17. Display and Illumination of Color and B&W Prints

The Alarming Light-Induced Image Discoloration and Base Cracking of B&W RC Prints on Long-Term Display

Those serving the needs of collections being heavily used for exhibition face a serious dilemma. On one hand, they are chronicling, aiding and abetting in the systematic destruction of the photographs they are charged to protect by supporting reprehensible exhibition practices. On the other hand, they largely owe their existence to those very exhibition programs.

. . . The current exhibition vogue amounts to a systematic program of accelerating the degradation of our most valued and important photographs. The practice can and must be changed. No doubt there will be many who will claim that such an assessment is too extreme and that the problem is being exaggerated. They will say that we do not have enough information to change our ways. I would say we do not have enough information to maintain them.[1]

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International Museum of Photography
at George Eastman House
Rochester, New York – September 1986

Introduction

Photographs are displayed for many different reasons and in an extremely wide range of lighting conditions — see **Table 17.1**. Whereas modern fiber-base black-and-white prints that have been correctly processed and treated with a protective toner are extremely stable and may be expected to have a very long life under typical conditions of display,[2] the same cannot be said for most kinds of color prints, or for black-and-white prints made on RC (polyethylene-resin-coated) papers.

With the singular exception of color pigment prints made with the new UltraStable Permanent Color process and the Polaroid Permanent-Color process,[3] exposure of color photographs to light during display will cause slow but inexorable fading and staining of the image; visible light and ultraviolet (UV) radiation may also cause cracking and other physical deterioration of the print emulsion and support material. This does not mean that color prints cannot or should not be displayed, but if such photographs are to be preserved for long periods of time, the stability characteristics (including fading rate) of the color print material must be understood. The planned total time of display must be determined with consideration for the intensity and spectral composition of the illumination source as well as for how much image fading and staining can be tolerated. As discussed in Chapter 7, valuable color prints should be monitored with a densitometer, and visually significant changes in color balance, overall density, and minimum density stain levels should not be permitted to take place.

See page 577 for Recommendations

Display of color prints is inherently detrimental to them, but avoiding display runs counter to the reasons most photographs are made and frequently conflicts with the purposes for which most individuals and museums collect prints.

The Expendable or Replaceable Color Print

If a color print has no lasting value — or if it can be replaced with a new print after the original has deteriorated — it can be displayed without much caution. Although they may be expensive to replace, decorative prints and murals of the types found in many corporate offices and in public places such as hotel lobbies, restaurants, and airports are usually expendable. Museums, however, do not generally consider their prints to be expendable, even if a faded print could be replaced during a photographer's lifetime.

In some instances it might be possible to obtain replacement color prints for faded baby pictures, high school portraits, wedding photographs, and family portraits from the photographer who took them. Many professional photographers, however, keep negatives for only a relatively short time — often only for as long as experience indicates that reorders might come in. Most of the low-cost "mass-market" portrait operations — such as those that travel from department store to department store, taking photographs only a few days at each location — dispose of their color negatives almost immediately after the selection of prints is made; the cost of filing and storing negatives is prohibitive for these low-overhead, high-volume businesses.

Even if a photographer does keep color negatives, the negatives may be too faded to make satisfactory prints after years have passed. This is especially true if the photographs were made on earlier, low-stability films such as Kodak Kodacolor II, Vericolor II, and Process E-1, E-2, and E-3 Ektachrome films.

Display of Nonreplaceable Color Prints

When it is desired to keep a color print in good condition for as long as possible, there are limitations on how long the print can be exposed to light on display. Guidelines for the display times of current and many older color print materials are given in Chapter 3. As a general rule, it may be assumed that under typical moderate display conditions, the light fading rate of a given type of color print is approximately proportional to the light intensity on the print. For example, a print displayed for 12 hours a day in

May 1982

The 1982 exhibition **Color as Form: A History of Color Photography** at the Corcoran Gallery of Art in Washington, D.C. The display area was illuminated with incandescent tungsten lamps with an average intensity of about 170 lux. The first major survey of color photography as an art form, this show was curated by John Upton for the International Museum of Photography at George Eastman House in Rochester, New York. The exhibition opened at the Corcoran for 3 months and was later shown at George Eastman House. With vintage prints made by a wide variety of color processes — most with unknown stability characteristics — this was the first photography exhibition to be densitometrically monitored for image fading and staining.

1,000 lux of light will fade at about twice the rate of a print displayed the same amount of time in 500 lux. Because the human eye has a great ability to adapt to different light intensities, a person is often not aware of the great range of light intensities that usually exist in a room, or in different parts of a building. In museum display of original color photographs, densitometric limits of tolerable color fading should be established and a monitoring program instituted to make certain that prints are not permitted to fade or stain beyond those limits (see Chapter 7).

Some museums have guidelines for exhibition of color and black-and-white photographs which apply to works both in the museum and out on loan. The Museum of Fine Arts in Boston permits a maximum display time of 3 months every 2 or 3 years; if a print has been exhibited in the previous year, the museum will not send it out on loan. The Metropolitan Museum of Art in New York City has a policy of displaying color photographs no more than 3 or 4 months every 5 to 10 years. In the past, the International Museum of Photography at George Eastman House kept a number of its better-known photographs on permanent display; some of the museum's traveling exhibitions were out on loan to a succession of institutions for years at a time. More recently, the museum has been periodically replacing most of the photographs in its regular exhibition areas with other photographs from the collection so that no print is on constant display.

When purchasing a color print, it may be possible to obtain a duplicate copy at low cost; one print can be displayed with the realization that it will fade over time, while the other can be kept in the dark for preservation purposes. When the displayed print has faded to the point where it is no longer acceptable, a copy print for display can be made from the stored print; the one remaining original print should continue to be kept in the dark under the most favorable conditions possible. For persons making their own color prints, it is a simple matter to produce one or two extra prints for display purposes. In recent years the Art Institute of Chicago has attempted to obtain duplicate prints of the color photographs acquired for its collection so that one print can be used for exhibition and study purposes and the other kept in the dark in the museum's humidity-controlled cold storage facility. The Museum of Modern Art in New York City also attempts to obtain two copies of each of its chromogenic color print acquisitions; one copy is kept in permanent storage in a frost-free refrigerator, and the other is withdrawn from the refrigerator when needed for study or exhibition purposes.

