta dye of greatly increased resistance to light fading and also has greater color purity. The resistance to light fading is further increased by special stabilizers incorporated into the emulsion of SFA3 papers.[16] The new Fuji magenta-dye-forming coupler has markedly reduced rates of yellowish stain formation when the prints are in dark storage, and, in terms of stain formation, Fuji reports that it makes little difference whether the prints are processed in the "washless mode" with Fuji washless stabilizer, or are given a water wash.

The magenta-dye-forming coupler employed by Kodak in its RA-4 and EP-2 Ektacolor papers has been little improved since the introduction of Ektacolor 37 RC paper in 1971; the magenta dye has poor light fading stability, and the unreacted magenta coupler has a pronounced tendency to form yellowish stain when the prints are in dark storage. With current RA-4 and EP-2 Ektacolor papers, dark storage stain formation is a more serious problem than dark storage dye fading.

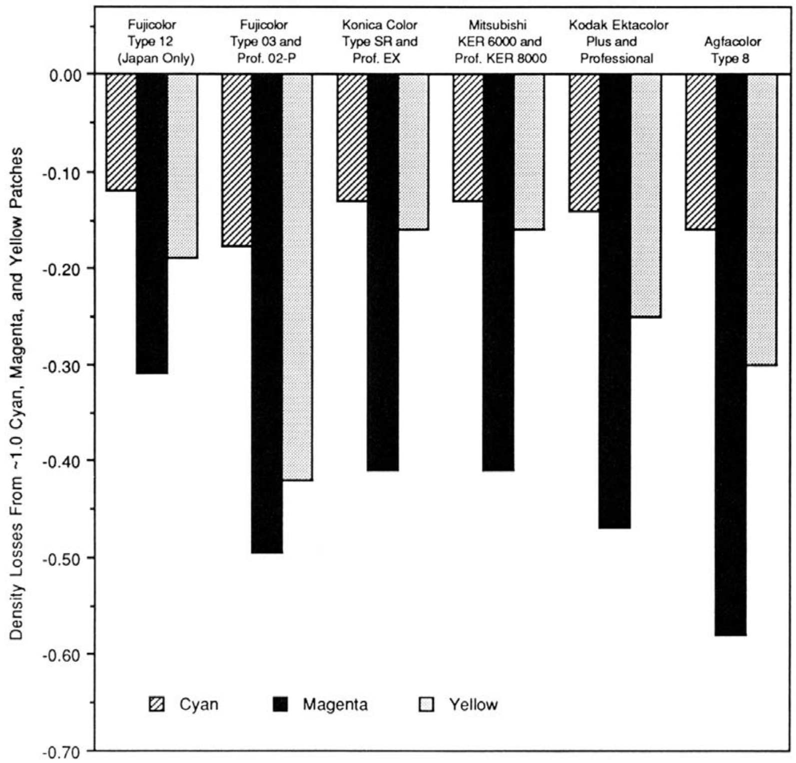


Figure 3.12 Process EP-2 compatible color negative papers compared by density losses from ~1.0 cyan, magenta, and yellow color patches. Fujicolor Type 12 paper has the best light fading stability among the papers; however, for a number of reasons, Fujicolor Type 12 paper has not generally been marketed outside of Japan. Among the papers available in the U.S. and Europe, Konica Color Type SR papers are recommended as the best of the EP-2 products.

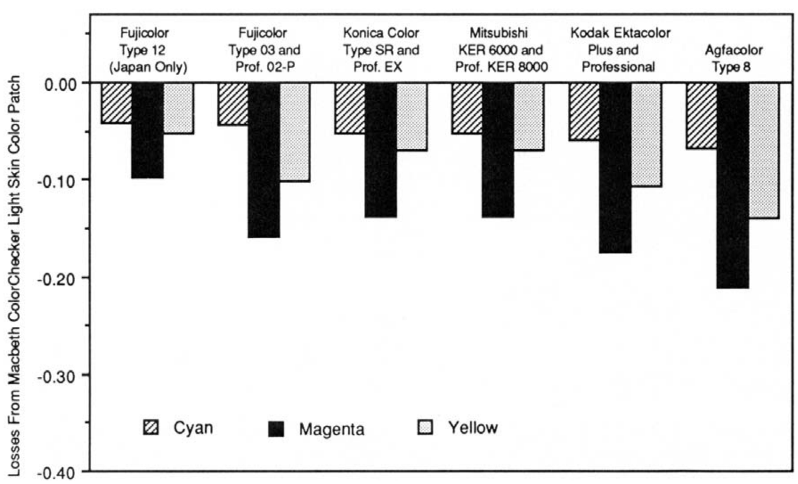


Figure 3.13 Process EP-2 compatible color negative papers compared by density losses from the Macbeth ColorChecker Light Skin Color patch. For portraits and wedding photographs, this is usually the most important indicator of a color paper's performance. The Konica (and Mitsubishi) papers are recommended as the best among available EP-2 papers and, in terms of overall stability, are significantly better than Kodak Ektacolor Plus and Professional papers. Because of the lower initial density of the ColorChecker Light Skin Color patch, a 60-day test period was used in this test (equivalent to 16 years of display under this author's "standard display condition").

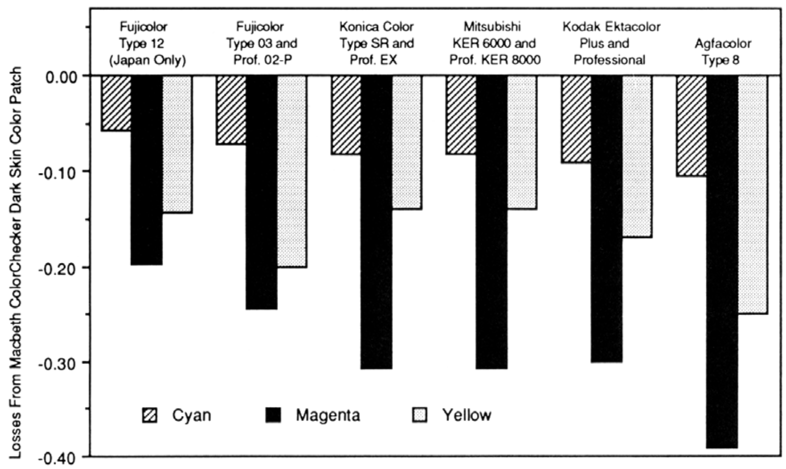


Figure 3.14 Process EP-2 compatible color negative papers compared by density losses from the Macbeth ColorChecker Dark Skin Color patch. This color is representative of the skin color of dark-skinned individuals. Most portraits, whether of light-skinned or dark-skinned people, have important areas of low-density highlights, and pictorial quality is adversely affected if these highlight areas fade or suffer color balance changes.

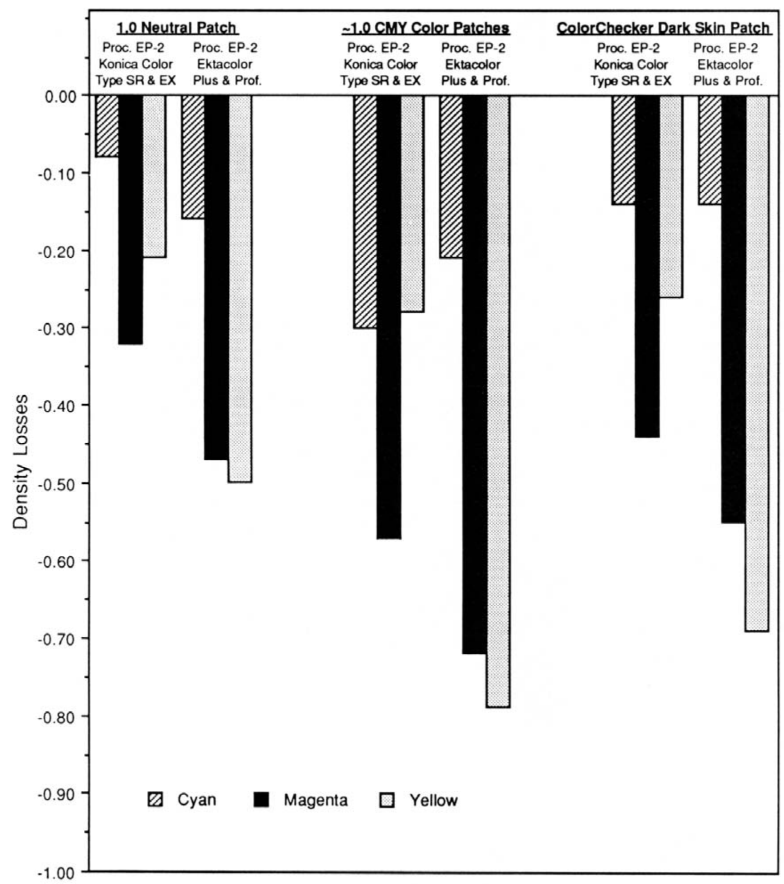


Figure 3.15 Konica Color PC Paper Type SR and Kodak Ektacolor Plus Paper compared in a 6-year, 1.35 klux test with fluorescent illumination. The sample area was maintained at 75°F (24°C) and 60% RH, and the print samples were covered with glass. In this test, Konica Type SR paper performed much better than did Ektacolor Plus. Because of light-fading reciprocity failures, which are more pronounced with the Ektacolor paper than with the Konica paper, the disparity between the two products is greater than indicated by short-term, high-intensity 21.5 klux tests. Particularly noteworthy is the substantially increased fading of the Ektacolor yellow dye in the 1.35 klux test compared with the 21.5 klux test. The low-intensity 1.35 klux test more closely approximates normal indoor display conditions than does the short-term, 21.5 klux test.

Although not as good as the Fujicolor SFA3 papers in either dark storage (yellowish stain) or light fading stability, Konica Color QA Paper Type A3 and its lower-contrast "professional" counterpart, Konica QA Paper Professional Type X2, are this author's second recommendation among the RA-4 papers.

Figures 3.7 and **3.8** compare the light fading stability of neutral and color patches with the current RA-4 papers. The superiority of the Fujicolor SFA3 papers over Ektacolor, Konica Color, and Agfacolor papers is obvious. The stability of the magenta dye in Fujicolor SFA3 papers closely matches that of the cyan and yellow dyes, thus minimizing color balance changes as fading progresses.

Of particular importance for portrait and wedding photographers is the performance of a color paper in terms of the fading of skin tones (see **Figures 3.9** and **3.10**; to this author's knowledge, this is the first publication of a comparison of color papers based on the stability of skin colors). Again, the superiority of the Fujicolor SFA3 papers over Kodak's Ektacolor papers is obvious. As light fading progresses, the disproportionate fading of the magenta dye in Ektacolor papers imparts an ever more sickly, greenish appearance to skin tones. This is especially apparent in light skin tones because of their low initial density.

Because of the superior performance of the Fujicolor SFA3 papers, both when exposed to light on display and when kept in dark storage, the papers are particularly recommended for portrait, wedding, photo-decor, and fine art photography — markets where long-lasting prints are a must.

Comparative Light Fading Stability of Current Process EP-2 Papers for Printing Color Negatives

As discussed previously, Process EP-2 papers are being phased out in favor of faster-processing RA-4 papers. The papers listed in **Table 3.1b** (page 132) are probably the last of their kind; with the market moving rapidly toward RA-4 papers, it is unlikely that any new EP-2 papers will be introduced in the future.

Figures 3.11 and **3.12** illustrate the light fading stability of neutral and color patches for the EP-2 papers. Compared with Ektacolor Plus

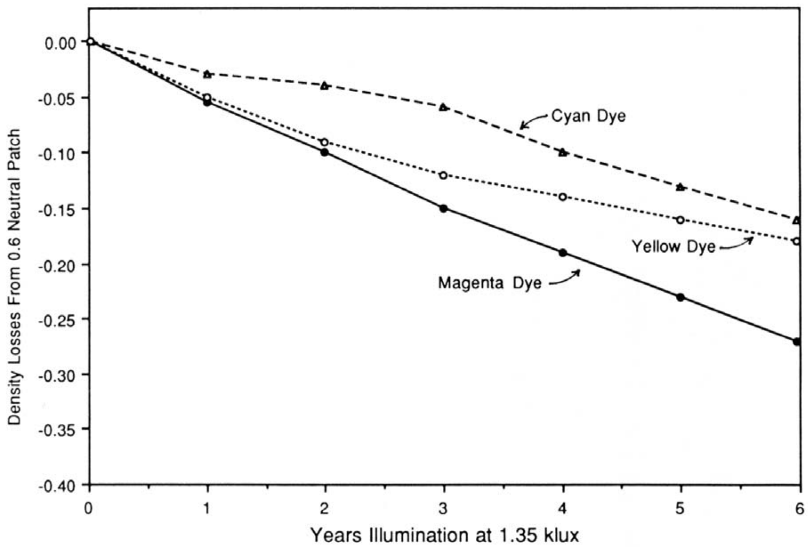


Figure 3.16 Konica Color Type SR and Type EX papers exposed to glass-filtered Cool White fluorescent illumination for 6 years in a low-level, 1.35 klux accelerated light fading test. With a relatively small change in color balance, the overall light fading stability of Konica Type SR and Type EX papers was better than that of any other Process EP-2 compatible papers tested.

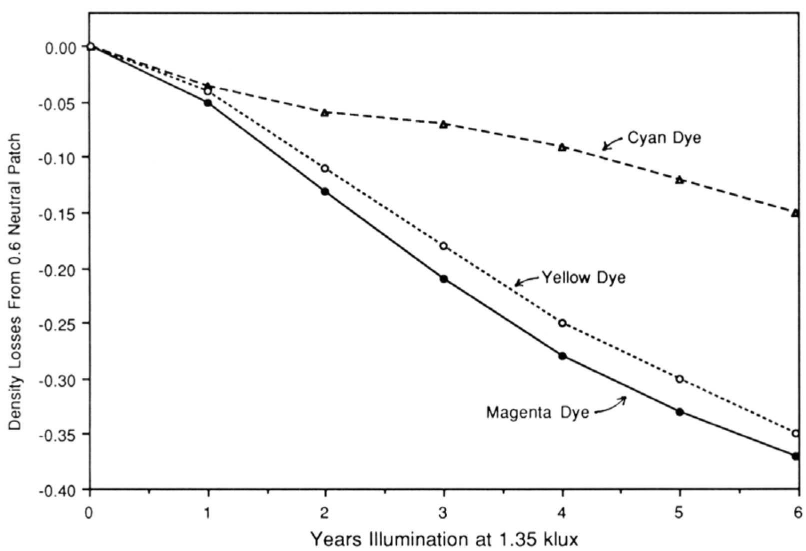


Figure 3.17 Kodak Ektacolor Plus and Ektacolor Professional papers exposed to glass-filtered Cool White fluorescent illumination for 6 years in a low-level, 1.35 klux accelerated light fading test. Note the more rapid fading of the magenta and yellow dyes, and the greater change in color balance, compared with that of Konica Type SR and Type EX papers (see above **Figure 3.16**). Generally similar data were obtained with prints exposed to bare-bulb fluorescent illumination and with prints covered with sheets of Plexiglas UF-3, a sharp-cutting acrylic UV filter.

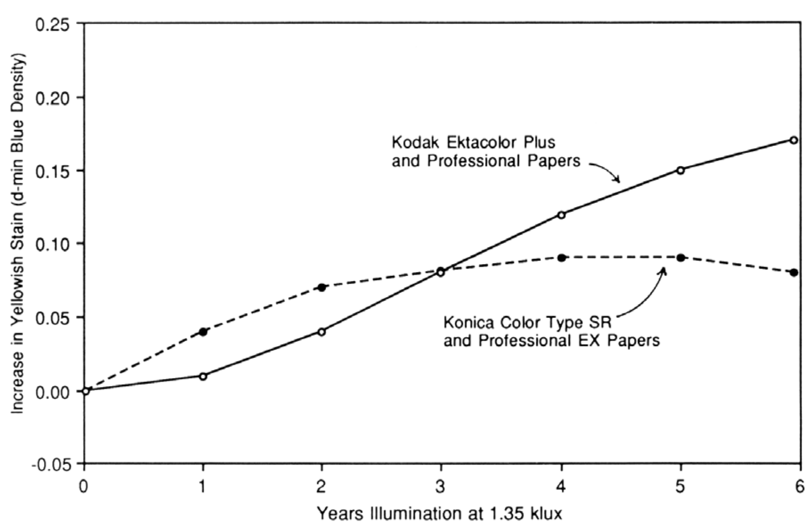


Figure 3.18 D-min yellowish stain formation in Konica Color Type SR and Ektacolor Plus papers compared in a 6-year, 1.35 klux test with fluorescent illumination. At the end of 6 years, the Ektacolor print had developed approximately twice the stain level of the Konica Type SR print. Because of pronounced stain-formation reciprocity failures, high-intensity tests offer little useful information on the light-induced staining tendency of chromogenic color papers. It should be noted, however, that dye fading, and not stain formation, is the most serious problem for displayed prints made with current papers.

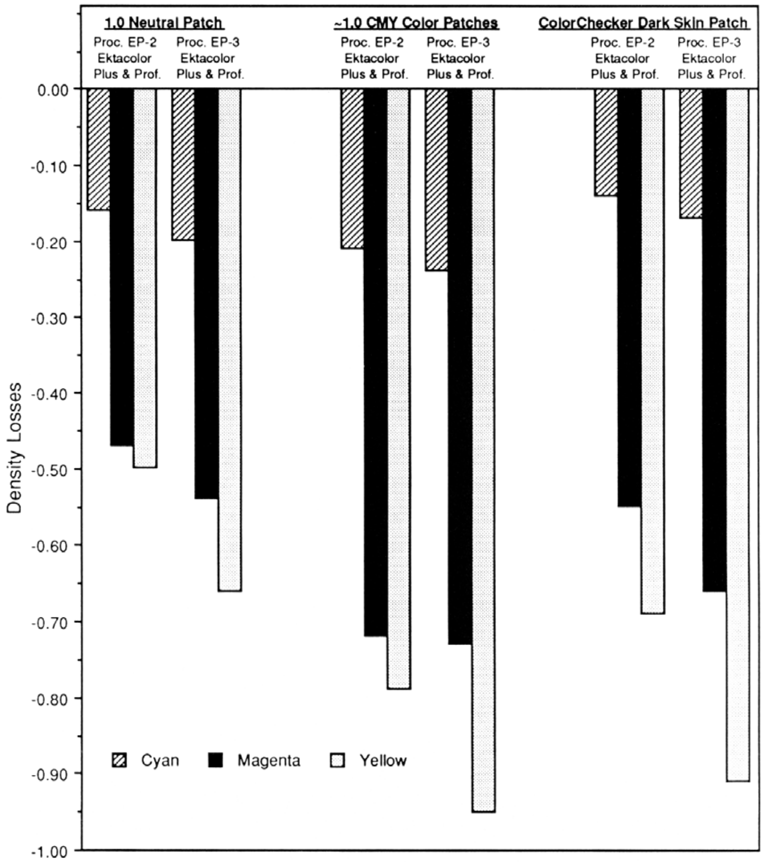


Figure 3.19 The light fading behavior of Ektacolor Plus prints processed by two different methods. In 6-year, glass-covered 1.35 klux fluorescent tests, yellow dye fading increased when prints were processed with Ektaprint EP-3 Stabilizer as a final rinse. This loss of yellow dye stability, which is particularly objectionable in skin-tone colors, exhibits large reciprocity failures in short-term, high-intensity (e.g., 21.5 klux) tests. Use of EP-3 Stabilizer was generally phased out after Ektacolor Plus Paper was introduced in 1984. EP-3 Stabilizer, which both increases cyan dye stability and reduces yellowish stain formation with Ektacolor papers in dark storage, was extensively used with Ektacolor 37 RC paper (1971–78) and Ektacolor 74 RC paper (1977–86). Unfortunately, EP-3 Stabilizer significantly reduced the yellow dye stability of these papers when displayed. The yellow dye in Konica Type SR paper is not similarly affected by EP-3 Stabilizer or other low-pH stabilizers such as Konica Super Stabilizer.

and Professional papers, Konica Type SR and Konica Professional EX papers demonstrate improved performance. This is particularly important for reproduction of light skin tones, as shown in **Figure 3.13**. Dark skin color stability is shown in **Figure 3.14**. The superiority of the Konica Color PC Paper Type SR and Professional EX papers over Ektacolor Plus and Ektacolor Professional paper becomes even more apparent in 6-year, low-level 1.35 klux tests, as shown in **Figure 3.15** through **Figure 3.18**.

One of the interesting findings of this author's long-term, low-level 1.35 klux tests is that with Ektacolor Plus and Professional papers, the yellow dye exhibited significant reciprocity failure and faded much more with equivalent illumination than it did in high-intensity 21.5 klux tests. In comparing **Figure 3.19** with the Ektacolor Plus data in **Figures 3.11**, **3.12**, and **3.14**, it can be seen that the color balance shift was more extreme in the 1.35 klux condition. Furthermore, as shown in **Figure 3.19**, when Ektacolor Plus and Professional papers were processed with EP-3 Stabilizer, the fading of the yellow dye (and resultant color balance change) was even more pronounced. Konica Type SR and Professional EX, on the other hand, exhibited much less of a reciprocity failure of the yellow dye in the 1.35 klux tests, and a more pleasing flesh tone color balance was maintained.

Except for limited sales under the name Fujicolor Minilab Paper, Fujicolor Paper Type 12 has not been available outside of Japan. This was the first Fuji paper to use one of Fuji's high-stability, low-stain magenta couplers, and it is the predecessor of Fuji's outstanding SFA3 papers. Fujicolor Type 12 paper was not supplied to the general U.S. market because, according to Fuji, Kodak and some other non-Fuji EP-2 developers produced unacceptable color-crossovers when the developers were mixed with certain types of water.

Even though Fujicolor Paper Type 03 and Professional Type 02-P had somewhat better light fading stability, this author recommends Konica Color Paper Type SR and Professional Type EX as the best of the EP-2 papers because the Konica papers had significantly better dark storage stability, particularly when processed in the washless mode with Konica Super Stabilizer.

Comparative Light Fading Stability of Discontinued Color Negative Papers

Most of the papers included in **Table 3.1c** (page 133) are EP-2 products, although some RA-4 papers are represented. One of the most striking findings is that very little improvement in the light fading stability of Ektacolor papers has been made since the introduction of Ektacolor 37 RC Paper in 1971 — over 20 years ago! The same general type of magenta dye continues to be used by Kodak in its current RA-4 and EP-2 papers. One improvement that can be seen in Ektacolor papers, however, is the UV-absorbing emulsion overcoat that appeared unannounced in Ektacolor 74 RC Paper in early 1982. The initial type of Ektacolor 74 RC Paper, which did not have a UV-absorbing overcoat, exhibited very rapid cyan dye fading when exposed to illumina-

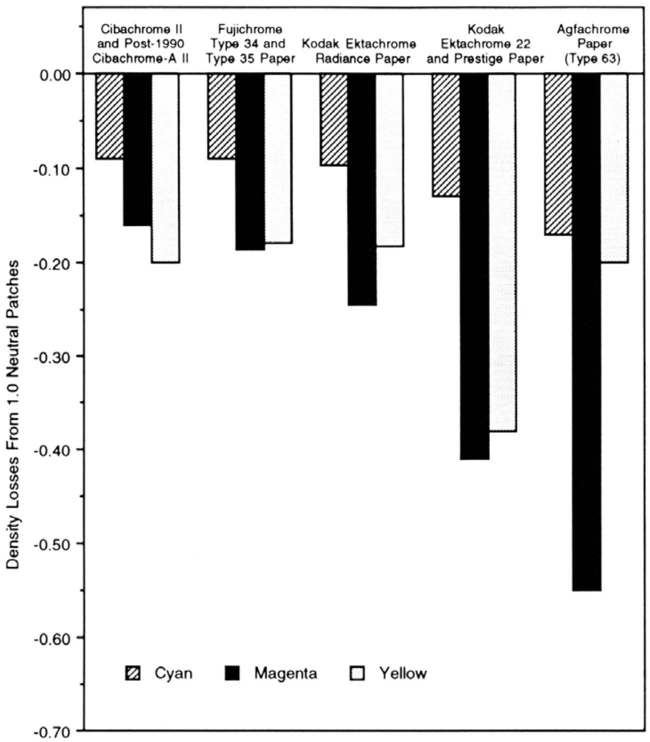


Figure 3.20 Papers for printing color transparencies compared by density losses from 1.0 neutral patches. As with the color negative papers discussed previously, the Process R-3 Fujichrome, Ektachrome, and Agfachrome print samples were covered with glass and exposed to 21.5 klux fluorescent illumination for 100 days in accelerated light fading tests conducted at 75°F (24°C) and 60% RH. Because of the large reciprocity failures exhibited by Ilford Cibachrome materials (renamed Ilford Ilfochrome in 1991) in short-term, high-intensity tests, the Cibachrome II samples were exposed to an equivalent total light exposure at 1.35 klux for 5 years (1,825 days), also at 75°F (24°C) and 60% RH. This light exposure is equivalent to about 30 years of display under this author's "standard display condition" of 450 lux for 12 hours per day. It is important to note that the relative performance of these papers when measured at a neutral density of 1.0 may differ from that when the density is measured at the visually more critical density of 0.6 which was employed in determining the image-life limits reported in **Table 3.2** on page 135.

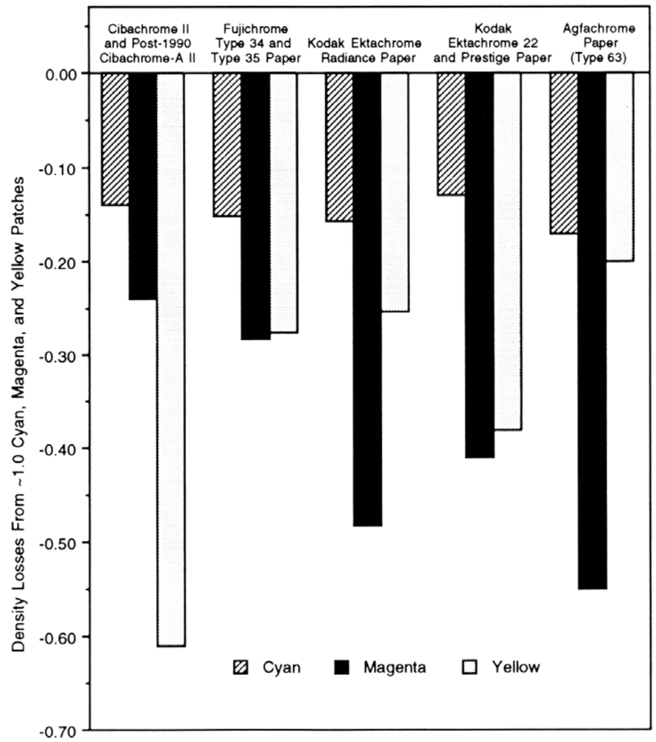


Figure 3.21 Papers for printing color transparencies compared by density losses from ~1.0 cyan, magenta, and yellow color patches. The large loss of yellow dye in the Ilford Cibachrome II (Ilfochrome Classic) print in this 1.35 klux test is not evident in short-term, high-intensity tests. In spite of comparatively large losses of the yellow dye in the pure yellow patch, this author nevertheless rates the overall light-fading stability of Ilfochrome as the best of all easily processed materials for printing color transparencies. Of the various image-life parameters employed by this author in evaluating color prints, the human eye is least sensitive to losses in yellow and near-yellow colors (see discussion in Chapter 2).

tion with a significant UV content (e.g., bare-bulb fluorescent lamps or bare-bulb quartz halogen lamps in fixtures with no glass covers). In indoor north daylight tests, with the light passing through a north-facing window, the benefit of the UV-absorbing overcoat is significant. All chromogenic color negative and color reversal papers are now made with UV-absorbing overcoats.

Comparative Light Fading Stability of Papers for Printing Color Transparencies

The comparative stability of materials for printing color transparencies is given in **Table 3.2** (page 135) and in **Figures 3.20** and **3.21**. Among conventional, easy-to-process color print materials, Ilford Ilfochrome materials (called Cibachrome, 1963–1991) are the only products that can be considered to be absolutely permanent (with essentially zero stain levels) in dark storage at normal room temperatures. Here we see the great advantage of the Ilfochrome preformed dye system over the chromogenic process.

If Ilford would develop an improved-stability, negative-printing version of Ilfochrome, which is well within the realm of silver dye-bleach technology, this new product would be enormously successful in the portrait, wedding, commercial display, and fine art fields.

Beginning with several of the new Ilfochrome Rapid print materials for Process P-4 announced during 1991 and 1992, Ilford introduced a new type of magenta dye that is said to have somewhat improved light fading stability compared with the previous magenta dye. Because both the cyan and yellow dyes remain unchanged from previous Ilfochrome (Cibachrome) print materials, the new magenta dye will probably have little effect on the image-life predictions given for Ilfochrome materials in **Table 3.2** (page 135) and **Table 3.4** (page 139). Ilford reports that the dark

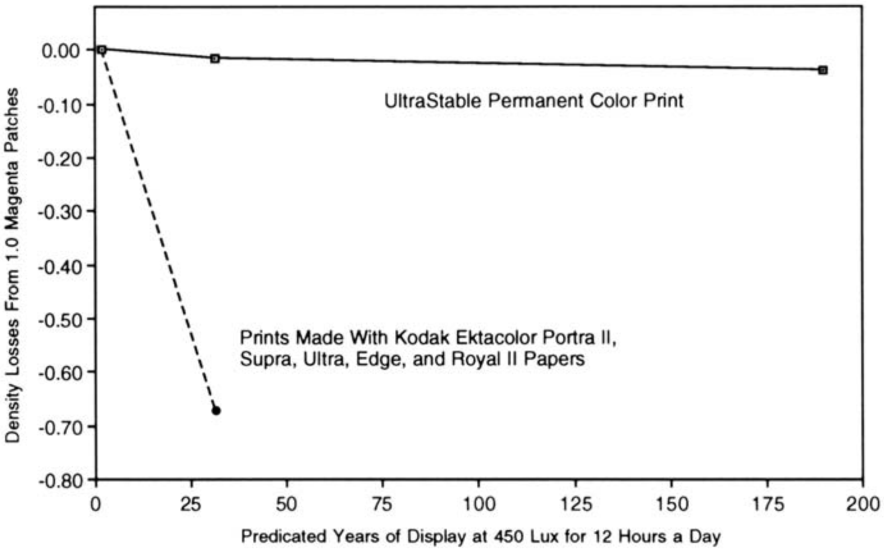


Figure 3.22 The predicted light-fading stability of Polaroid Permanent-Color prints compared with Kodak Ektacolor prints. Polaroid Permanent-Color prints employ color pigments that are far more resistant to light fading than the organic dyes in Ektacolor and other traditional color prints. UltraStable Permanent Color prints, which also employ high-stability pigments, have cyan and magenta pigments with light fading stability that is similar to that of Polaroid Permanent-Color prints. The "improved-stability" non-toxic (lead-free) metal-type yellow pigment to be introduced in early 1993 for the UltraStable process is expected to have light fading stability that is similar to that of the cadmium yellow pigment in Polaroid Permanent-Color prints.

fading stability of the new magenta dye is "as outstanding as it was for the older magenta dye."

As shown in **Figures 3.20** and **3.21**, Fujichrome Type 35 paper is by far the best choice among Process R-3 reversal papers. With its good dye stability and low stain level in dark storage together with good light fading stability, this is the slide-printing counterpart to Fujicolor SFA3 papers for printing color negatives. It should be noted, however, that although Fuji SFA3 and Type 35 papers have similar dark storage stability, SFA3 paper is much more resistant to light fading on display. For that matter, the light fading stability of Fujicolor SFA3 paper is significantly better than that of current Ilfochrome prints!