(continued on page 578)

Recommendations

Display of Color Prints

* **Nonreplaceable color prints.** Unfortunately, with the exception of UltraStable Permanent Color and Polaroid Permanent-Color pigment prints, almost all other types of color photographs exposed to light on display slowly fade over time and will eventually become severely degraded. Valuable or nonreplaceable color prints should never be subjected to prolonged display. The light fading stability of different types of color prints varies over a wide range, with some color prints lasting far longer than others under the same display conditions (see Chapter 3). Only **expendable** color prints having no lasting value, or those for which duplicates are being kept in dark storage, or those for which it is certain that replacement prints can be made in the future, should be subjected to prolonged or "permanent" display.

Illumination Levels

* **For museums, galleries, and archives.** Approximately 300 lux of incandescent tungsten or glass-filtered quartz halogen illumination is recommended. This author believes that light levels below 300 lux are insufficient for proper visual appreciation of photographs, particularly color photographs. Prints should be displayed with adequate illumination. There is no "minimum" illumination level at which color print fading does not occur. Accumulated display time must be limited to prevent excessive fading. Modern black-and-white fiber-base prints may be displayed at significantly higher illumination levels (e.g., 600 lux or higher) as long as the surface temperature of the prints in black (d-max) areas does not increase more than a few degrees. Heating of prints reduces emulsion and base moisture content, which may in turn cause increased curl and/or eventual cracking, especially in RC prints.

* **For home and commercial applications.** Approximately 450 lux of incandescent tungsten, glass-filtered quartz halogen, or glass-filtered fluorescent illumination is recommended. In many commercial display situations, bright ambient lighting conditions will require significantly higher illumination levels to show photographs to their best advantage.

* **Museums and photographers should adopt a standard illumination level.** A photograph on display should accurately convey the subtleties envisioned by the photographer. To accomplish this, it is essential that the print be evaluated for density and color balance in the darkroom under the same intensity and type of illumination with which it will be displayed in a gallery or museum. It is proposed that galleries, museums, and archives formally adopt the above-recommended 300 lux of incandescent tungsten or glass-filtered quartz halogen illumination against a light, neutral background and that photographers be encouraged to use this illumination condition for evaluating prints.

* **Museums and archives should monitor prints.** Densities at selected image locations on color and black-and-white prints should be measured periodically with an accurate electronic densitometer, and predetermined limits of fading and staining should not be exceeded (see Chapter 7). It is recommended that salted paper prints (ca. 1840–1855) and albumen prints (ca. 1850–1895) never be displayed — not even for short periods.

Glass and UV-Absorbing Framing Materials

* **UV filters do little to protect most color prints.** With Ektacolor, Fujicolor, Konica Color, Agfacolor, and most other current color print materials displayed in typical indoor conditions, image fading is caused primarily by **visible** light, not by ultraviolet radiation. Ultraviolet filters such as Plexiglas UF-3 do little if anything to increase the life of these color materials, largely because they are manufactured with an effective UV-absorbing emulsion overcoat. One exception is Ilford Ilfochrome print materials (called Cibachrome 1963–1991), which are manufactured without a UV-absorbing overcoat. When Ilfochrome prints are displayed under direct or indirect daylight, framing with a UV filter markedly increases their stability. The improvement is much less for prints illuminated with fluorescent or tungsten light (see Chapter 3).

* **Glass is recommended over Plexiglas and other plastics for most framing applications.** Glass is inexpensive, easy to cut, chemically inert, and resistant to scratches; however, it should not be used for traveling exhibitions or for very large prints where breakage could occur. For these applications, standard clear Plexiglas G is recommended. Displaying prints framed with glass or Plexiglas G adjacent to prints framed with Plexiglas UF-3 can be visually distracting. The light-yellow tint of UF-3 gives white mount boards and low-density areas of photographs a distinctly yellowish, or warm, appearance; prints framed with glass look distinctly different. Furthermore, UF-3 suppresses the effects of fluorescent brighteners that are incorporated in virtually all current black-and-white papers; this has the effect of subtly dulling the appearance of the prints. Even with incandescent tungsten illumination, which has very low UV content, the dulling effect of UF-3 is noticeable.

Black-and-White RC and Fiber-Base Prints

* **Double-weight, fiber-base papers are strongly recommended.** Current information indicates that fiber-base prints are, overall, substantially more stable than RC prints, especially when displayed for prolonged periods. Fiber-base prints also appear to be less susceptible than RC prints to image discoloration caused by surface contaminants, poor-quality storage materials, and/or commonly encountered levels of air pollutants. Many RC prints made with developer-incorporated papers (e.g., the now-obsolete Ilford Multigrade II RC paper) have, after only a few years of storage, developed serious brownish stain within the paper base itself. RC papers should not be used for historically important photographs, fine art prints, or portraits. Fiber-base prints intended for long-term display or storage should be treated with an image-protective toner (see text). This author considers treatment with a protective toner to be an **essential** part of "archival" processing. Virtually all modern black-and-white papers are made with fluorescent brighteners, which gradually lose activity ("fade") when displayed. Thus, although the image and base of an "archivally" processed fiber-base print are extremely stable, the loss of brightener effect will cause the whites and highlights of the print to lose some of their original brilliance.

* **Display of black-and-white RC prints.** Valuable black-and-white RC prints should never be displayed. Especially when framed under glass or plastic and displayed for prolonged periods, even at low light levels with UV-filtered illumination, black-and-white RC prints may be subject to light-induced oxidation of the silver image, resulting in ugly yellowish or orange-red image discolorations. Black-and-white RC prints are also subject to base and/or emulsion cracking as a result of display.

* **Kodak B&W RC papers are recommended.** If it is decided to use an RC paper, then Kodak Polymax RC Paper and Polyprint RC Paper, both conventional-emulsion (non-developer-incorporated) papers, currently are recommended. There are **substantial** differences in image and base stability of black-and-white RC papers. At the time of this writing, Kodak was the only manufacturer that had published meaningful accelerated aging projections for its RC papers with respect to base cracking, and Kodak also has described the stability benefits afforded by its "stabilizer in the paper core" technology. Until meaningful comparative accelerated aging data are available on the base and image stability characteristics of the RC papers supplied by other manufacturers, Kodak RC papers will continue to be recommended. It is recognized, however, that with the most common methods of drying RC prints, the image and surface quality of most RC papers, including Kodak, may prove visually unacceptable because of "veiling" of the blacks (see below). Should this be the case, Oriental New Seagull Select VC-RP, a variable-contrast paper, and Oriental New Seagull RP, a graded paper, both of which give good results even when dried at room temperature, are probably the only satisfactory alternatives.

* **Ilford RC print processors and dryers are recommended.** The depth of the blacks, the print surface gloss, and the overall visual image quality of Kodak and most other black-and-white RC papers are significantly degraded when the prints are dried at room temperature or dried with conventional hot-air RC print dryers, such as the dryer in the Kodak Royalprint processor (discontinued in 1991). For best results, RC prints should be dried with one of the Ilford infrared print dryers. The stand-alone Ilford 1250 dryer and the dryers incorporated in the Ilford 2240 and 2150 RC print processors all provide excellent results. Also satisfactory is the Kodak Polymax IR processor; introduced in 1991, this is the first Kodak processor to be equipped with an infrared dryer. Unlike the case with RC prints, the images on fiber-base papers are not noticeably affected by the method of drying; fiber-base prints can be dried emulsion-side down on clean, plastic-coated fiberglass screens at room temperature with outstanding results.

* **Valuable RC prints should be treated with an image-protective toner.** Especially if they are to be displayed, valuable black-and-white RC prints should be treated with Kodak Poly-Toner or Kodak Rapid Selenium Toner to help protect the silver image against the peculiar types of discoloration (oxidation) to which RC prints are susceptible. Toner treatment will not, however, increase the resistance of RC papers to cracking.

Instant color photographs, none of which have usable negatives for making new prints, are in most cases not replaceable. In addition, all current Polaroid and Fuji instant color prints have relatively poor light fading stability; valuable instant prints should be displayed for short periods only.

Display of Black-and-White RC Prints: Caution Is Necessary

Black-and-white RC (polyethylene-resin-coated) papers first became generally available in the United States with the introduction of Kodak Polycontrast Rapid RC Paper in October 1972.[4] RC papers made by Ilford (Ilfospeed and Ilford Multigrade papers), Agfa-Gevaert (Brovira PE Paper, later called Brovira-Speed Paper), and other manufacturers worldwide soon followed. RC papers now constitute the great majority of all black-and-white photographic papers produced. Use of fiber-base papers increasingly is limited to fine art photographers, advanced darkroom hobbyists, and top-quality advertising and commercial photographers (advertising photographers prefer the superior retouching and knife-etching capabilities of fiber-base papers).

Whether because of an appreciation of the superior surface and image qualities afforded by the best fiber-base papers, or perhaps because of a reluctance to adopt an unproven material, fine art photographers in the U.S. and most other countries have — fortunately — thus far almost completely avoided black-and-white RC papers in making prints for exhibition or sale.

RC paper is made by hot-extruding a thin layer of polyethylene on both sides of a fiber-base paper core; clear polyethylene is coated on the back of the print (often the paper core is first printed with the manufacturer's name in light gray ink) and polyethylene pigmented with white titanium dioxide (TiO_2) is coated on the emulsion side; the high-reflectance pigmented layer serves the same general function as the baryta layer (composed of barium sulfate suspended in gelatin) in fiber-base prints. The emulsion is coated on top of the pigmented polyethylene layer, leaving the emulsion accessible to developer and other processing solutions.

Because the polyethylene layers render the paper support essentially waterproof, very fast processing, washing, and drying of RC prints are possible. With an automatic processing machine, an RC print can be developed, fixed, washed, *and dried* in as little as 55 seconds; manual processing, including washing in trays and drying with an electric hair dryer, typically takes 8 or 10 minutes. To correctly process, wash, and dry double-weight fiber-base prints, on the other hand, requires a minimum of about an hour. When processing fiber-base prints for maximum permanence, with air-drying on plastic-coated fiberglass screens at room temperature — what is often called "archival processing" — the total time can extend to as long as 12 hours. Speed of processing is the primary appeal of RC papers and is the principal reason they were invented. And unlike fiber-base prints, RC papers have little tendency to curl, even in environments with low or fluctuating humidity .

RC papers should not be confused with print materials coated on ICI Melinex 990, a high gloss, opaque white polyester sheet manufactured by Imperial Chemical Industries (through a complex manufacturing process which forms billions of microscopic "voids" of high refractive index within the polyester structure of Melinex 990, a bright white material is produced without the need for an added pigment such as titanium dioxide). Among current products coated on Melinex 990 (or other closely related high gloss, opaque white polyester support) are Ilford Ilfochrome glossy print materials (semi-gloss Ilfochrome is an RC paper), and special-purpose products such as Fujiflex SFA3 Super-Gloss Printing Material, Fujichrome Printing Material, Kodak Duraflex RA Print Material, Konica Color QA Super Glossy Print Material Type A3, and Agfachrome 410 high gloss polyester color print material for transparencies.

UltraStable Permanent Color prints and Polaroid Permanent-Color prints are also made on an opaque white polyester support; the surface gloss of these prints can vary from a semi-gloss to a fairly high gloss, depending on the formulation of the gelatin used to overcoat the image layers after they have been affixed to the polyester support.