Kodak Ektachrome Radiance Paper, introduced in 1991 as the successor to Ektachrome 22 Paper, falls considerably short of Fujichrome Type 35 paper in both light fading stability and dark storage stability. In particular, the rates of yellowish stain formation in dark storage are far higher with Ektachrome Radiance papers than with Fujichrome Type 35 papers.

Kodak's Ektachrome Copy Paper, which was still on the market at the time this book went to press in 1992, has a cyan dye with very poor dark fading stability. Ektachrome Copy Paper is a relic from an earlier era of color papers and should be strictly avoided.

Comparative Light Fading Stability of Pigment Color Prints

The estimated image life of displayed pigment color prints is given in **Table 3.2** (page 135). To a greater or lesser degree, all of the organic dyes used to form the images in conventional color films and prints gradually fade when exposed to light. Even Ilford Ilfochrome and Kodak Dye Transfer prints, both of which are exceedingly stable when stored in the dark, will fade to an objectionable degree after relatively few years of display.

(In long-term display, no current color material with a dye image can even approach the stability of the silver image of a carefully processed black-and-white photograph made on fiber-base paper).

UltraStable Permanent Color Prints and Polaroid Permanent-Color Prints

To make a color photograph that can withstand hundreds of years exposure to light on display, UltraStable Permanent Color prints[17–19] and Polaroid Permanent-Color prints[20] employ highly stable cyan, magenta, yellow, and black pigments instead of the organic dyes used by other types of color photographs to form the image. The pigments are similar to those in automobile paints, which must be able to survive years of outdoor sun exposure under the harshest conditions. The prints are made on long-lasting polyester-base materials.

Both UltraStable and Polaroid Permanent-Color materials were developed by Charles Berger of Ben Lomond, California. The Polaroid materials are manufactured by the Polaroid Corporation under contract with commercial users and are not sold in the general market.

UltraStable materials, which have a number of improvements over the earlier Polaroid Permanent-Color materials, are supplied by UltraStable Color Systems, Inc. of Santa Cruz, California.

When made properly, UltraStable prints are extremely sharp and have excellent color and tone reproduction. Prints can be made from existing prints, color negatives, or transparencies. Because separation negatives the size of the final image are required, having the prints made is fairly expensive. A 16x20-inch UltraStable print may cost $500 or more for the first print; additional copies are less. (The UltraStable process is described in detail on pages 49–51.)

This author has employed various tests, including a 6-year, high-intensity 21.5 klux accelerated fluorescent test, to evaluate the stability of Polaroid Permanent-Color pigment prints.[21] Because UltraStable Permanent Color materials with the "improved-stability" yellow pigment (to be introduced in early 1993) were not available when this book went to press, test data for these materials could not be included. (Long-term tests were done with prototype materials having a different, less light-stable yellow pigment.)

What information that is available, however, leaves no doubt that UltraStable prints made with the "improved-

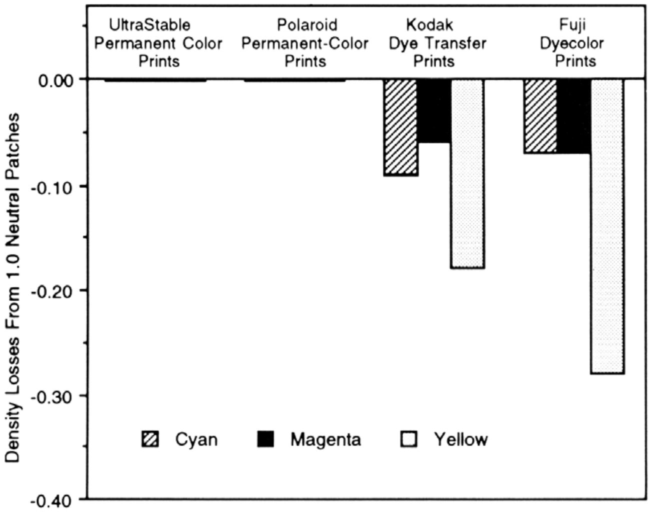


Figure 3.23 A comparison of UltraStable Permanent Color prints (based on the estimated stability of the new yellow pigment to be introduced in early 1993) and Polaroid Permanent-Color pigment prints with Kodak Dye Transfer and Fuji Dyecolor prints by density losses from 1.0 neutral density patches. In this accelerated test, the prints were covered with glass and exposed to 21.5 klux fluorescent illumination for 100 days. Dye Transfer and Fuji Dyecolor prints employ preformed dyes to form the image; while the prints are subject to light fading, they are essentially permanent in dark storage (see Chapter 5). All four of these processes require black-and-white separation films that are the same size as the final prints; because of this, they are considerably more labor-intensive and costly than Fujicolor, Ektacolor, Agfacolor, Konica Color, Ilfochrome, and other easy-to-process materials.

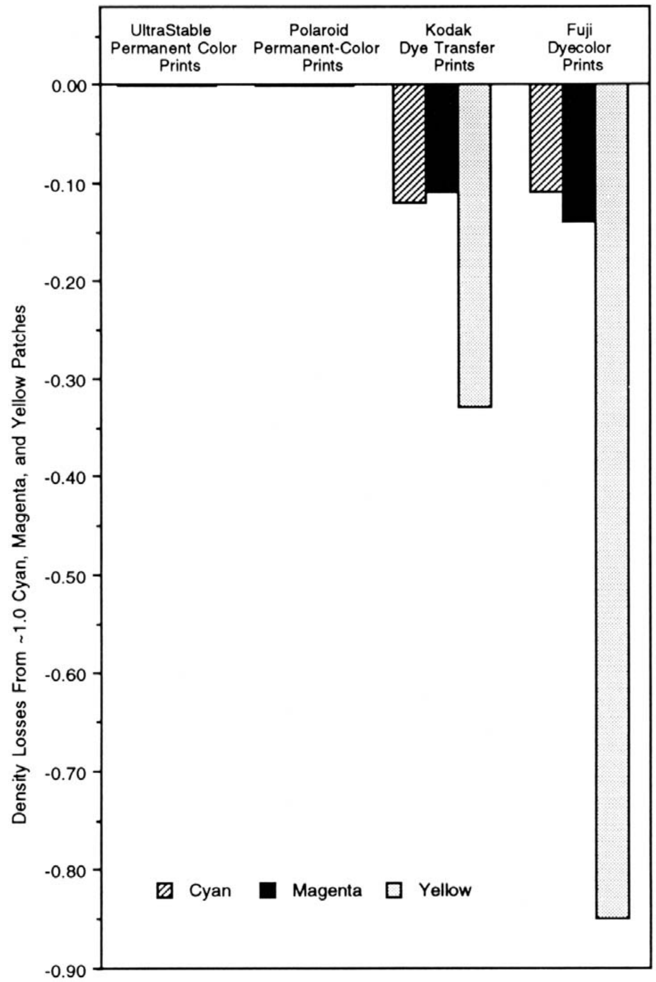


Figure 3.24 A comparison of UltraStable Permanent Color prints (based on the estimated stability of the new yellow pigment to be introduced in early 1993) and Polaroid Permanent-Color pigment prints with Kodak Dye Transfer prints and Fuji Dyecolor prints by density losses from ~1.0 cyan, magenta, and yellow patches. (The test conditions were the same as those employed in **Figure 3.23**.) Fujicolor Dyecolor prints, which are made by a method which is similar to that used with the Kodak Dye Transfer Process, are produced by the Fujicolor Services lab in Osaka, Japan and are not available outside of Japan.

stability" yellow pigment and Polaroid Permanent-Color prints are far more stable than any other type of color print on the market (**see Figures 3.22** through **3.24**). Under typical indoor display conditions, it is expected that both types of prints should last for 500 years or more before noticeable fading or staining occurs. The prints also have extremely good dark storage stability.

The stability of the color pigments in UltraStable and Polaroid Permanent-Color Prints is such that the display life of the prints probably is not limited by fading, but rather by cracking (which most likely would be caused by fluctuating relative humidity) of the pigment-containing gelatin image layers, by instability of the gelatin after years of exposure to light, by adhesion failures between the gelatin and white polyester support material, or by the eventual failure of the polyester support itself.

The comparative light fading characteristics of UltraStable Permanent Color Prints (made with the "improved-stability" yellow pigment introduced in early 1993), Polaroid Permanent-Color Prints, Kodak Dye Transfer Prints, and Fuji Dyecolor prints are shown in **Figures 3.23** and **3.24**.

EverColor Pigment Prints

In late 1992 the EverColor Corporation of El Dorado Hills, California announced the EverColor process for making long-lasting pigment color prints.[22] The EverColor process is a high-stability modification of the AgfaProof graphic arts proofing process which employs silver-halide gelatin emulsions that contain cyan, magenta, yellow, and black pigments. EverColor plans to offer the prints commercially in early 1993.

In succession, each layer is mechanically transferred onto a polyester print support sheet with an AgfaProof automated transfer machine. Following transfer, the sheet is dried in an AgfaProof dryer. The print sheet is then exposed through the appropriate screened separation negative in a low-wattage graphic arts contact printer. Following exposure, the print sheet is run through an AgfaProof processing machine which develops the image in a "tanning developer" that hardens the gelatin in proportion to image density, immerses the print in a bleach/fix bath to remove the developed silver image, and then washes off unhardened pigment-containing gelatin in a warm water bath to reveal the color image. The print is then dried in an AgfaProof dryer, and the process is repeated for each of the remaining three colors to complete the print.

The AgfaProof system was designed as a graphic arts proofing process, and as such the cyan, magenta, yellow, and black pigments normally employed by Agfa have been selected to precisely match 4-color printing inks; light fading stability was not a consideration. The EverColor Corporation contracted with Agfa to coat special emulsions that are formulated with carefully selected high-stability color pigments.

The EverColor process appears to have all of the needed characteristics for making very long lasting, high-quality prints at reasonable cost. The image quality of AgfaProof graphic arts proofs is very good, and the process is highly reproducible. In the future, with the incorporation of high-speed silver halides in the emulsions, it would appear that the materials could be direct-written by a laser scanner output device. This would eliminate the expense of making full-size separations and would lower the cost of making the prints when only one or two copies are required.

Based on limited information on the pigments provided by Bill Nordstrom of the EverColor Corporation, this author has included EverColor prints in **Table 3.2** (page 135). It must be emphasized, however, that at the time this book went to press in late 1992, this author had not had the opportunity to test EverColor prints. Indeed, at the time of this writing, this author had not even seen an EverColor print. Nevertheless, it was felt that the reader would want to know about the EverColor process, and for that reason it is included here.

At the time this book went to press in 1992, Nordstrom was producing UltraStable prints through his firm, Color Prints by Nordstrom. He has indicated that his company will probably continue to supply UltraStable prints on request after the EverColor process goes into production.

Fuji-Inax Photocera Ceramic Color Photographs

Fuji-Inax Photocera ceramic color photographs (see page 44) are a joint development of Fuji Photo Film Co., Ltd. and Inax Corporation, a major Japanese producer of ceramic tiles and bathroom fixtures. The photographs are available only in Japan through Fujicolor Processing Service.

The Photocera process, which was introduced in 1991, employs inorganic pigments to print images on ceramic substrates which are fired at very high temperatures. The resulting "photographic ceramic tile" is permanent in the dark and is also unaffected by light, rain, seawater, and fire; in addition, the images are very resistant to surface abrasion. Intended markets for Fuji-Inax Photocera color photographs include heirloom gifts, outdoor signs in zoos and parks, and portraits for memorials and gravestones. Samples of Photocera photographs were not received in time for test results to be included in this book. However, test data made available to this author by Fuji leave little doubt that Photocera photographs are *extremely* long lasting. Fuji calls the photographs "quasi-eternal."

Photocera photographs, which have screened images, can be printed from any type of photographic original and are available in a variety of sizes from 2½ x 3½ inches ($260 for the first print, less for additional copies) to 24 x 31 inches ($5,820 for the first print, less for additional copies).

Fresson Quadrichromie Pigment Prints

Fresson Quadrichromie pigment color prints are made in France by Atelier Michel Fresson. The Fresson lab, located near Paris,[23] has been producing limited quantities of Quadrichromie prints since 1952. The materials to make the prints are not available to the public.

Comparative Light Fading Stability of Color Prints Made by Thermal Dye Transfer, Canon Laser Copier, Iris Ink Jet, and Other Processes

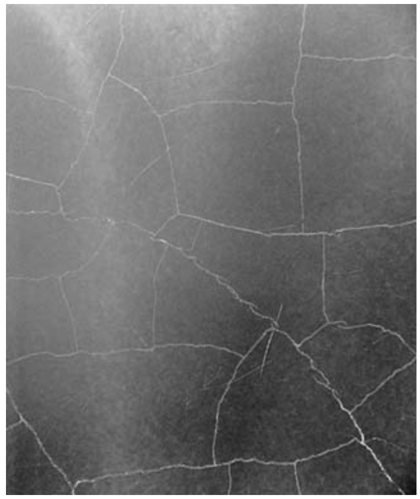
Among the color print materials and processes listed in **Table 3.3** (page 137) are a number of new technologies for making color prints that have emerged during the last 10 years and are now beginning to make serious inroads in the photography field. Probably foremost among them is the thermal dye transfer process, which is being employed in digital desktop thermal printers made by Kodak, Sony, Hitachi, and other manufacturers to produce fairly high-quality "photorealistic" color prints. Ektatherm prints, which are made with the Kodak XL7700-series digital printers (costing between $18,000 and $25,000), are perhaps the most prominent example of this technology. With the commercial introduction of the Kodak Photo CD system in the summer of 1992, Ektatherm prints will be the only type of print initially available from the Photo CD's; in addition, the Photo CD Index Print supplied with each Kodak Photo CD as a "contact sheet" visual reference to the images recorded on the disc will be an Ektatherm print.

Unlike conventional color materials such as Ektacolor and Fujicolor prints, Ektatherm and other thermal dye transfer papers do not have a UV-absorbing overcoat. The image dyes in Ektatherm prints are adversely affected by UV radiation, and in display situations where significant UV radiation is present, such as with bare-bulb fluorescent illumination, the prints fade much more rapidly than they do when protected from UV radiation (see **Figure 3.5**). Because thermal dye transfer materials use preformed dyes or pigments to form the color image, the stability of the images could probably be significantly improved in the future with the selection of more stable colorants.

Ink jet printing, in which color images are formed by spraying millions of tiny ink droplets in precise position onto paper, has found significant application in the graphic arts field for direct proofing of the digital data from laser or CCD scanners. Because of the ability of ink jet printers to make large prints on almost any sort of paper or other support material, there has been significant interest in the technology in the fine arts field (see pages 52–54 for discussion of the use of Iris ink jet printers for making fine art prints at Nash Editions in California). Unfortunately, at the time this book went to press in late 1992, all of the ink sets available for use in Iris ink jet printers had very poor light fading stability.

Image-life predictions for the standard Iris ink set are given in **Table 3.3** (page 137); also tested was an ink set made by American Ink Jet, which proved only somewhat

A Polaroid SX-70 color print made in 1973 that has developed internal image-receiving layer cracks. Early SX-70 prints (1972–76) are frequently found to have developed such cracks, especially if they have been stored in very dry conditions.



A magnified view of the image cracks, which form in the upper layers of the print's internal structure. The transparent polyester sheet that covers the top of the print is not affected by the internal cracking and remains intact.