Solid polyester supports are more expensive — but tougher and far more stable during aging — than RC paper supports. Prints made on Melinex 990 have a mirror-like gloss that is much smoother and glossier than the highest gloss surface that can be produced on an RC paper. One drawback of Melinex 990, however, is that it cannot readily be manufactured with other than a high gloss surface. A semi-gloss surface similar to the popular Kodak N surface is not available and this, along with the higher cost of polyester materials, has restricted their use in portrait, wedding, fine art, and most other areas of photography where photographers generally prefer semi-gloss or matte surface papers.

With the exception of a few special-purpose products, black-and-white papers are not presently supplied on polyester supports. This is unfortunate, because if such a print material were properly manufactured, it would avoid most of the stability problems associated with black-and-white RC papers (it would, however, also be more expensive).

Before the invention of RC paper base in the 1960's — and before opaque white polyester supports became available around 1980 — waterproof print supports were made with white-pigmented cellulose acetate (in its transparent form, the same material is used for film base). Beginning in the early 1940's, Kodak Minicolor and Kotavachrome prints (processed by Kodak using the Kodachrome system) were coated on pigmented acetate supports, as was Ansco Printon, a reversal color material for printing slides produced by Ansco from 1943 until 1973. From 1963 until around 1980, Cibachrome print materials were coated on a pigmented cellulose triacetate support. With the introduction of Ilford Cibachrome II materials, the support material was changed to Melinex 990 (in 1991, Ilford changed the name of all Cibachrome materials to Ilfochrome — Cibachrome II became Ilfochrome Classic). Because of processing considerations, all of these color materials required a nonabsorbent support; had this not been the case, a less costly fiber-base support could have been used.

Pigmented cellulose triacetate is a far more stable material than the RC base papers of the 1970's — but it is also more expensive. Kodak had long searched for a low-cost, waterproof substitute for pigmented cellulose triacetate. Kodak wanted a material that cost little more than single-weight fiber-base paper, and after considerable experimentation, the company found it in polyethylene-coated paper. An important reason that polyethylene was chosen for this application is that it is the least expensive of all plastics — which is why it is also the material of choice for garbage bags, plastic milk bottles, and many other inexpensive disposable consumer items.

Deterioration of Displayed RC Prints

Many framed black-and-white prints made on Kodak Polycontrast Rapid RC Paper and Ilford Ilfospeed [RC] Paper manufactured in the 1970's and early 1980's have, during the course of only a few years of display under normal conditions, suffered catastrophic, irregular gold-like, orange-red, or yellow image discolorations (sometimes called "bronzing") and have developed localized "silver mirror" deposits on the emulsion surface in high-density areas of the image. Sometimes these discolorations are accompanied by large numbers of small, bright orange-red spots, identical in structure to the microspots (also known as "redox blemishes" or "microscopic blemishes") that in the past have been found principally on stored microfilms and astronomical plates. Microspots are also occasionally encountered on conventional camera and motion picture films, glass-plate negatives, and glass lantern slides. But, to the best of this author's knowledge, microspots of this type have *never* been found on fiber-base prints.

The Corcoran Gallery of Art in Washington, D.C., the Art Institute of Chicago, and the National Archives of Canada in Ottawa are among the well-known institutions that have deteriorated black-and-white RC prints in their collections. These prints became severely discolored after only a few years of display and storage; with the passage of time, it is inevitable that huge numbers of RC prints worldwide will be similarly affected.

Judging from the speed at which the images of framed and displayed Polycontrast Rapid RC prints from the 1970's and Polycontrast Rapid II RC prints from the early 1980's can become severely discolored, these papers could certainly be ranked as some of the most inherently unstable black-and-white photographic materials ever to be marketed since the introduction of the first silver-gelatin developing-out papers in the late 1800's. The deterioration of the Kodak RC prints has occurred despite careful processing and washing.

The discolorations which this author has observed in Kodak Polycontrast Rapid RC prints generally are concentrated along density gradients where light and dark portions of the image meet; Polycontrast Rapid RC prints sometimes also have large numbers of orange-red microspots. Deteriorated Ilford RC prints, on the other hand, usually have had a more uniform, overall brownish-yellow image discoloration.

Both Kodak and Ilford RC papers can suffer from microspot formation and surface mirroring; with some prints, the mirroring has become quite extreme. Although all of the deteriorated Kodak RC prints which this author has been able to positively identify were made on Polycontrast Rapid RC Paper and Polycontrast Rapid II RC Paper, it is assumed that Kodabrome RC and other Kodak black-and-white RC papers from the period can be similarly affected.

1981

Fern Bleckner, at the time a conservator at the Corcoran Gallery of Art in Washington, D.C., and Joe Cameron, a photographer and teacher at the Corcoran, examine discolored black-and-white RC prints that had been made on Polycontrast Rapid RC Paper in the mid-1970's. Although the prints had been displayed for only 2 months, they had nevertheless developed serious image discoloration by the time this photograph was taken in 1981. It is not known whether the damage was caused by exposure to light or by air pollutants (or a combination of both). At the time, the Corcoran was not air conditioned, and during warm months windows in the photograph storage area, which is near to a busy Washington street, were open much of the time. Pollutants from automobile exhaust might have been a significant factor in the rapid deterioration that occurred in these unstable prints.

Some Kodak Polycontrast Rapid RC prints also have suffered from severe cracking of the polyethylene-coated support material (cracking has also occurred in many displayed Kodak Ektacolor RC prints from the late 1960's and early 1970's). As discussed below, cracking of the RC support is facilitated by a combination of exposure to light and storage or display in an environment in which the relative humidity fluctuates over a wide range. With the passage of time, it is expected that increasing numbers of these prints will develop cracks. To date, however, image discoloration appears to be a much more serious problem than support cracking in black-and-white RC prints.

Ilford Ilfospeed RC paper was not particularly popular in the U.S. in the 1970's, and this author has encountered only a relatively small number of Ilfospeed RC prints that have been displayed for significant periods (complicating the matter is the fact that Ilford did not imprint the back of the paper with the company's name, so it is often impossible to tell whether a particular print is in fact an Ilford product). This author has not yet encountered a verified Ilfospeed RC print which has developed cracks; however, cracking of Ilford RC prints from this era has been reported in the literature.[5]

Light-Induced Oxidation and Subsequent Cracking of the Image-Side Polyethylene Layer

Polyethylene plastic has long been recognized as having poor stability when subjected to prolonged exposure to light or ultraviolet radiation. According to a 1974 patent issued to Eastman Kodak for improvements in the formulation of its RC papers:

> In the use of such resin coated papers many problems occur, not the least of which relates to the relatively low stability of the resins and, especially polyolefins [polyethylenes], used to coat the paper to achieve the desired wet strength, etc. Such resins [polyethylenes] typically deteriorate quite rapidly due to the action of, for example, ultraviolet light or the oxidative action of photographic printing and developing chemicals. . . . It has therefore become of prime importance that such resinous layers be suitably stabilized against such hazards if they are to be useful in photographic papers.[6]

This small print, made on Kodak Polycontrast Rapid RC Paper from the early 1970's, has developed severe RC base cracks. The print was exhibited for about 5 years in a glass-enclosed display cabinet in the Grinnell College Physics Museum in Grinnell, Iowa. The cabinet was illuminated with bare-bulb Cool White fluorescent lamps. (Print courtesy of Grant Gale, physics professor and curator of the Physics Museum)

1990

A magnified view of the RC base cracking. The fluorescent lamps elevated the temperature inside the cabinet, thus lowering the relative humidity. When the lamps were turned off at night, the humidity returned to the ambient level, and this daily humidity cycling, in combination with the degrading effects of light and UV radiation on the unstable RC base, eventually produced the cracking seen here.

The light-induced deterioration of polyethylene can be greatly accelerated by the presence of white titanium dioxide pigment, incorporated in the top polyethylene layer of RC prints. Titanium dioxide is a photochemically active substance and when exposed to light it can generate an active form of oxygen, which in turn can attack adjacent polyethylene. Although both ultraviolet radiation and visible light can trigger these reactions, study of the display conditions of large numbers of deteriorated RC prints suggests that visible light is, in most cases, the primary cause of the deterioration. In typical indoor display conditions, a Plexiglas UF-3 or other UV filter will probably do little to improve the long-term stability of a black-and-white RC print.

Oxidation of the polyethylene results in gradually increasing brittleness of the plastic and, in conjunction with the physical stresses produced by normal fluctuations in relative humidity (e.g., between 30 and 60%)[7], will eventually cause cracks to form in the image-side polyethylene layer and print emulsion.

Light-induced deterioration of polyethylene and accelerated test methods used by Eastman Kodak to evaluate the cracking tendency of its RC papers have been reviewed in an important 1979 article by Parsons, Gray, and Crawford.[8] The addition of antioxidants and stabilizers to the structure of Kodak RC papers, the change to a less reactive form of titanium dioxide in the emulsion-side RC layer, and other improvements in Kodak RC papers were also described (the article restricted its discussion to the problem of RC print cracking and did not deal with silver-image discoloration of displayed RC prints).

Light-Induced Destruction of the Silver Images of RC Prints

The peroxides and other oxidants generated in the titanium dioxide pigmented polyethylene layer during long-term exposure to light and UV radiation — in association with by-products of polyethylene degradation (certain emulsion ingredients or other components of the RC paper structure may also be involved) — can progressively attack (oxidize) the adjacent silver image. The eventual result can be severe image discoloration and the formation of "silver mirrors" on the emulsion surface. This apparently is the mechanism responsible for the rapid image deterioration that has been observed in many framed and displayed prints made on early Kodak and Ilford black-and-white RC papers. Unframed prints exposed to light can also be affected. The relative humidity of the display and storage environment appears to be an important variable in these reactions, with high relative humidity substantially increasing the rate of image discoloration. High temperatures undoubtedly also accelerate the rate of deterioration.

Internally generated peroxides and/or by-products of polyethylene degradation may also be implicated in the increased rates of fading that this author has observed in certain types of Ektacolor, Fujicolor, Agfacolor, and 3M color papers when they are framed under glass or plastic on long-term display. With color prints, it is of course a dye image, rather than a silver image, that is affected (see Chapter 2 for discussion of RC-base-associated fading of color prints).

The sensitivity of silver photographic images to even very low levels of peroxides and other oxidants, especially in humid environments, is well established, and logic would suggest that an oxidant level sufficient to degrade and embrittle polyethylene should also be capable of oxidizing the delicate filamentary silver grains which make up the image.

The chemical processes involved in the oxidation and subsequent reduction of the silver image, resulting in the formation of yellow-orange colloidal silver and "silver mirrors," are also generally understood and have been discussed at length in the literature. As described by Larry Feldman of Eastman Kodak,[9] the silver grains forming the image are oxidized by peroxides or some other oxidizing substance to form silver ions. Particularly when the emulsion has a high moisture content, the silver ions can physically migrate a short distance from the site of the original silver grains. Through the action of light, or in the presence of various atmospheric contaminants, the silver ions are then reduced to tiny particles of metallic colloidal silver, or converted to silver sulfide (silver sulfide can be formed by reaction with, for example, hydrogen sulfide, a common air pollutant). According to Feldman, "Since these minute particles refract light, groupings of these particles have a characteristic yellow, orange, or red appearance. When concentrated near the [emulsion] surface, the metallic silver or silver sulfide particles can reflect light as a silver mirror."

Changes have been made in the structure of the silver grains in print emulsions in recent years in order to reduce the amount of silver required to produce an adequate black (thus increasing the "covering power" of the silver), and thereby reduce the manufacturers' costs. These changes may also be implicated in the increased susceptibility of some black-and-white RC papers to image discoloration.