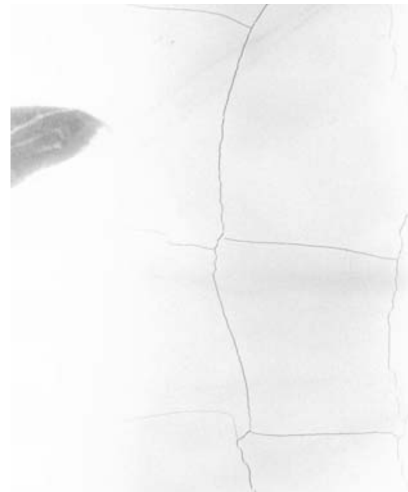


Image-receiving layer cracks are often easier to detect in light areas of an SX-70 image. Unlike the light-induced cracks found in RC prints, light apparently plays no role in the formation of image-receiving layer cracks in SX-70 prints.

more stable than the Iris inks, and an ink set supplied by Siemens, which was even less stable than the Iris inks. It is hoped that a much more light-stable ink set can be developed for ink jet printing; the process has much to offer from an aesthetic and functional point of view, especially for large display prints.

Two ink set supplied by Stork Bedford B.V. for Stork ink jet printers were also tested, but the light fading stability of these inks proved to be little better than the Iris ink set.

Electrophotographic or xerographic color prints, all of which use preformed colorants to form images, show great promise as a means of making stable color prints. Using a Canon Color Laser Copier, for example, photographs of sufficient quality for proofs, business presentations, and short-run publications can be produced quickly and at low cost. The light fading stability of Canon color copies is much better than that of Ektacolor prints, but not as good as that of Fujicolor SFA3 prints.

Polaroid Instant Color Prints

As shown in **Table 3.3** (page 137), Polaroid Spectra and Polaroid 600 Plus prints also have poor light fading stability. Polaroid Spectra film was replaced with Spectra HD (High Definition) film in 1991; samples of Spectra HD were not available in time for 1.35 klux test data to be included in this book; however, the image stability of Spectra HD prints is believed to be similar to that of previous Spectra prints.

When displayed, Polaroid Spectra, 600 Plus, and SX-70 prints fade significantly faster than typical chromogenic papers. The dyes in Polaroid instant prints are extremely stable in dark storage. The problem with these prints is that in dark storage at normal room temperatures, they develop an objectionable yellowish overall stain in a relatively short period. In non-accelerated (real-time) tests, the stain levels exceeded this author's d-min stain limits in only a few years. The stain is produced by slow migration of non-image dyes and/or other chemical constituents residing in the lower layers of the tightly sealed Polaroid print package.

In 1992 Polaroid introduced the Vision 95 system in Europe, a smaller format camera and film employing an improved version of the Spectra HD print emulsion. In 1993, "Vision 95" cameras and film will be introduced in the United States and other parts of the world under different names. A Polaroid spokesman told this author that the light fading stability of Vision 95 prints is expected to be essentially the same as that of Spectra and Spectra HD prints. The spokesman also indicated that Vision 95 prints have a somewhat reduced rate of yellowish staining in dark storage; however, specific stain data for Vision 95 prints were not available from Polaroid or independent laboratories at the time this book went to press.

Polaroid color prints have no usable negative (like daguerreotypes, each exposure produces a unique image). If important pictures have been made on these materials, the best policy is to make two copies on a more stable print material (Polaroid itself offers good-quality copies, made on Fujicolor color negative paper, at reasonable cost). Keep one copy in the dark and display the other.

Polaroid peel-apart prints (e.g., Polacolor ER and Polacolor 2) do much better in dark storage than Spectra and other Polaroid integral prints because in the peel-apart prints, the negative layer (with its unused image-forming dyes and other chemicals) is stripped away after processing. However, these prints have poor light fading stability and should be displayed with caution. Copies should be made for long-term display.

Beginning with the introduction of SX-70 prints in 1972, Polaroid has made numerous misleading claims about the

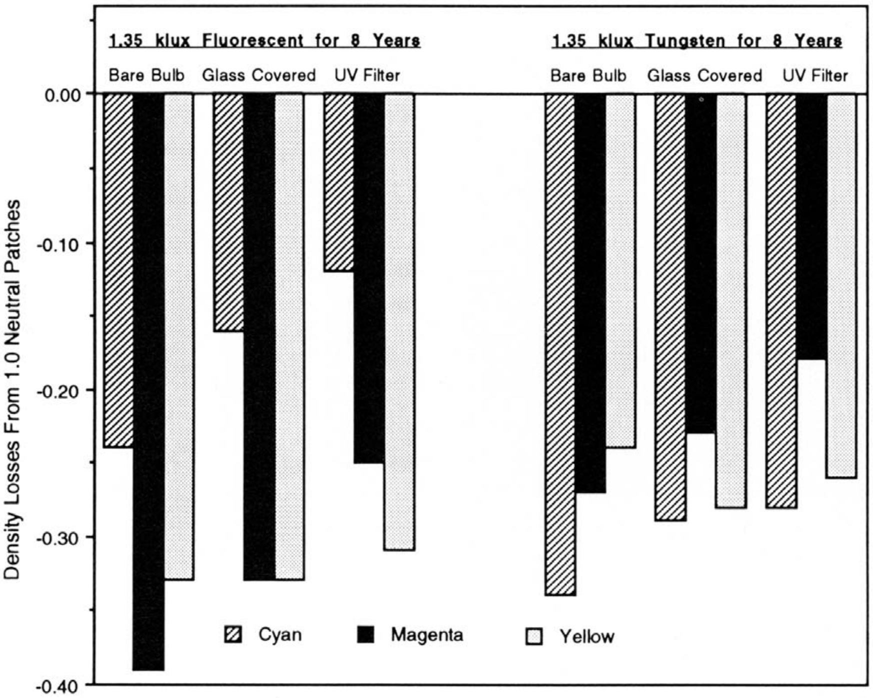


Figure 3.25 A comparison of glossy, polyester-base Ilford Cibachrome II (Ilfochrome Classic) prints in an 8-year test with 1.35 klux fluorescent and 1.35 klux incandescent tungsten illumination by density losses from 1.0 neutrals. Note that the cyan dye faded more under tungsten illumination than it did under fluorescent illumination. Using this author's image-life fading and color balance change limits, and a starting density of 0.6, the tungsten-illuminated print actually reached its first image-life limit sooner than did the fluorescent-illuminated print (see **Table 3.5**).

dye stability of its materials.[24–26] For example, in a two-page advertisement that appeared in *Newsweek* and a number of other national magazines, Polaroid said:

> The photographer is Marie Cosindas. The medium is Polaroid's Polacolor Land film. The result is the remarkable photograph at the right, "Dolls," a work of art recently acquired by the Museum of Fine Arts in Boston. Now, Polacolor 2 film has the same unique metallized dyes found in Polaroid's SX-70 film. It has the same exceptional clarity and stability. And its brilliant colors are among the most permanent and fade resistant ever developed in photography. Polacolor film is used by amateur, professional and scientific photographers throughout the world. Polaroid, the choice of the artist in the creation of her art.[27]

The Polaroid Corporation even operates a service called the Polaroid Museum Replica Collection, which reproduces works of art in the Boston Museum of Fine Arts collection on large-format Polacolor ER film and offers the lacquered, mounted, and framed prints to the public. The Polaroid Museum Replica Collection will also reproduce works of art for private individuals. There is no mention of the poor light fading stability of these expensive prints, and no cautions whatever are given concerning the fading that inevitably will occur in the course of long-term display.[28]

There are signs, however, that Polaroid is beginning to take a more realistic public stance regarding the image stability of its color print materials. In a technical data sheet for Polacolor 64 Tungsten instant print film, dated January 1992, Polaroid stated: "Photographs can be damaged by, and must be protected from, the effects of light."[29] Polacolor 64 Tungsten, introduced in 1992, is a tungsten-balanced derivative of daylight-balanced Polacolor ER instant print film.

Internal Image-Receiving Layer Cracking of Polaroid SX-70 Instant Prints

The cracking of the internal image-receiving layer that has occurred in many Polaroid SX-70 prints made during the 1970's is another example of an entirely new type of print material having a completely new type of deterioration. Cracking of this type, in which the internal image layer cracks but the polyester cover and backing sheets are unaffected, has not yet been observed in Fuji instant prints (available only in Japan) or the now-obsolete Kodak instant prints.

Apparently caused by low and/or widely fluctuating relative humidity, the cracking of SX-70 prints does not appear to be influenced by the presence or absence of light unless the light is accompanied by significant heating of the print (which occurs if the print is subjected to direct sunlight, for example). There is no accepted accelerated test for SX-70 cracking. Polaroid has declined to release the details of the tests it uses to evaluate the problem, although the company has said that improvements were made in SX-70 prints around 1980 and that the prints are no longer subject to cracking except under extreme conditions.

Because unacceptable levels of yellow stain can occur after only a few years of storage under normal conditions (see Chapter 5) and because catastrophic internal image-layer cracking is a possibility, this author does not recommend Polaroid Spectra HD prints (called Polaroid Image prints in Europe), Polaroid 600 Plus prints, or SX-70 prints for other than short-term applications. Polaroid instant color prints have no negative from which a new print can be made when the original deteriorates.

Comparative Light Fading Stability of Color Prints Illuminated Under Incandescent Tungsten Lamps

Table 3.4 gives image-life predictions for prints illuminated with incandescent tungsten lamps. This is of primary interest to museums and archives where display areas are usually illuminated solely with tungsten lamps. In this table, both the strict set of "Critical Museum and Archive Use" criteria, which allows very little change in image characteristics, and the more tolerant set of "General Home and Commercial Use" criteria have been included to make display-life extrapolations from the accelerated test data (see Chapter 2).

To report image-life predictions for color prints displayed with incandescent tungsten illumination in museums and archives, this author has adopted an illumination intensity of 300 lux (28 fc) for 12 hours a day. This is a higher illumination level than many conservators recommend, but this author feels that this is the minimum level acceptable for proper viewing of photographs, especially color photographs.

There is no minimum "safe" illumination for color photographs below which fading does not take place, and this author believes that it is better to provide adequate illumination for museum exhibits and at the same time to regularly monitor the fading/staining of the color photographs in the collection. Fading and staining must not be allowed to progress beyond pre-set limits.

Display of originals will have to be restricted in any event, and, where it is deemed acceptable from a curatorial point of view, facsimile color copy prints can be substituted for long-term or "permanent" display while the originals are preserved in cold storage. (The reader is referred to Chapter 7 and Chapter 17 for further discussion of this sometimes controversial subject.)

Because incandescent tungsten illumination has a low UV and blue content (the most photochemically active wavelengths) it has often been recommended that color prints be displayed with tungsten illumination to minimize image fading. This author's tests indicate that for equal illumination intensities, the fading rates observed for many types of prints are not substantially different with tungsten or fluorescent illumination. In fact, as shown in **Table 3.5** (page 142), Ilford Ilfochrome Classic prints (formerly called Cibachrome II prints), and the now-obsolete Agfachrome-Speed and Kodak PR10 instant prints, along with several other materials, actually faded more rapidly under tungsten light than they did with fluorescent.

In the case of Ilford Ilfochrome Classic, as shown in **Figure 3.25**, the cyan dye faded significantly more under tungsten illumination than it did under fluorescent illumination of the same 1.35 klux intensity in 10-year, low-level tests. The most likely explanation for this is the proportionally higher red content in tungsten illumination than in Cool White fluorescent light. Although the photochemical energy of red light is low, it is apparently sufficient to cause fading of the Ilfochrome cyan dye, which has its primary absorption in the red portion of the spectrum. This also appears to be true of the cyan dyes in the now-obsolete Agfachrome-Speed and Kodak PR10 instant prints.

Most of the light to which displayed photographs are exposed in homes and offices is either indirect daylight through window glass or light from fluorescent fixtures. In other than museum display, tungsten light is usually of such low intensity and/or hours of duration that its contribution to the overall light fading of a print is relatively small.

The surprising conclusion of these incandescent illumination studies, as shown in **Table 3.5** (page 142), is that in most cases color prints fade at about the same rate under fluorescent and tungsten illumination of the same lux intensity. There are some differences in fading rate and the direction and degree of color balance change, but the magnitude of these differences is generally small (e.g., refer to the data in **Table 3.5** for Konica Color PC Paper Type SR and Kodak Ektacolor Plus and Professional papers).

Tungsten halogen lamps (also called quartz halogen lamps) are increasingly found in museums, galleries, commercial buildings, and homes. Tungsten halogen lamps have become popular because they operate at a somewhat higher color temperature than incandescent lamps and therefore produce a "whiter" light (see discussion in Chapter 17). Halogen lamps also last longer and use less electricity than incandescent lamps.

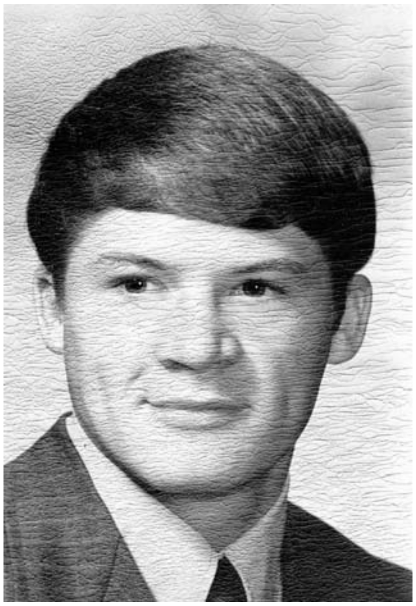
To withstand their high operating temperature, halogen lamps are made with a quartz bulb instead of the glass bulb used in incandescent tungsten lamps. Quartz is transparent to much shorter wavelengths than is glass, and for this reason bare-bulb halogen lamps emit significant energy in both the long- and short-wavelength ultraviolet region. Such UV radiation can be very damaging to color photographs (especially Kodak Ektatherm and other types of color materials that lack a UV-absorbing overcoat). For this reason, halogen lamps should always be fitted with a protective glass or plastic cover that will absorb UV radiation below about 330 nm.

Recent studies have shown that exposure to bare-bulb tungsten halogen illumination may also increase the risk of skin cancer in humans.[30] Covering the lamps with a sheet of glass or plastic to absorb short-wavelength UV radiation apparently eliminates such risk.

Comparative Light Fading Stability of Color Prints Illuminated with North Daylight

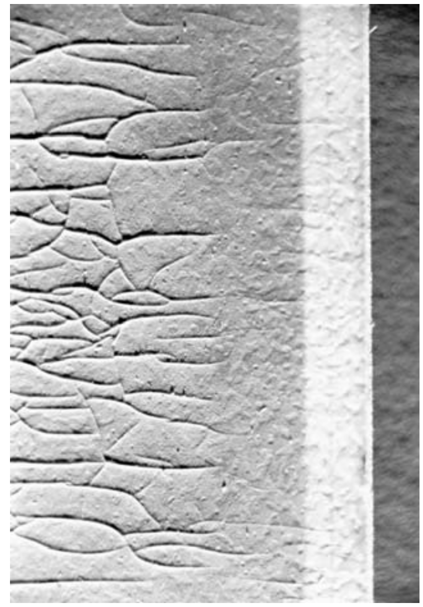
Table 3.6 (page 143) gives the relative stability of many types of color prints exposed to north daylight through window glass. With the prints located close to the window, this is a "worst-case" display situation. North daylight contains a significantly higher percentage of blue light and UV radiation than either tungsten or glass-filtered fluorescent light.

In comparing the image-life predictions in this table with the predictions given in **Tables 3.1b** and **3.1c**, and **Tables 3.2** and **3.3**, it can be seen that north daylight illumination is in most cases more harmful to color prints than is either fluorescent or tungsten illumination. This is true even when prints exposed to north daylight are shielded from ultraviolet radiation with a UV-absorbing filter. Because the average illumination intensity in this north daylight test was only 0.78 klux (averaged over a 24-hour period), much longer test periods were required than was the case with the high-intensity 21.5 klux fluorescent tests re-



A Kodak Ektacolor RC (resin-coated) print that has suffered light-induced cracking of the thin white RC layer coated on the paper core of the print beneath the emulsion. The RC layer is made of polyethylene pigmented with titanium dioxide. This print, which was made in 1970, developed the cracks after only about 6 years of display under normal conditions in a home. The print had been dry mounted and framed under glass. (Original color photograph by Max Brown)

A magnified view of part of the cracked print. By the time the cracks appeared, the print had also showed significant fading. Like most professional portraits, this print had been lacquered. Similar Ektacolor prints from the time that had not been lacquered have in many cases also suffered light-induced RC layer cracking. This author has observed similar light-induced RC cracking in Agfacolor, Ektachrome, and Cibachrome RC prints made from about 1974 until the early 1980's.