Displayed Black-and-White RC Prints Can Self-Destruct

We have here a very alarming situation — with their built-in ability to generate oxidants during the course of normal display, black-and-white RC prints contain a potentially powerful source of their own destruction. With both the silver image and support material being attacked, this constitutes an entirely new type of photographic deterioration. Although unframed RC prints on display are also subject to light-induced image discoloration, framing an RC print under glass or plastic exacerbates the problem, apparently by preventing the diffusion of oxidants and volatile degradation products into the atmosphere, and away from the silver image. With everything trapped inside the frame, and with the print emulsion sandwiched between the RC support and framing glass, the print is left to "stew in its own juices." (See pages 600–601 for reproductions of RC prints that suffer from light-induced image discoloration.)

Over the years Kodak has carefully avoided discussion of this mode of RC image deterioration, and this author is aware of only one reference — a vague one at that — in Kodak literature to this phenomenon. In the April 1978 revision of *Kodak B/W Photographic Papers*, Kodak Publication No. G-1, it is stated:

> In addition to protecting the paper base from absorption of processing chemicals (thus permitting easier working), the resin [polyethylene] layers restrict the flow of gases. When prints are stored or displayed in a confined atmosphere (such as being framed under glass), any oxidants present may react with the silver grains and result in image discolorations. Such oxidants might result from the environment, residual processing chemicals, adhesives used in frame construction, cleaning agents, or *base degradation* [italics added]. . . .[10]

Although Kodak placed "base degradation" last on its list of potential causes of image discoloration in framed RC prints, this author believes that at least with early Kodak Polycontrast Rapid RC prints, base degradation is in the great majority of cases the *primary* reason that images have discolored, or will do so in the future if displayed for a sufficient length of time. In the subsequent edition of Kodak Publication No. G-1, released in May 1982, and a later edition published in 1985, all reference to a possible relationship between RC base degradation and image discoloration was deleted.

In May 1978, at a conference on preservation of color photographs at the International Center of Photography (ICP) in New York City, this mode of black-and-white RC image discoloration was discussed by Klaus B. Hendriks.[11] Commenting on the previously discussed statement in the 1978 edition of *Kodak B/W Photographic Papers*, Hendriks dismissed the influence of oxidants originating from the environment or from residual processing chemicals as likely causes of image discoloration in framed RC prints, and said: "First the base degrades and produces some oxidizing agent, and then it will continue to attack itself [and the silver image] because it is enclosed in a glass frame."

Hendriks, who is director of the Conservation Research Division at the National Archives of Canada, said that displaying a framed black-and-white RC print created a "closed system" of deterioration, and he speculated that this could prove to be a serious problem in the years to come. (When the presentation was given in 1978, neither Hendriks nor this author had yet seen an example of image discoloration in the then-new black-and-white RC papers which could definitely be attributed to this mechanism of "self-destruction"; however, a number of Ektacolor RC prints that had developed cracks after less than 10 years of normal display in homes had been encountered.)

David Vestal, a photographer and influential writer who in early 1976 had started a public campaign to alert photographers to the shortcomings of RC papers and to convince Kodak and other manufacturers not to cease production of fiber-base papers, gave a detailed account of Hendriks's presentation in the October 1978 issue of *Popular Photography* magazine in an article entitled, "RC Report: The TiO_2 Blues."[12]

The "Edge Effect" in the Discoloration of Framed and Displayed RC Prints

Supporting the view that image deterioration of framed and displayed Kodak Polycontrast Rapid RC prints can be caused by oxidants generated by the RC paper itself is the nature of the discoloration observed after several years of display in two RC prints made in 1977 by this author. The photographs were taken in the middle of the night of a lumberyard in Grinnell, Iowa going up in flames — the lumberyard was located next door to this author's home (which, fortunately, was spared). These prints were among many made by this author from a box of 8x10-inch Polycontrast Rapid RC Paper purchased in 1974;[13] all of the prints had been carefully processed, washed, and air-dried at room temperature, following Kodak's instructions. The white borders were trimmed from the prints after processing. The prints were dry mounted in the centers of sheets of 11x14-inch, 4-ply, 100% cotton fiber museum mount board (made by the Rising Paper Company). The mounted prints, without overmats, were placed under glass in metal frames.

After less than 5 years of display, severe image discoloration, microspots, and surface mirroring had occurred in medium- and high-density image areas, with the discoloration and mirroring especially pronounced in high-density locations adjoining low-density or white areas of the prints. However, the very outer edges of the prints — extending inward about ¹⁄₁₆ inch — suffered little or no discoloration.

This author believes that this "edge effect" is caused by the oxidants generated by the pigmented polyethylene layer diffusing through the paper core at the outer edges of a print. Passing into the thin air pocket surrounding the edges of the framed print (the thickness of the print kept the mount board slightly separated from the framing glass) and then absorbed by the mount board, the localized concentrations of oxidants at the edges of the print were lower than oxidant levels in the rest of the image area.

In correctly processed and washed fiber-base prints suffering from image deterioration caused by *external* contaminants from polluted air or unsuitable storage materials, it is frequently observed that the discoloration and fading are most severe near the edges of the prints. With framed and displayed RC prints, the opposite is generally true; this is additional support for the theory that the images are oxidized by substances generated within the print structure itself. In the examples of discolored RC prints just cited, the prints showing the "edge effect" had been trimmed after processing and drying, thus eliminating the possibility that edge-penetration of processing chemicals into the paper core of the RC prints was involved.

In view of the fact that the RC print structure has two polyethylene layers, that the prints were mounted on 4-ply, 100% cotton fiber museum mount board (all of which would help protect the image from attack from the back by airborne contaminants), and that the print emulsions were protected from the environment by framing glass, the reduced edge-fading also suggests that contaminants within the frame itself or from the surrounding environment were not a significant factor in the discoloration.

(It is important to note that unframed RC prints may also discolor. Indeed, this author had a stack of prints sitting on a shelf in his office for a number of years, and several Kodak Polycontrast Rapid RC prints among the group discolored where the edges or corners had protruded from the stack and were exposed to light. Fiber-base prints in the stack were unaffected.)