That prolonged exposure to light was the cause of the cracking of this print is evident in this magnified view of the edge of the print: the cracking of the RC layer stopped where the edge of the print was protected from light by a frame. Black-and-white RC prints may also develop light-induced cracking of the RC layer; in addition, they may suffer from light-induced discoloration and fading of the silver image (see discussion of the problems of B&W RC prints in Chapter 17).

ported earlier in this chapter. Reciprocity failures probably contributed to the shorter image-life predictions for many of the materials in the north daylight test. In addition, because an integrating lux-hour meter was available for measuring the accumulated illumination only during the last few years of this 10-year test, there is some uncertainty about what the average illumination actually was during the early years of the test.

The north daylight test does, however, provide valuable information on the stability of one type of print versus another under this display condition; the test also indicates the possible effectiveness of an ultraviolet filter in slowing the rate of fading.

In most display situations, the relative percentage of UV radiation is less than what the prints were exposed to in this north daylight test because UV radiation is largely absorbed by most painted surfaces, walls, ceilings, and floors, which reflect to the print a significant portion of incident illumination. Because of this, the actual effectiveness of UV filters in normal display conditions will probably be less than indicated by this test.

Eastman Kodak has used filtered Cool White Deluxe fluorescent light as the illuminate for most of its published data on print fading, saying, "It's the type of energy to which most prints displayed in public buildings will be subjected. Simulated daylight sources have more UV than a print is likely to see in most applications."

Light-Induced RC Paper Cracking — A Serious Problem with Early RC Color Papers

The introduction in September 1968 of Kodak Ektacolor 20 RC Paper — the first quick-processing RC (polyethylene-resin-coated) paper sold in the general consumer market — also introduced an entirely new type of deterioration: the embrittlement and subsequent cracking of the titanium dioxide-pigmented polyethylene layer as a result of exposure to even low-level light during normal display (for additional discussion of the structure of RC papers and light-induced RC paper cracking, see Chapter 17).

Many of these early RC prints developed cracks after only a few years of display — something that Kodak became aware of even before the first RC papers were put on the market. Previous fiber-base papers such as Ektacolor Professional Paper, which took much longer to process, wash, and dry than do "waterproof" RC papers, were not subject to this type of cracking. (Fiber-base color prints could, however, develop emulsion cracks as a consequence of cycling relative humidity during storage and/or display. Such cracks, which are not light-induced, are different from the cracks found in RC papers.)

February 1981

The rapid cracking and fading of Ektacolor RC prints in the 1970's presented a major problem for professional portrait and wedding photographers. Here, Robert and Bernice Fehrenbach of Fehrenbach Studios in Reedsburg, Wisconsin discuss the problem with photographers at their "Faded and Cracked Photographs" booth during the 1981 annual convention of the Wisconsin Professional Photographers Association, held in Milwaukee, Wisconsin. On the table are a selection from the many hundreds of faded and cracked Ektacolor RC prints that disgruntled customers had returned to portrait studios in Wisconsin, Minnesota, North Dakota, and South Dakota. The Fehrenbachs, who founded the Committee on Faded and Cracked Photographs of the Wisconsin Professional Photographers Association, had previously circulated a petition asking Kodak to improve the stability of its color films and papers. They were also involved in a class-action lawsuit against Eastman Kodak regarding these issues (see Chapter 8).

During the 1970's, Kodak made a number of improvements in the RC paper base which lengthened the time a print could be displayed before cracks started to develop. By about 1977 Kodak started to manufacture RC paper with a polyethylene stabilizer incorporated into the conventional paper core in the center of the RC paper structure; over time the stabilizer diffuses into the adjacent polyethylene layers, thereby significantly increasing their resistance to embrittlement and cracking.

Kodak will not say when this improvement was actually introduced, but it is assumed that by 1980 all general-purpose Kodak color and black-and-white RC papers had been converted to the new RC base.

As yet there is no ANSI standard for testing the physical stability of RC papers, but an American National Standards Institute subcommittee is developing a new black-and-white print stability standard that will include an accelerated test procedure for black-and-white RC prints; the test method should also be applicable to color RC prints. The new ANSI standard is expected to be published in 1994.

Kodak has described a test the company has been using since the 1970's for evaluating the stability of RC papers in which the effects of light are accelerated by increasing the temperature of the test prints.[31] Unfortunately, the applicability of such tests to the many different types of RC papers now on the market has yet to be confirmed by independent laboratories.

At the time this book went to press, Fuji, Agfa, Ilford, Mitsubishi, Konica, and other manufacturers had not published any details of their RC-base test procedures; how the RC papers supplied by these companies compare to each other and to Kodak papers is not yet known. It is probable that there are significant differences in the stability characteristics of these papers.

Compared with the Problem of Dye Fading in Displayed Color Prints, RC Base Cracking Is No Longer A Serious Concern

Considering the fact that the color image dyes in all current chromogenic RC prints are subject to light fading during the course of display, available data indicate that, under normal indoor display conditions, significant dye fading will have occurred well before there is any likelihood of cracks developing in the RC paper base. In other words, unlike the situation with some of the earlier RC papers, light-induced RC base cracking is no longer the weakest link in the overall stability of these products (although only long-term testing and experience in the coming years with prints on display and stored in a variety of environments can confirm this). This author's single-temperature accelerated dark storage tests with a variety of recent RC color papers indicate that the dark storage stability of these RC support materials is reasonably good.

Given the choice, however, this author recommends polyester-base print materials such as Fujiflex SFA3 Super-Gloss Printing Material over their RC-base counterparts when maximum stability is desired. A polyester base also avoids the potential problem of RC base-associated fading and staining that has afflicted some chromogenic RC color papers. As the dye stabilities of color print materials are improved — and the images last longer on display and/or when stored in the dark — the demands on the stability of the RC base will also increase.

Ilford Ilfochrome materials are supplied both on a low-cost, RC base and on a more expensive and highly stable glossy, solid polyester support. Given the potentially extremely long life of these prints when stored in the dark, it is recommended that the polyester-base types of Ilfochrome be used if long-term storage is contemplated.

Furthermore, the long-term display characteristics of the present Ilfochrome RC base are not now known, and if maximum stability is desired, the polyester-base types of Ilfochrome are recommended. RC-base Cibachrome II prints (now called Ilfochrome Classic prints) made in 1980 which were tested by this author developed serious overall yellowish stain after several years of storage in the dark after a moderate accelerated light fading test; the polyester-base version of Cibachrome II was not affected in this manner and remained free of stain (see Chapter 2).

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(***Tables 3.1a*** *through* ***3.6*** *on following pages)*

Table 3.1a Comparative Light Fading Stability of Current Process RA-4 Compatible Papers for Printing Color Negatives

All of these papers were available at the time this book went to press in 1992.

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc) with Cool White fluorescent lamps. With these color papers, all of which have effective UV-absorbing emulsion overcoats, generally similar behavior may be expected with indirect daylight and incandescent tungsten illumination in typical indoor display situations. These predictions are based on equivalent light exposures in accelerated tests at 21.5 klux (2,000 fc) at 75°F (24°C) and 60% RH.

Initial neutral density of 0.6 with full d-min corrected densitometry. Letters inside parentheses ( ) following number of years indicate the first image-life fading limit reached: (–C) = cyan dye; (–M) = magenta dye; (–Y) = yellow dye. (C–M) means, for example, that the color-balance change limit between cyan and magenta was reached first, with the magenta dye fading more than the cyan dye.

	Predicted Years of Display		
Type of Color Paper	Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Fujicolor Paper Super FA Type 3 **Fujicolor SFA3 Professional Portrait Paper** **Fujicolor Professional Paper SFA3 Type C** **Fujicolor Supreme Paper SFA3** **Fujiflex SFA3 Super-Gloss Printing Material** [polyester] **Fujicolor Peel-Apart Paper SFA3** **Fujicolor Thin Paper SFA3** ("Fujicolor Print") (1993— for low-contrast SFA3 Professional Portrait Paper) (1992— for other papers)	**54.4 (–M)**	**57.3 (–M)**	**38.2 (–M)**
Fujicolor Prof. Paper Super FA Type P (1991–93) (low-contrast professional portrait paper)	**24.0 (–M)**	**24.8 (–M)**	**20.5 (–M)**
Konica Color QA Paper Type A3 **Konica Color QA Paper Professional Type X2** **Konica Color QA Super Glossy Print Material Type A3** [polyester] **Konica Color QA Paper Peelable Type A3** (Konica Color "Century Paper" or "Century Print") (Konica Color "Long Life 100 Print") (1991—)	**17.5 (–M)**	**17.7 (–M)**	**16.9 (–M)**
Mitsubishi Color Paper SA 2000 [improved] **Mitsubishi Color Paper SA 5000 Pro** [improved] (papers are believed to be identical to Konica Color QA Type A3 and X2 papers) (improved types: 1992—)	**17.5 (–M)** [tentative]	**17.7 (–M)** [tentative]	**16.9 (–M)** [tentative]
Ilford Ilfocolor Deluxe Print Material [polyester] (ILRA.1K high-gloss polyester-base print material manufactured by Ilford in Switzerland with emulsion components supplied by Konica; stability is believed to be similar if not identical to Konica Color QA Super Glossy Print Material Type A3.) (1991—)	**17.5 (–M)** [tentative]	**17.7 (–M)** [tentative]	**16.9 (–M)** [tentative]
Agfacolor Paper Type 9 **Agfacolor Paper Type 9i** [improved] ("Agfacolor Print") (1988–92 for Type 9; 1992— for Type 9i)	**15.3 (–M)**	**15.9 (–M)**	**15.2 (–M)**
Konica Color QA Paper Type A5 (Konica Color "Century Paper" or "Century Print") (Konica Color "Long Life 100 Print") (1990—) (initially available only in Japan)	**13.2 (–M)**	**13.2 (–M)**	**12.7 (–M)**
Kodak Ektacolor Edge Paper **Kodak Ektacolor Portra II Paper** **Kodak Ektacolor Royal II Paper** **Kodak Ektacolor Supra Paper** **Kodak Ektacolor Ultra Paper** **Kodak Duraflex RA Print Material** [polyester] ("Ektacolor Print") ("Kodalux Print") (1991— for Ektacolor Edge and Royal II) (1992— for Ektacolor Portra II) (1989— for other papers)	**12.1 (–M)**	**12.8 (–M)**	**11.9 (–M)**

Table 3.1b Comparative Light Fading Stability of Current Process EP-2 Compatible Papers for Printing Color Negatives

All of these papers were available at the time this book went to press in 1992. It is likely that many of these papers will have been discontinued by the end of 1994 in favor of faster-processing RA-4 papers.

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc) with Cool White fluorescent lamps. With these color papers, all of which have effective UV-absorbing emulsion overcoats, generally similar behavior may be expected with indirect daylight and incandescent tungsten illumination in typical indoor display situations. These predictions are based on equivalent light exposures in accelerated tests at 21.5 klux (2,000 fc) at 75°F (24°C) and 60% RH. Initial neutral density of 0.6 with full d-min corrected densitometry.

Type of Color Paper	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Fujicolor Paper Type 12 **Fujicolor "Minilab Paper"** ("Fujicolor Print") (Type 12 paper generally is not available outside of Japan) (1985—)	21.3 (–M)	22.4 (–M)	21.0 (–M)
Fujicolor Paper Type 03 **Fujicolor "Minilab Paper"** **Fujicolor Professional Paper Type 02-P** **Fujicolor Paper Type 02-C** **Fujicolor HR Printing Material** [polyester] ("Fujicolor Print") ("Fujicolor SuperGloss Print") ("Fujicolor HR Super Deluxe Print") (1988—)	15.8 (–M)	16.8 (–M)	14.3 (–M)
Konica Color PC Paper Type SR **Konica Color PC Paper Prof. Type EX** **Konica Color PC Paper Type SR (SG)** [polyester] **Konica Color PC Paper Peelable Type SR** (Konica Color "Century Paper" or "Century Print") (Konica Color "Century ProPrint Type EX") (Konica Color "Long Life 100 Print") (Konica Color "Peerless Print") (in Japan, Konica Color Paper Type SR was originally called Sakuracolor PC Paper Type SR) (1984 [April]— for Type SR) (1984 [July]— for Type SG) (1987— for Type EX) (1988— for Peelable Type SR)	13.1 (–M)	13.1 (–M)	12.1 (–M)
Mitsubishi Color Paper KER Type 6000 Super **Mitsubishi Color Paper KER Type 8000 Pro** (papers are believed to be identical to Konica Type SR and EX papers) (1985— for Type 6000 Super) (1989— for Type 8000 Pro)	13.1 (–M)	13.1 (–M)	12.1 (–M)
Ilford Colorluxe Print Material [polyester] (IL.1K high-gloss polyester-base print material is manufactured by Ilford in Switzerland using emulsion components supplied by Konica; the stability of the Ilford product is believed to be similar if not identical to Konica Color Paper Type SR [SG] polyester-base print material.) (1990–)	13.1 (–M)	13.1 (–M)	12.1 (–M)
Kodak Ektacolor Plus Paper **Kodak Ektacolor Plus Thin Paper** **Kodak Ektacolor Professional Paper** **Kodak Duraflex Print Material** [polyester] ("Ektacolor Print") ("Kodalux Print") (formerly "Kodacolor Print") (1984 [August]— for Ektacolor Plus) (1985— for Ektacolor Professional)	11.8 (–M)	11.7 (–M)	11.7 (–M)
Agfacolor Paper Type 8 [improved] **Agfacolor Paper Type 8 ML** ("Agfacolor Print") (1986—)	11.5 (–M)	11.7 (–M)	11.7 (–M)

Table 3.1c Comparative Light Fading Stability of Discontinued Process EP-2, EP-3, and RA-4 Compatible Papers for Printing Color Negatives

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc) with fluorescent lamps. These predictions are based on equivalent light exposures in accelerated tests at 21.5 klux (2,000 fc) at 75°F (24°C) and 60% RH. Initial neutral density of 0.6 with full d-min corrected densitometry.

Additional "dark fading" changes that slowly occur with many of these papers during normal long-term display are not considered in these predictions. In particular, the fading observed in displayed prints made with Agfacolor PE Paper Type 4 paper usually consists largely of "dark fading" changes, with light fading making a much smaller contribution to the total change. Agfacolor Type 4 paper, in use from 1974 until 1982, has astonishingly poor dark fading stability.

Type of Color Paper	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Fujicolor Paper Super FA Type II Fujicolor Supreme Paper Fujicolor Professional Paper Super FA Type C Fujiflex SFA Super-Gloss Printing Material [glossy polyester base] ("Fujicolor Print") (RA-4) (1990–92 for Super FA Type II) (1990–92 for Supreme) (1991–92 for Super FA Type C) (1991–92 for Fujiflex SFA)	24 (–M)	25 (–M)	21 (–M)
Fujicolor Paper Super FA ("Fujicolor Print") (initial type: 1989–90) (RA-4)	24 (–M)	25 (–M)	21 (–M)
Konica Color QA Paper Type A2 Konica Color QA Paper Professional Type X1 Konica Color QA Super Glossy Print Material Type A2 [glossy polyester base] Konica Color QA Paper Peelable Type A2 (Konica Color "Century Paper") (Konica Color "Century Print") (Konica Color "Long Life 100 Print") (1988–92 for Type A2) (RA-4) (1990–92 for other papers)	17 (–M)	18 (–M)	17 (–M)
Konica Color QA Paper Type A (Konica Color "Century Paper") (Konica Color "Century Print") (Konica Color "Long Life 100 Print") (initial type: 1988–89) (RA-4)	17 (–M)	18 (–M)	17 (–M)
Mitsubishi Color Paper SA 2000 Mitsubishi Color Paper SA 5000 Pro (Mitsubishi "Speed Access" Paper) (Mitsubishi "Rapid Access" Paper) (papers are believed to be identical to Konica Color QA Type A2 and X1 papers) (initial type: 1989–92 for SA 2000) (RA-4) (initial type: 1990–92 for SA 5000)	17 (–M) [tentative]	18 (–M) [tentative]	17 (–M) [tentative]
Mitsubishi Color Paper KER Type 1000 SA (Mitsubishi "Speed Access" Paper) (Mitsubishi "Rapid Access" Paper) (paper is believed to be identical to Konica Color QA Paper Type A) (1988–89) (RA–4)	17 (–M) [tentative]	18 (–M) [tentative]	17 (–M) [tentative]
Ilford Colorluxe Print Material [polyester] (SP-729s high-gloss polyester-base print material manufactured by Ilford in Switzerland using emulsion components supplied by Konica; the stability of the Ilford product is believed to be similar if not identical to Konica Color QA Super Glossy Print Material Type A2.) (initial type: 1990–91) (RA-4)	17 (–M) [tentative]	18 (–M) [tentative]	17 (–M) [tentative]
Fujicolor Paper Type 02 Fujicolor "Minilab Paper" Fujicolor Professional Paper Type 01-P Fujicolor HR Printing Material [glossy polyester base] ("Fujicolor Print") (1985–88) (EP-2)	14 (–M)	15 (–M)	14 (–M)

Table 3.1c (continued from previous page)

Type of Color Paper	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Fujicolor Paper Type 8901 ("Fujicolor Print") (1984–86) (EP-2)	14 (–M)	14 (–M)	13 (–M)
Mitsubishi Color Paper KER Type 7000 Pro (paper is believed to be identical to Konica Type EX paper) (1985–89) (EP-2)	13 (–M)	13 (–M)	12 (–M)
Kodak Ektacolor 2001 Paper Kodak Ektacolor Portra Paper Kodak Ektacolor Royal Paper ("Ektacolor Print") ("Kodalux Print") (1986–91 for Ektacolor 2001) (RA-4) (1989–91 for Ektacolor Royal) (1989–92 for Ektacolor Portra)	13 (–M)	13 (–M)	12 (–M)
Fujicolor Paper Type 8908 ("Fujicolor Print") (1980–84) (EP-2)	13 (–M)	13 (–M)	9 (Y–C)
Fujicolor Paper FA ("Fujicolor Print") (1988–89) (RA-4)	12 (–M)	12 (–M)	12 (–M)
Konica Color PC Paper SIII Sakuracolor PC Paper SIII (1983–84) (EP-2)	11 (–M)	11 (–M)	4 (Y–C)
Sakuracolor PC Paper SII (1978–83) (EP-2)	11 (–M)	10 (–M)	5 (Y–C)
Kodak Ektacolor 74 RC Paper ("Ektacolor Print") ("Kodacolor Print") (initial type: 1977–82) (EP-2)	11 (–M)	11 (–M)	4 (M–C)
Kodak Ektacolor 37 RC Paper Type 2261 ("Ektacolor Print") ("Kodacolor Print") (1971–78) (EP-3)	11 (–M)	11 (–M)	4 (M–C)
Kodak Ektacolor 74 RC Paper Type 2524 Kodak Ektacolor 78 Paper Type 2524 ("Ektacolor Print") ("Kodacolor Print") (1982–86) (EP-2)	10 (–M)	10 (–M)	9 (–M)
Agfacolor PE Paper Type 8 ("Agfacolor Print") (initial type: 1984 [October]–86) (EP-2)	10 (–M)	9 (–M)	8 (–C)
Agfacolor PE Paper Type 7i ("Agfacolor Print") (1984–85) (EP-2)	10 (–M)	10 (–M)	9 (–M)
Agfacolor PE Paper Type 589i Agfacolor PE Paper Type 7 ("Agfacolor Print") (1983–85) (EP-2)	8 (–M)	8 (–M)	8 (–C)
3M Professional Color Paper Type 25 3M High Speed Color Paper Type 19 (1978–88; 3M ceased manufacture of color paper in 1988) (EP-2)	8 (–M)	9 (–M)	5 (Y–C)
Agfacolor PE Paper Type 5 ("Agfacolor Print") (1977–82) (Agfa AP-87)	7 (–M)	7 (–M)	3 (M–C)
Agfacolor PE Paper Type 589 ("Agfacolor Print") (1981–83) (EP-2)	6 (–M)	7 (–M)	5 (–M)
Agfacolor PE Paper Type 4 ("Agfacolor Print") (this paper has extremely poor dark fading stability) (1974–82) (Agfa AP-85)	6 (–C)	7 (–C)	5 (–C)

Table 3.2 Comparative Light Fading Stability of Silver Dye-Bleach; Chromogenic Reversal; Dye-Imbibition; and UltraStable, EverColor, and Polaroid Permanent Color Pigment Print Materials

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc) with fluorescent lamps. These predictions are based on equivalent light exposures in accelerated tests at 21.5 klux (2,000 fc) at 75°F (24°C) and 60% RH. Ilford Ilfochrome (formerly called Cibachrome) and Fresson Quadrichromie prints were tested at 1.35 klux (125 fc) at 75°F (24°C) and 60% RH, as described below. Initial neutral density of 0.6 with full d-min corrected densitometry.

Test duration of up to 12 years (4,380 days).

Boldface Type indicates products that were being marketed in the U.S. and/or other countries when this book went to press in 1992; the other products listed had been either discontinued or replaced with newer materials.

(T) = For printing color transparencies
(T+N) = For printing either color transparencies or negatives

(T) = For printing color transparencies
(T+N) = For printing either color transparencies or negatives

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
UltraStable Permanent Color Prints (T+N) (pigment color process) [polyester & fiber-base] (UltraStable Permanent Color Process) (improved yellow pigment type: 1993—)	**>500 (—)** [tentative]	**>500 (—)** [tentative]	**>200 (—)** [tentative]
Polaroid Permanent-Color Prints (T+N) **Ataraxia Studio Collectors Color Prints** (pigment color process) [polyester] (1989—) (Polaroid Permanent-Color Process)	**>500 (—)** [tentative]	**>500 (—)** [tentative]	**>200 (—)** [tentative]
Fuji-Inax Photocera Color Photographs (T+N) (fired pigment color process) [ceramic support] (initially available only from Fujicolor Processing Service in Japan) (1991—) (Fuji-Inax Ceramic Color Process)	**>500 (—)** [tentative]	**>500 (—)** [tentative]	**>500 (—)** [tentative]
EverColor Pigment Color Prints (T+N) (pigment color process) [polyester] (A high-stability version of the AgfaProof Process marketed by the EverColor Corporation.) (1993—) (EverColor Pigment Color Print Process)	(new product – test data not available)		
Fresson Quadrichromie Prints (T+N) (pigment color process) [fiber base] (available only in France) (1952—) (Fresson Color Print Process)	**225 (–M)**	**>225 (—)**	**100 (–M)**
Agfachrome CU 410 Color Prints (T) [pigmented triacetate base] (Abandoned by Agfa, this was an outstanding example of the silver dye-bleach process.) (1970–73) (Agfachrome Process 60)	88 (M–Y)	134 (–M)	43 (M–Y)
Kodak Dye Transfer Prints [fiber-base] (T+N) (high-stability Kodak MX-1372 yellow dye and paper with UV-absorbing overcoat trade-tested in 1988–89) (The paper and yellow dye proved difficult to work with and Kodak decided not to market the materials.)	50 (–M)	54 (–M)	50 (–M)
Kodak Dye Transfer Prints [fiber-base] (T+N) (Kodak Film and Paper Dyes) (1946—, with minor changes)	**32 (M–Y)**	**21 (C–Y)**	**8 (M–C)**
Ilford Ilfochrome Classic Prints (T) Ilford Cibachrome II Prints Ilford Cibachrome-A II Prints [improved type] **Fuji CB Prints** (material supplied by Ilford) (P-3, P-3X, P-30, and P-30P) [polyester and RC] (Although Ilfochrome "Pearl" semi-gloss and glossy-surface RC prints have dye stability that is similar to Ilfochrome high-gloss polyester-base prints, the RC prints are subject to RC base cracking and image yellowing, and therefore are not recommended for long-term applications.) (1980–91 for Cibachrome II) (1989–91 for "improved" Cibachrome-A II) (1991— for Ilfochrome Classic)	**29 (–M)***	**33 (C–Y)***	**21 (–M)***
Fujichrome Paper Type 35 (T) **Fujichrome Copy Paper Type 35H** **Fujichrome Super-Gloss Printing Material** [polyester] ("Fujichrome Super Deluxe Prints") [polyester] (1992—) (R-3)	**19 (–M)**	**19 (–M)**	**14 (–M)**

Table 3.2 (continued from previous page)

(T) = For printing color transparencies
(T+N) = For printing either color transparencies or negatives

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Predicted Years of Display: Prints Covered With UF-3 Ultraviolet Filter	Predicted Years of Display: Prints Not Covered (Bare Bulb)
Fujichrome Paper Type 34 (T) Fujichrome Copy Paper Type 34H Fujichrome Super-Gloss Printing Material [polyester] (1986–92) (R-3)	19 (–M)	19 (–M)	14 (–M)
Fuji Dyecolor Prints [fiber-base] (T+N) (dye transfer type process) (available only in Japan) (1970—) (Fuji Dyecolor process)	**17 (C–Y)**	**16 (C–Y)**	**7 (M–Y)**
Ilford Cibachrome-A II Prints (T) [polyester and RC] (Although Cibachrome “Pearl” semi-gloss and glossy-surface RC prints have dye stability that is similar to Cibachrome high-gloss polyester-base prints, the RC prints are subject to RC base cracking and image yellowing, and therefore are not recommended for long-term applications.) (initial type: 1981–89) (P-30)	16 (–M)*	21 (C–Y)*	14 (–M)*
Ilford Cibachrome-A Prints (T) [pigmented triacetate base] (1975–81) (P-12)	16 (–M)*	19 (–M)*	11 (–M)*
Fujichrome Paper Type 33 (T) (1983–86) (R-3)	16 (–M)	17 (–M)	15 (–M)
Kodak Ektachrome Copy Paper (T) Kodak Ektachrome HC Copy Paper Kodak Ektachrome Thin Copy Paper Kodak Ektachrome 22 Paper [initial type] Kodak Ektachrome Prestige Paper [glossy polyester base] (Not recommended: these Ektachrome papers have very poor dark fading stability compared with Fujichrome, Konica Chrome, Agfachrome, and Ektachrome Radiance Process R-3 papers.) (1984–90 for initial type of Ektachrome 22) (1986–91 for Ektachrome Prestige) (1984–92 for Ektachrome HC Copy and Thin) (1984— for Ektachrome Copy) (R-3)	**15 (–M)**	**15 (–M)**	**14 (–M)**
Kodak Ektachrome Radiance Paper (T) **Kodak Ektachrome Radiance Select Material** [glossy polyester base] **Kodak Ektachrome Radiance HC Copy Paper** **Kodak Ektachrome Radiance Thin Copy Paper** (1991— for Radiance and Radiance Select) (R-3) (1992— for Radiance HC Copy and Thin Copy)	**14 (–M)**	**14 (–M)**	**13 (–M)**
Kodak Ektachrome 22 Paper [improved] (T) (improved type: 1990–91) (R-3)	14 (–M)	14 (–M)	13 (–M)
Kodak Ektachrome 2203 Paper (T) (1978–84) (R-100)	14 (–M)	14 (–M)	13 (–M)
Konica Chrome Paper Type 81 (T) (1989—) (R-3)		(test data not available, but probably has light fading stability similar to that of Konica Color QA Paper Type A3)	
Fujichrome Reversal Paper Type 31 (T) (1978–83) (R-100)	10 (–M)	12 (–M)	11 (–M)
Agfachrome Paper CRN [Type 63] (T) **Agfachrome High Gloss Material CRP** [polyester] **Agfachrome Copy Paper CRH** (1984–90 for initial types) (1990— for “improved” types) (R-3)	**10 (–M)**	**11 (–M)**	**10 (–M)**
Kodak Ektachrome 14 Paper (T) (1981–85) (R-100)	8 (C–Y)	7 (C–Y)	5 (C–Y)
Kodak Ektaflex PCT Color Prints (T+N) (dye-diffusion transfer process) (Kodak Ektaflex Process) (1981–88)	7 (C–M)	7 (C–M)	6 (C–M)
Agfachrome Reversal Paper CU 310 (T) (1979–84) (R-100)	5 (–M)	6 (–M)	5 (C–M)
Kodak Ektachrome RC Paper Type 1993 (T) (1972–79) (R-5)	5 (–M)	4 (–M)	3 (–C)
Agfachrome-Speed Color Prints (T) (single-sheet dye-diffusion process) (Agfachrome-Speed Process) (1983–85)	2 (M–C)	2 (M–C)	2 (M–C)

* Because of their large reciprocity failure factors (RF Factors) in high-intensity accelerated light fading tests, Ilford Ilfochrome (Cibachrome) prints were illuminated with a lower intensity of 1.35 klux (125 fc) for periods of up to 10 years; this lower intensity illumination better simulates the performance of Ilfochrome prints in normal display conditions and also affords a more valid comparison with most current chromogenic print materials, which generally exhibit much smaller RF Factors than does Ilfochrome.

Table 3.3 Comparative Light Fading Stability of Polaroid, Fuji, and Kodak Instant Color Prints; Canon and Kodak Digital Copier/Printer Color Prints; Color Offset Printing; Mead Cycolor Prints; and Thermal Dye Transfer Prints and Ink Jet Color Prints for Digitized Pictorial Images and Computer-Generated Images

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc) with fluorescent lamps. These predictions are based on equivalent light exposures in accelerated tests at 1.35 klux (125 fc) at 75°F (24°C) and 60% RH for photographic instant color prints, and 21.5 klux (2,000 fc) at 75°F (24°C) and 60% RH for the other materials listed (marked with an *). Initial neutral density of 0.6 with full d-min corrected densitometry. With Mead Cycolor prints, the stain limit was reached before any of the dye-fading limits. With Stork ink jet color prints, pure magenta and yellow colors faded unusually rapidly compared with the fading of more neutral colors, and this lowered the rankings of the Stork prints.

Test duration of up to 6 years (2,190 days).

Boldface Type indicates products that were being marketed in the U.S. and/or other countries when this book went to press in 1992; the other products listed had been either discontinued or replaced with newer materials. Kodak, which introduced its first instant cameras and film in 1976, was forced to abandon the instant photography field in 1986 after a federal court found that Kodak had infringed on Polaroid patents.