It has been noted by this author that after prolonged exposure to light, most RC papers evolve gases that have a distinct, pungent odor. The odor is especially pronounced if the prints have been framed under glass or plastic. Once the prints have been exposed to light for a sufficient period, emission of these gases can continue for many months, or even years, after the prints are placed in dark storage. The evolution of the gases is probably associated with the slow decomposition of polyethylene. The exact composition of these volatile substances has not been identified.

Accelerated Light Exposure Tests to Induce Silver Image Discoloration and Base Cracking in RC Prints

In 1986, after examining the nature of the severe image discoloration that occurred with the 1972 "initial type" Polycontrast Rapid RC prints discussed above, this author subjected a small print made from the same box of paper to a high-intensity 21.5 klux accelerated light exposure test with the expectation of being able to quickly simulate the discoloration. After several months had passed and the test print had been exposed to far more light (intensity x time) than the displayed print could possibly have received during the 5 years that it had been hanging on the wall — and with no sign of discoloration in the test print — it was concluded that the discoloration mechanism must have an extremely large reciprocity failure in light exposure tests. (If no reciprocity failure were involved, increasing the light intensity 25 times, for example, would reduce the length of time for image discoloration to appear by a factor of 25 — see Chapter 2 for a discussion of reciprocity failures as applied to the light fading and light-induced staining of color prints.)

To more systematically investigate the light intensity reciprocity relationship, the influence of UV radiation on image discoloration, and the effects of framing under glass or plastic, this author began a series of tests with samples cut from duplicate prints made in 1977 with paper from the same box that had been used for the 5-year displayed prints. All of the prints had been made during the same darkroom session and had been processed, washed and dried in the same manner. The duplicate prints had been stored in the dark during the 9 years before the tests were started. Each test sample contained a white border and a full range of densities — from a clean white to a deep black.

One group of prints was placed under low-intensity 1.35 klux (125 footcandles) Cool White fluorescent illumination at 75°F (24°C) and 60% RH. Another group was exposed to high-intensity 21.5 klux (2,000 footcandles) illumination, also at 75°F (24°C) and 60% RH (for a description of the test equipment, see Chapter 2). Illumination at 21.5 klux is 16 times more intense than at 1.35 klux. Included were unframed prints exposed to bare-bulb illumination, prints framed with glass (both with and without an overmat), and prints framed with Plexiglas UF-3, a UV-absorbing acrylic sheet.

At the time this book went to press in 1992, the tests had been in progress for 6 years (72 months) and visible deterioration had occurred in most of the prints:

1. **1.35 klux Unframed Print:** After 4 years, significant yellowish discoloration had rather suddenly occurred, and this was most evident in medium and low density areas immediately adjacent to white portions of the image. Unlike the prints that were framed with glass or Plexiglas UF-3, no microspots were evident, although surface "silvering-out" was noted adjacent to the most severely discolored areas. Even after 6 years, no base/emulsion cracking was observed with the unframed print, even though it had been exposed to the relatively high UV content of bare-bulb fluorescent illumination.

2. **1.35 klux Overmatted Glass-Framed Print:** After 1½ years of light exposure, "classic" orange-colored, surface-mirrored microspots were observed (if this author had been experienced in looking for early-stage discoloration, the spots probably would have been noticed sooner). These spots occurred in medium-density areas, adjacent to lower-density parts of the image. After

2⅓ years, the spots had grown in size, but the total number of these "large" spots remained fairly small. In addition, a narrow band of the image, approximately 1.0mm wide, and running along the full length of the adjacent, untrimmed white print border, had become uniformly discolored and surface-mirrored. Under 10X magnification, a large number of very small microspots could be observed in an image area 3mm to 8mm from the print border. After 4 years, significant yellowish discoloration in low- and medium-density areas adjacent to white portions of the image had rather suddenly occurred. Few additional large microspots were noted. After 6 years, this pattern continued with image discoloration becoming more severe; no surface cracking could be detected.

3. **1.35 klux Print Framed in Contact with Glass:** After 1⅔ years, the print had developed large numbers of very small microspots, which were fairly evenly distributed in medium- to high-density areas of the print (the microspots tended to be concentrated along image-density gradients). No discoloration was evident in low-density areas of the image. After 4 years, the print had not developed a discolored area next to the white print border as had occurred with No. 2 above. But, overall, the number of small microspots had increased markedly. None of these spots, however, approached the size of the "large" spots that occurred with the overmatted print. After 6 years, little of the yellowish discoloration noted in the overmatted print was evident.

4. **1.35 klux Print Framed in Contact with UF-3:** After 2⅓ years, the print exhibited a narrow, strongly discolored band immediately adjacent to the untrimmed white print border (identical to that described in No. 2 above) and the print had also developed some small microspots 3mm to 10mm from the border; these spots were concentrated near one corner of the sample. After 6 years, more microspots and discoloration were noted.

5. **21.5 klux Unframed Print:** After 1½ years the print had developed extensive emulsion and/or base cracking (which type of crack could not be determined) in minimum-density (white) and low-density areas. The first cracks probably occurred at an earlier point in the test; but because the cracks were not accompanied by image discoloration, and at that time this author was not consciously looking for cracks, they were not noticed. After 2⅓ years the cracks covered most of the print surface, with only the maximum-density areas still remaining free of cracks. After 4 years, cracking was very extensive and covered all areas of the print. Even after 6 years of illumination, however, and with the print severely cracked, no microspots or other image discoloration could be detected.

6. **21.5 klux Print Framed in Contact with Glass:** After 4 years, the print rather suddenly began to show significant image discoloration in the form of large numbers of distinct microspots. The discoloration was most evident in medium- and high-density areas immediately adjacent to low-density and/or white areas. After 6 years, this pattern continued with the size and number of microspots and the degree of image discoloration becoming more severe.

7. **21.5 klux Print Framed in Contact with UF-3:** After 2⅓ years, the print had developed a very narrow, strongly discolored band along the full length of the image adjacent to the white print border; the print also exhibited small microspots along an area farther in from the border. Like the 1.35 klux print framed with UF-3, these spots were concentrated near one corner of the print. In fact, after 6 years of light exposure, the pattern of discoloration on these two prints was almost identical — despite the fact that the 21.5 klux print had received 16 times more light exposure than the 1.35 klux print!