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
3M Electrocolor Prints [continuous-tone, liquid-toner electrophotographic color process] (Abandoned by 3M, this was an outstanding example of the liquid-toner color electrophotographic process.) (1965–66) (3M Company, St. Paul, Minnesota)	28.0 (–M)	Data Not Available	26.0 (–M)
Canon Color Laser Copier Prints* [scanned, electronically produced prints] (Xerographic plain-paper digital color copier/printer; test prints made in 1989.)	**25.0 (C–M)**	**40.0 (C–Y)**	**7.8 (C–M)**
Kodak ColorEdge Digital Copier Prints* [scanned, electronically produced prints] (Xerographic plain-paper digital color copier/printer; test prints made in 1992.)	**19.7 (C–Y)**	**23.1 (C–Y)**	**15.7 (C–Y)**
Kodak Ektatherm Color Prints* [scanned, electronically produced prints] (Thermal dye transfer color prints made with Kodak XL 7700 Digital Printer; test prints made in 1992.)	**11.5 (M–C)**	**23.3 (M–C)**	**4.5 (–C)**
Polaroid 600 High Speed Prints [continuous-tone instant photographic prints] (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid 600 prints are not recommendedfor other than short-term applications.) (1981–88)	11.0 (–M)	12.0 (–M)	12.0 (–M)
Polaroid SX-70 Time-Zero Prints [improved] **Polaroid Type 778 Time-Zero Prints** [continuous-tone instant photographic prints] (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid SX-70 Time-Zero and Type 778 prints are not recommended for other than short-term applications.) (improved type: 1980—)	**11.0 (–M)**	**12.0 (–M)**	**12.0 (–M)**
Polaroid SX-70 Prints [improved] [continuous-tone instant photographic prints] (improved type: 1976–79)	10.0 (M–Y)	11.0 (M–Y)	11.0 (M–Y)
Polaroid SX-70 Time-Zero Prints [continuous-tone instant photographic prints] (initial type: 1979–80)	6.0 (–M)	7.0 (–M)	6.0 (–M)
Polacolor 2 Prints (Types 88; 108; 668; 58; and 808) [continuous-tone instant photographic prints] (The images of Polacolor 2 prints suffer a yellowish color shift that may become objectionable after only a few years of dark storage under normal conditions; because of this, Polacolor 2 prints are not recommended for fine art or other critical applications.) (1975—) (peel-apart prints)	**6.0 (–M)**	**5.0 (C–Y)**	**4.0 (–M)**

Table 3.3 (continued from previous page)

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Kodak Trimprint Instant Color Prints [continuous-tone instant photographic prints] (1983–86)	4.1 (–M)	4.6 (–M)	4.0 (–M)
Polaroid 600 Plus Prints **Polaroid Autofilm Type 330 Prints** **Polaroid Type 990 Prints** Polaroid Spectra Prints Polaroid Image Prints (Spectra name in Europe) [continuous-tone instant photographic prints] (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra prints, Image prints, and 600 Plus prints are not recommended for other than short-term applications.) (1986–91 for Spectra) (1988— for other prints)	**4.1 (–M)**	**4.2 (–M)**	**3.5 (–M)**
Polaroid Spectra HD Prints **Polaroid Image Prints** (Spectra HD in Europe) [continuous-tone instant photographic prints] (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra HD prints are not recommended for other than short-term applications.) (1992—)	**4.1 (–M)** [tentative]	**4.2 (–M)** [tentative]	**3.5 (–M)** [tentative]
Polaroid Vision 95 Prints (name in Europe) **Polaroid “ ? ” 95 Prints** (name in Asia) **Polaroid “ ? ” 95 Prints** (name in North & South America) [continuous-tone instant photographic prints] (The internal structure of Vision 95 prints is basically the same as that of Spectra HD and 600 Plus prints; however, the rate of formation of yellowish stain that occurs over time in dark storage is said by Polaroid to be “somewhat reduced” compared with that of Spectra HD and 600 Plus prints. The names Polaroid will use for Vision 95 products in non-European markets were not available at the time this book went to press.) (1992— for Vision 95 products sold in Germany) (1993— for Asia, North and South America, and other markets)	**4.1 (–M)** [tentative]	**4.2 (–M)** [tentative]	**3.5 (–M)** [tentative]
Polaroid Polacolor ER Prints **(Types 59; 559; 669; and 809)** [continuous-tone instant photographic prints] (1980—) (peel-apart prints)	**3.7 (M–Y)**	**2.8 (M–Y)**	**3.7 (–C)**
Polaroid Polacolor 64T and 100 Prints [continuous-tone instant photographic prints] (1992—) (peel-apart prints)	**3.7 (M–Y)** [tentative]	**2.8 (M–Y)** [tentative]	**3.7 (–C)** [tentative]

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Polaroid Polacolor Pro 100 Prints [continuous-tone instant photographic prints] (1993—) (peel-apart prints)	(New product: test data not available, but probably has light fading stability similar to that of Polacolor ER prints.)		
Stork Ink Jet Color Prints (Standard ink set)* [scanned, electronically produced prints] (Ink jet color prints made with a Stork Bedford B.V. ink jet printer and the Stork #1010 “Standard” graphic arts ink set; test prints made in 1992.)	**3.6 (–M)**	**4.4 (–M)**	**2.0 (–M)**
Stork Ink Jet Color Prints (Reactive Dyes ink set)* [scanned, electronically produced prints] (Ink jet color prints made with a Stork Bedford B.V. ink jet printer and the Stork “Reactive Dyes” ink set; test prints made in 1992.)	**3.5 (–Y)**	**4.0 (–Y)**	**3.1 (–Y)**
Fuji FI-10 Instant Color Prints [continuous-tone instant photographic prints] (1981—) (available only in Japan)	**2.6 (Y–C)**	**2.8 (Y–C)**	**2.4 (Y–C)**
4-Color Offset Printed Images* [screened, photomechanical prints] (Cyan, magenta, yellow, and black 4-color process inks typical of those used in color offset printing of books and magazines; samples printed in 1990.)	**2.5 (C–Y)**	**2.5 (C–Y)**	**2.5 (C–Y)**
Iris Ink Jet Color Prints (Standard ink set)* [scanned, electronically produced prints] (Ink jet color prints made on 100% cotton fiber paper with an Iris Graphics, Inc. 3047 printer using the “Standard” Iris ink set; test prints made in 1992.)	**2.5 (C–Y)**	**2.5 (C–Y)**	**1.7 (C–M)**
Mead Cycolor Prints* [continuous-tone photographic prints] (Mead Imaging Corporation microencapsulated acrylate image color prints made with a Noritsu QPS-101 Cycolor Slideprinter; test prints made in 1988.)	**2.5 (C+Y)**	**Data Not Available**	**1.1 (C+Y)**
Fuji 800 Instant Color Prints [continuous-tone instant photographic prints] (1984—) (available only in Japan)	**2.1 (M–C)**	**2.1 (M–C)**	**2.0 (M–C)**
Sony Mavigraph Still Video Color Prints* [scanned, electronically produced prints] (Thermal dye transfer prints made with Sony UP-5000 ProMavica Color Video Printer; test prints made in 1989.)	**1.2 (–M)**	**1.7 (–M)**	**0.6 (–M)**
Kodak PR10 Instant Color Prints [continuous-tone instant photographic prints] (initial type: 1976–79)	0.5 (M–C)	0.5 (M–C)	0.6 (M–C)

Table 3.4 Comparative Light Fading Stability of Color Prints Illuminated with Incandescent Tungsten Lamps

Predicted years of display to reach "Home and Commercial" and "Museum and Archive" image-life fading limits for color prints illuminated 12 hours a day at 300 lux (28 fc) with incandescent tungsten reflector flood lamps. Predictions based on equivalent light exposures in accelerated tests at 1.35 klux (125 fc) at 75°F (24°C) and 60% RH. Initial neutral density of 0.6 ("Home and Commercial") and 0.45 ("Museum and Archive") with full d-min corrected densitometry.

Test duration of up to 10 years (3,650 days).

Boldface Type indicates products that were being marketed in the U.S. and/or other countries when this book went to press in 1992; the other products listed had been either discontinued or replaced with newer materials.

* Indicates print materials with poor dark fading stability. In most cases, the performance of these prints in actual long-term display will be worse than indicated by these accelerated light fading tests, which, because of their comparatively short duration, generally do not account for the contribution of dark storage to overall print fading and staining.

Com: "Home and Commercial" Fading Limits
Mus: "Museum and Archive" Fading Limits

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
UltraStable Permanent Color Prints (pigment color process) [polyester] (UltraStable Permanent Color Process) (improved yellow pigment type: 1993—)	**Com:** **Mus:**	**>500 (—)** **>500 (—)** [tentative]	**>500 (—)** **>500 (—)** [tentative]	**>500 (—)** **>500 (—)** [tentative]
Polaroid Permanent-Color Prints **Ataraxia Studio Collectors Color Prints** (pigment color process) [polyester] (1989—) (Polaroid Permanent-Color Process)	**Com:** **Mus:**	**>500 (—)** **>500 (—)** [tentative]	**>500 (—)** **>500 (—)** [tentative]	**>500 (—)** **>500 (—)** [tentative]
Fujicolor Paper Super FA Type 3 **Fujicolor Supreme Paper SFA3** **Fujicolor SFA3 Professional Portrait Paper** **Fujicolor Professional Paper SFA3 Type C** **Fujiflex SFA3 Super-Gloss Printing Material** [polyester] ("Fujicolor Print") (1992/93—) (RA-4)	**Com:** **Mus:**	**105 (–M)** **40 (–M)** [estimated]	**105 (–M)** **40 (–M)** [estimated]	**80 (–M)** **35 (–M)** [estimated]
Kodak Dye Transfer Prints [fiber-base] (Made with "standard" Kodak Dye Transfer Film and Paper Dyes and "standard" Kodak Dye Transfer Paper.) (1946—, with minor modifications)	**Com:** **Mus:**	**48 (M–Y)** **9 (–C)**	**46 (M–Y)** **12 (–Y)**	**33 (–C)** **6 (–C)**
Fuji Dyecolor Prints [fiber-base] (dye transfer type) (Fuji Dyecolor process) (1970—) (available only in Japan)	**Com:** **Mus:**	**29 (M–Y)** **11 (–Y)**	**31 (M–Y)** **12 (–Y)**	**22 (M–Y)** **11 (–Y)**

Com: "Home and Commercial" Fading Limits
Mus: "Museum and Archive" Fading Limits

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Ilford Ilfochrome Classic Prints Ilford Cibachrome II Prints Ilford Cibachrome-A II Prints [improved type] **Fuji CB Prints** (material supplied by Ilford) (P-3, P-3X, P-30, and P-30P) [polyester and RC] (Although Ilfochrome "Pearl" semi-gloss and glossy-surface RC prints have dye stability that is similar to Ilfochrome high-gloss polyester-base prints, the RC prints are subject to RC base cracking and light-induced yellowing, and therefore are not recommended for long-term applications.) (1980–91 for Cibachrome II) (1989–91 for "improved" Cibachrome-A II) (1991— for Ilfochrome Classic)	**Com:** **Mus:**	**25 (M–C)** **4 (–C)**	**29 (M–C)** **6 (–C)**	**17 (Y–C)** **4 (–C)**
Fujicolor Paper Type 8901* (1984–86)	Com: Mus:	24 (–M) 9 (–M)	24 (–M) 9 (–M)	23 (–M) 7 (–M)
Konica Color PC Paper Type SR **Konica Color PC Professional Type EX** **Konica Color PC Paper Type SR (SG)** [polyester] (Konica Color "Century Prints") (Konica Color "Century Paper") (Konica Color "Century ProPrint Type EX") (Konica Color "Peerless Prints") (1984 [April]— for Type SR) (1984 [July]— for Type SG) (1987— for type EX)	**Com:** **Mus:**	**24 (–M)** **9 (–M)**	**23 (–M)** **9 (–M)**	**21 (–M)** **7 (–M)**

Table 3.4 (continued from previous page)

Com: "Home and Commercial" Fading Limits
Mus: "Museum and Archive" Fading Limits

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Kodak Ektacolor Edge Paper **Kodak Ektacolor Portra II Paper** **Kodak Ektacolor Royal II Paper** **Kodak Ektacolor Supra Paper** **Kodak Ektacolor Ultra Paper** **Kodak Duraflex RA Print Material** [polyester] Kodak Ektacolor 2001 Paper Kodak Ektacolor Portra Paper Kodak Ektacolor Royal Paper ("Ektacolor Print") ("Kodalux Print") (formerly "Kodacolor Print") (1986–91 for Ektacolor 2001) (RA-4) (1991— for Ektacolor Edge and Royal II) (1992— for Portra II) (1989— for other papers)	**Com:** **Mus:**	**24 (–M)** **9 (–M)** [estimated]	**23 (–M)** **9 (–M)** [estimated]	**24 (–M)** **9 (–M)** [estimated]
Fujicolor Paper Type 8908* (1980–84)	Com: Mus:	24 (–M) 9 (–M)	24 (–M) 8 (–M)	22 (–M) 9 (–M)
Fujichrome Reversal Paper Type 31* (1978–83)	Com: Mus:	24 (–M) 7 (–M)	24 (–M) 6 (–M)	22 (–M) 6 (–M)
Konica Color PC Paper SIII* (1983–84)	Com: Mus:	23 (–M) 8 (–M)	22 (–M) 8 (–M)	Data Not Available
Ektacolor Plus Paper **Ektacolor Professional Paper** ("Ektacolor Print") ("Kodalux Print") (formerly "Kodacolor Print") (1984 [August]— for Ektacolor Plus) (1985— for Ektacolor Professional)	**Com:** **Mus:**	**21 (–M)** **9 (–M)**	**23 (–M)** **9 (–M)**	**21 (–M)** **9 (–M)**
Kodak Ektachrome 2203 Paper* (1978–84)	Com: Mus:	19 (–M) 8 (–M)	21 (–M) 8 (–M)	19 (–M) 8 (–M)
Kodak Ektacolor 74 RC Paper* ("Ektacolor Print") ("Kodacolor Print") (initial type: 1977–82)	Com: Mus:	19 (–M) 6 (–M)	19 (–M) 6 (–M)	19 (–M) 6 (–M)
Kodak Ektacolor 37 RC Paper Type 2261* ("Ektacolor Print") ("Kodacolor Print") (1971–78)	Com: Mus:	19 (–M) 6 (–M)	17 (–M) 5 (–M)	19 (–M) 6 (–M)

Com: "Home and Commercial" Fading Limits
Mus: "Museum and Archive" Fading Limits

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Agfacolor PE Paper Type 7i* (1984–85)	Com: Mus:	17 (–M) 6 (–M)	19 (–M) 6 (–M)	14 (–M) 5 (–M)
Kodak Ektacolor 78 Paper Type 2524* Kodak Ektacolor 74 RC Paper Type 2524* ("Ektacolor Print") ("Kodacolor Print") (1982–86)	Com: Mus:	17 (–M) 4 (–M)	17 (–M) 5 (–M)	17 (–M) 4 (–M)
Kodak Ektachrome 14 Paper* (1981–85)	Com: Mus:	17 (–M) 3 (–M)	16 (–M) 3 (–M)	17 (–M) 3 (–M)
Agfacolor PE Paper Type 589i* Agfacolor PE Paper Type 7* (1983–85)	Com: Mus:	14 (–M) 5 (–M)	16 (–M) 6 (–M)	14 (–M) 6 (–M)
Agfacolor PE Paper Type 5* (1977–82)	Com: Mus:	10 (Y–M) 4 (–M)	11 (–M) 4 (–M)	11 (–M) 4 (–M)
Agfacolor PE Paper Type 589* (1981–83)	Com: Mus:	9 (C–Y) 4 (–Y)	9 (C–Y) 4 (–M)	9 (C–Y) 4 (–Y)
Agfacolor PE Paper Type 4* (This paper has extremely poor dark fading stability.) (1974–82)	Com: Mus:	9.0 (–C) 3.1 (–C)	11.0 (–C) 3.1 (–C)	9.0 (–C) 2.3 (–C)
Polaroid High Speed Type 779 Prints **Polaroid Autofilm Type 339 Prints** Polaroid 600 High Speed Prints (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Type 779 and Type 339 prints are not recommended for other than short-term applications.) (1981–88 for Polaroid 600) (1981— for other prints)	**Com:** **Mus:**	**8.0 (M–Y)** **2.7 (M–Y)**	**10.0 (M–Y)** **2.9 (M–Y)**	**8.0 (M–Y)** **3.1 (M–Y)**
Polaroid 600 Plus Prints **Polaroid Autofilm Type 330 Prints** **Polaroid Type 990 Prints** Polaroid Spectra Prints (Image Prints in Europe) (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra prints, Image prints, and 600 Plus prints are not recommended for other than short-term applications.) (1986–91 for Spectra)	**Com:** **Mus:**	**8.0 (–M)** **2.8 (–M)**	**8.0 (–M)** **2.6 (–M)**	**7.0 (–M)** **2.4 (–M)**

(Table 3.4 continued on following page . . .)

Table 3.4 (continued from previous page)

Com: "Home and Commercial" Fading Limits
Mus: "Museum and Archive" Fading Limits

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Polaroid Spectra HD Prints **Polaroid Image Prints** (Spectra in Europe) (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra HD prints and Image prints are not recommended for other than short-term applications.) (1991—)	**Com: 8.0 (–M)** **Mus: 2.8 (–M)** [tentative]	**8.0 (–M)** **2.6 (–M)** [tentative]	**7.0 (–M)** **2.4 (–M)** [tentative]
Polaroid SX-70 Prints [Improved] (1976–79)	Com: 7.0 (C–Y) Mus: 3.3 (C–Y)	7.0 (C–Y) 3.4 (C–Y)	7.0 (C–Y) 2.9 (C–Y)
Kodak Ektaflex PCT Color Prints (1981–88)	Com: 5.7 (–M) Mus: 2.3 (–M)	5.7 (–M) 2.3 (–M)	5.0 (–M) 1.7 (–M)
Kodak Trimprint Instant Color Prints (1983–86)	Com: 4.6 (–C) Mus: 1.4 (–C)	4.6 (–C) 1.4 (–C)	4.6 (–C) 1.1 (–C)
Polaroid Polacolor 2 Prints **(Types 88; 108; 668; 58; and 808)** (The images of Polacolor 2 prints suffer a yellowish color shift that may become objectionable after only a few years of dark storage under normal conditions; because of this, Polacolor 2 prints are not recommended for fine art or other critical applications.) (1975—)	**Com: 3.6 (M–Y)** **Mus: 2.2 (–Y)**	**3.3 (M–Y)** **2.1 (C–Y)**	**3.5 (M–Y)** **2.1 (–Y)**
Polaroid Polacolor ER Prints **(Types 59; 559; 669; and 809)** (1980—)	**Com: 3.4 (M–Y)** **Mus: 2.4 (–Y)**	**3.3 (M–Y)** **2.1 (C–Y)**	**2.9 (M–Y)** **1.8 (–Y)**
Polaroid Polacolor 100 Prints **Polaroid Polacolor 64T Prints** (1992—)	**Com: 3.4 (M–Y)** **Mus: 2.4 (–Y)** [tentative]	**3.3 (M–Y)** **2.1 (C–Y)** [tentative]	**2.9 (M–Y)** **1.8 (–Y)** [tentative]
Polaroid Polacolor Pro 100 Prints (1993—)	(New product: test data not available, but probably has light fading stability similar to that of Polacolor ER prints.)		
Fuji FI-10 Instant Color Prints* (1981—) (available only in Japan)	**Com: 1.7 (Y–C)** **Mus: 0.6 (–C)**	**1.6 (Y–C)** **0.6 (–C)**	**1.4 (Y–C)** **0.6 (–C)**
Fuji 800 Instant Color Prints* (1984—) (available only in Japan)	**Com: 1.2 (M–C)** **Mus: 0.5 (M–C)**	**1.2 (M–C)** **0.5 (M–C)**	**1.1 (M–C)** **0.5 (M–C)**
Kodak PR10 Instant Color Prints* (initial type: 1976–79)	Com: 1.2 (–C) Mus: 0.4 (–C)	1.4 (–C) 0.4 (–C)	1.1 (–C) 0.4 (–C)
Agfachrome-Speed Color Prints (1983–85)	Com: 1.2 (M–C) Mus: 0.5 (M–C)	1.1 (M–C) 0.5 (M–C)	1.0 (M–C) 0.4 (M–C)

Table 3.5 Color Print Fading: Tungsten vs. Fluorescent Illumination

Predicted years of display to reach “Home and Commercial” image-life fading limits for color prints displayed in home and office locations illuminated 12 hours a day at 450 lux (42 fc). These predictions are based on equivalent light exposures in Cool White fluorescent and incandescent tungsten accelerated tests conducted at 1.35 klux (125 fc) at 75°F (24°C) and 60% RH. Initial neutral density of 0.6 with full d-min corrected densitometry.

Test duration of up to 10 years (3,650 days).

Boldface Type indicates products that were being marketed in the U.S. and/or other countries when this book went to press in 1992; the other products listed had been either discontinued or replaced with newer materials.

Tung: Tungsten Illumination Test
Fluor: Fluorescent Illumination Test

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Ilford Ilfochrome Classic Prints Ilford Cibachrome II Prints (1980–92 for Cibachrome II) (1992— for Ilfochrome Classic)	**Tung:**	**17.0 (Y–C)**	**20.0 (M–C)**	**12.0 (Y–C)**
	Fluor:	**29.0 (–M)**	**33.0 (C–Y)**	**21.0 (–M)**
Konica Color PC Paper Type SR **Konica Color PC Paper Prof. Type EX** (1984 [April]—)	**Tung:**	**16.0 (–M)**	**15.0 (–M)**	**14.0 (–M)**
	Fluor:	**15.0 (–M)**	**15.0 (–M)**	**13.0 (–M)**
Kodak Ektacolor 74 RC Paper (initial type: 1977–82)	Tung:	10.0 (–M)	11.0 (–M)	10.0 (–M)
	Fluor:	9.0 (–M)	9.0 (–M)	4.2 (Y–C)
Kodak Ektacolor Plus Paper **Kodak Ektacolor Professional Paper** (1984 [August]—)	**Tung:**	**14.0 (–M)**	**15.0 (–M)**	**14.0 (–M)**
	Fluor:	**12.0 (–M)**	**13.0 (–M)**	**11.0 (–M)**
Agfacolor PE Paper Type 4 (1974–82)	Tung:	6.0 (–C)	7.0 (–C)	6.0 (–C)
	Fluor:	6.0 (–C)	7.0 (–C)	5.0 (–M)
Agfacolor PE Paper Type 5 (1977–82)	Tung:	7.0 (Y–M)	7.0 (C–M)	7.0 (–M)
	Fluor:	7.0 (–M)	8.0 (–M)	6.0 (Y–C)
Agfacolor PE Paper Type 589 (1981–83)	Tung:	6.0 (C–Y)	6.0 (C–Y)	7.0 (C–Y)
	Fluor:	5.0 (C–Y)	5.0 (C–Y)	7.0 (–M)
Polaroid High Speed Type 779 Prints **Polaroid Autofilm Type 339 Prints** Polaroid 600 High Speed Prints (1981–88 for Polaroid 600) (1981— for other prints)	**Tung:**	**5.0 (M–Y)**	**6.0 (M–Y)**	**5.0 (M–Y)**
	Fluor:	**11.0 (–M)**	**12.0 (–M)**	**10.0 (–M)**

Tung: Tungsten Illumination Test
Fluor: Fluorescent Illumination Test

Type of Color Print Product		Predicted Years of Display: Prints Covered With Glass	Prints Covered With UF-3 Ultraviolet Filter	Prints Not Covered (Bare Bulb)
Polaroid 600 Plus Prints **Polaroid Autofilm Type 330 Prints** **Polaroid Type 990 Prints** Polaroid Spectra Prints Polaroid Image Prints (Spectra in Europe) (1986–91 for Spectra) (1988— for other prints)	**Tung:**	**5.0 (–M)**	**5.0 (–M)**	**4.4 (–M)**
	Fluor:	**4.1 (–M)**	**4.2 (–M)**	**3.5 (–M)**
Polaroid SX-70 Prints [improved] (1976–79)	Tung:	6.0 (C–Y)	6.0 (C–Y)	6.0 (C–Y)
	Fluor:	10.0 (M–Y)	10.0 (M–Y)	11.0 (M–Y)
Kodak Ektaflex PCT Color Prints (1981–88)	Tung:	4.0 (–M)	4.0 (–M)	3.5 (–M)
	Fluor:	7.0 (C–M)	7.0 (C–M)	6.0 (C–M)
Polaroid Polacolor ER Prints **(Types 59; 559; 669; and 809)** (1980—)	**Tung:**	**2.0 (M–Y)**	**2.1 (M–Y)**	**1.8 (M–Y)**
	Fluor:	**3.7 (M–Y)**	**2.8 (M–Y)**	**3.7 (–C)**
Kodak PR10 Instant Color Prints (initial type: 1976–79)	Tung:	0.8 (–C)	0.9 (–C)	0.8 (–C)
	Fluor:	2.0 (–C)	2.0 (–C)	2.0 (–C)
Agfachrome-Speed Color Prints (1983–85)	Tung:	0.8 (M–C)	0.8 (M–C)	0.6 (M–C)
	Fluor:	2.0 (M–C)	2.0 (M–C)	2.0 (M–C)

Table 3.6 Comparative Stability of Color Prints Illuminated with Diffuse North Daylight Through Window Glass

Predicted years of display to reach "Home and Commercial" image-life fading limits for color prints displayed close to a window in home and office locations and illuminated for 12 hours a day with north daylight having an average intensity of 450 lux (42 fc). Predictions based on equivalent light exposures in accelerated north daylight tests with an average light intensity (over a 24 hour period) of about 0.78 klux (75 fc) at 75°F (24°C) and 60% RH. Initial neutral density of 0.6 with full d-min corrected densitometry.

Test duration of up to 10 years (3,650 days).

Boldface Type indicates products that were being marketed in the U.S. and/or other countries when this book went to press in 1992; the other products listed had been either discontinued or replaced with newer materials.

	Predicted Years of Display	
Type of Color Print Product	**Prints Covered With Glass**	**Prints Covered With UF-3 Ultraviolet Filter**
Ilford Ilfochrome Classic Prints Ilford Cibachrome II Prints **Fuji CB Prints** (material supplied by Ilford) (P-3, P-3X, P-30, and P-30P) [polyester and RC] (Although Ilfochrome "Pearl" semi-gloss and glossy-surface RC prints have dye stability that is similar to Ilfochrome high-gloss polyester-base prints, the RC prints are subject to RC base cracking and image yellowing, and therefore are not recommended for long-term applications.) (1980–91 for Cibachrome II) (1991— for Ilfochrome Classic)	**9.5 (–M)**	**16.0 (–M)**
Konica Color PC Paper Type SR **Konica Color PC Paper Prof. Type EX** (1984 [April]— for Type SR) (1987— for Type EX)	**9.0 (–M)**	**9.6 (–M)**
Kodak Dye Transfer Prints ("standard" Kodak Dye Transfer Film and Paper Dyes) (1946—, with minor modifications)	**8.3 (M–C)**	**6.3 (M–Y)**
Fujicolor Paper Type 8901 (1984–86)	7.4 (–M)	9.6 (–M)
Kodak Ektacolor Plus Paper **Kodak Ektacolor Professional Paper** (1984 [August]— for Ektacolor Plus) (1985— for Ektacolor Professional)	**7.1 (–M)**	**7.6 (–M)**
Kodak Ektacolor 37 RC Paper (1971–78)	6.5 (–M)	8.2 (–M)

	Predicted Years of Display	
Type of Color Print Product	**Prints Covered With Glass**	**Prints Covered With UF-3 Ultraviolet Filter**
Kodak Ektacolor 78 Paper Type 2524 Kodak Ektacolor 74 RC Paper Type 2524 (1982–86)	6.3 (–M)	6.9 (–M)
Konica Color Paper SIII (1983–84)	5.8 (Y–C)	8.6 (–M)
Kodak Ektacolor 74 RC Paper (initial type: 1977–82)	5.7 (–M)	7.3 (–M)
Fujicolor Paper Type 8908 (1980–84)	5.5 (Y–C)	8.6 (–M)
Kodak Ektachrome 14 Paper (1981–85)	5.4 (–M)	7.4 (–M)
Agfacolor PE Paper Type 7i (1984–85)	5.0 (d-min: C+Y)	6.1 (–M)
Fujichrome Reversal Paper Type 31 (1978–83)	4.9 (–M)	7.7 (–M)
Kodak Ektachrome 2203 Paper (1978–84)	4.9 (–C)	6.5 (–C)
Fuji Dyecolor Prints (dye transfer type) (1970—) (available only in Japan)	**4.6 (M–Y)**	**5.4 (C–Y)**
Agfacolor PE Paper Type 589i Agfacolor PE Paper Type 7 (1983–85)	4.2 (–M)	5.4 (–M)

Table 3.6 (continued from previous page)

Type of Color Print Product	Predicted Years of Display: Prints Covered With Glass	Predicted Years of Display: Prints Covered With UF-3 Ultraviolet Filter
Ilford Cibachrome-A Prints (1975–81) (P-12)	4.2 (–M)	8.9 (M–Y)
3M Profesional Color Paper Type 25 3M High Speed Color Paper Type 19 (1978–88)	4.0 (–M)	5.7 (–M)
Agfacolor PE Paper Type 5 (1977–82)	3.5 (–M)	3.8 (–M)
Agfacolor PE Paper Type 589 (1981–83)	3.4 (C–Y)	2.6 (C–Y)
Kodak Ektaflex PCT Color Prints (1981–88)	3.2 (–M)	3.2 (–M)
Polaroid SX-70 Prints [improved] (1976–79)	3.0 (M–Y)	2.7 (C–Y)
Kodak Trimprint Instant Color Prints (1983–86)	2.8 (–M)	3.0 (–M)
Kodak Ektachrome RC Paper Type 1993 (1972–79)	2.6 (–M)	2.5 (–M)
Polaroid 600 Plus Prints **Polaroid Autofilm Type 330 Prints** **Polaroid Type 990 Prints** Polaroid Spectra Prints Polaroid Image Prints (Spectra in Europe) (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra prints, Image prints, 600 Plus prints, and other Polaroid products using the Spectra emulsion are not recommended for other than short-term applications.) (1986–91 for Spectra) (1988— for other prints)	**2.5 (–M)**	**3.1 (–M)**
Polaroid Spectra HD Prints **Polaroid Image Prints** (Spectra in Europe) (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid Spectra HD prints are not recommended for other than short-term applications.) (1991—)	**2.5 (–M)** [tentative]	**3.1 (–M)** [tentative]
Polaroid High Speed Type 779 Prints **Polaroid Autofilm Type 339 Prints** Polaroid 600 High Speed Prints (Because of high levels of yellowish stain that form over time in normal dark storage, Polaroid 600, Type 779, and Type 339 prints are not recommended for other than short-term applications.) (1981–88 for Polaroid 600) (1981— for other prints)	**2.1 (M–Y)**	**2.0 (M–Y)**
Agfacolor PE Paper Type 4 (This paper has extremely poor dark fading stability.) (1974–82) (Agfa AP-85)	1.8 (–C)	3.3 (–C)
Polaroid Polacolor 2 Prints **(Types 88; 108; 668; 58; and 808)** (The images of Polacolor 2 prints suffer a yellowish color shift that may become objectionable after only a few years of dark storage under normal conditions; because of this, Polacolor 2 prints are not recommended for fine art or other critical applications.) (1975—)	**1.8 (–C)**	**1.7 (C–Y)**
Fuji FI-10 Instant Color Prints (available only in Japan) (1981—)	**1.6 (Y–C)**	**2.1 (Y–C)**
Polaroid SX-70 Time-Zero Prints (initial type: 1979–80)	1.6 (M–Y)	1.3 (M–Y)
Fuji 800 Instant Color Prints (available only in Japan) (1984—)	**1.3 (M–C)**	**1.3 (M–C)**
Polaroid Polacolor ER Prints **(Types 59; 559; 669; and 809)** (1980—)	**1.2 (M–C)**	**1.6 (M–Y)**
Agfachrome-Speed Color Prints (1983–85)	0.8 (M–C)	1.1 (M–C)
Kodak PR10 Instant Color Prints (initial type: 1976–79)	0.6 (–C)	1.0 (–C)