The previously discussed *severely* discolored and spotted print that had been normally displayed for 5 years (made on the same paper as the test samples described above), was displayed under Cool White fluorescent illumination with an intensity of about 195 lux — the total display time is estimated to have been approximately 14,300 hours. The print was framed under glass, without an overmat, and for most of the time, the area where it was displayed was air conditioned. The length of time that had passed before the first discolorations occurred in this print is not known.

Accumulated Light Exposure of Prints:

Print normally displayed for 5 years = **2,790 klux-hours** (estimated light exposure accumulated during 5 years)

1.35 klux test prints for 6 years = **70,956 klux-hours** (25x light exposure of normally displayed print)

21.5 klux test prints for 6 years = **1,130,040 klux-hours** (405x light exposure of normally displayed print)

Conclusions Suggested by These Tests

It is clear that to produce the type of image discoloration caused by long-term display under normal conditions with this particular RC paper, accelerated light-exposure tests have an *extremely* large reciprocity failure (although the 21.5 klux test samples had received an estimated 405 times more light exposure than did the severely discolored print that had been displayed under normal conditions for 5 years, the discoloration observed in the 21.5 klux print samples was less pronounced). Therefore, one would have to conclude that — compared with long-term display under normal conditions — short-term, high-intensity tests (at least at room temperature) may in fact do little if anything to accelerate the discoloration process.

These results, together with an investigation of the illumination history of a number of prints that became discolored during normal display, suggest that the threshold level of illumination necessary to initiate the production of oxidants by the titanium dioxide pigmented polyethylene layer may be very low indeed (and that although exposure to UV radiation appears to accelerate the reaction, visible light alone is quite sufficient to initiate and sustain the process).

The fact that, even after 6 years of light exposure, the unframed print in the high-intensity, forced-air-cooled 21.5

klux test had not yet discolored lends considerable support to the theory that the discoloration observed with framed RC prints is brought about primarily by the light-initiated production of oxidizing substances (e.g., peroxides) by the titanium dioxide white pigment in the emulsion-side polyethylene coating of the prints. With unframed prints, these oxidants are free to diffuse into the atmosphere, and away from the print emulsion. With framed prints, the oxidants are to a much greater extent retained within the frame package, forming a destructive microclimate that over time can cause severe discoloration of the silver image.

In the 1.35 klux test, there is much less air circulation over the surface of the print than is the case with the 21.5 klux test, and this is probably the reason that the unframed print in this test began to show discoloration after 4 years, while the 21.5 klux unframed print still had not after 6 years. This correlates well with the patterns of discoloration that have been observed in unframed prints that became discolored after several years of sitting in stacks exposed to light in normal office storage conditions.

For any given type of RC paper, the most critical factors affecting discoloration of the image appear to be the duration of the illumination (regardless of how intense the illumination level might be, prolonged exposure periods are required for this type of light-induced discoloration to occur) and the ambient relative humidity. Examination of discolored prints displayed in tropical countries, humid southern areas in the United States, and in drier regions in the northern United States and in Canada makes it clear that relative humidity is a very important variable: high relative humidity, especially in conjunction with high temperatures, can greatly accelerate the discoloration of displayed black-and-white RC prints.

Exactly why the test prints, which had been exposed to 6 years of high-intensity illumination in accelerated tests, had not discolored as much as did the print that was displayed under normal conditions for 5 years, remains unanswered. All of the prints were made with Kodak Polycontrast Rapid RC Paper from the same box, they had the same image, and they were processed at the same time.

This author can suggest only three things that might account for the more severe discoloration that occurred in the normally displayed print: **(1)** At times during the course of 5 years, the normally displayed print was subjected to relative humidity that was significantly higher than the 60% RH used in the accelerated tests. **(2)** The test prints were stored in the dark for nearly 9 years before they were subjected to the intense illumination of the accelerated tests, and during this period of dark storage subtle changes may have occurred in the silver image (e.g., mild sulfiding of the silver grains that resulted in the image becoming more resistant to oxidation) and/or changes in the RC paper base that rendered the test prints less susceptible to light-induced image discoloration. **(3)** The test prints were exposed to continuous illumination for 24 hours a day, and the normally displayed print was in the dark for approximately 12 hours each day; it is possible that these dark periods in some way accelerated image discoloration.

An important finding of these tests is that there is nothing to be gained (with respect to image discoloration at least) by separating prints from framing glass with an overmat; in fact, in the 1.35 klux tests with framed prints, the overmatted print was the most severely discolored of the group at the end of 6 years. (Unfortunately, an overmatted print was not included in the 21.5 klux tests.)

It is also worth noting that, after 1½ years of light exposure, the gray Kodak identification (sometimes called a watermark) printed on the back of the RC paper had faded beyond recognition on both the 1.35 and 21.5 klux unframed prints (to avoid disturbing the microclimate inside the sealed frames, the backprinting on the prints framed under glass and UF-3 was not examined). Like the discoloration of the images, the fading of the ink used to backprint the paper also appears to have a large reciprocity failure.

The often irregular patterns of discoloration noted with many RC prints suggests that surface contamination, processing chemical or wash water residues, or print drying irregularities may also influence the rate and visual appearance of the discoloration. An increased number of test samples would be useful in this type of test. The kinds of "clean" extrapolations that can be done with the rates of dye fading in color prints in high-intensity light fading tests are simply not valid when it comes to the discoloration of the silver images of framed black-and-white RC prints.

Observation of displayed RC prints made with more recent Kodak RC papers suggests that they almost certainly have greater resistance to discoloration than the "initial type" Polycontrast Rapid RC Paper evaluated in these tests. But how much better they are and what kinds of accelerated tests can be devised to meaningfully evaluate the tendency for these papers to discolor on long-term display remain unanswered questions. Likewise, the long-term behavior of RC papers made by Ilford, Agfa-Gevaert, Oriental, Fuji, and the many other manufacturers worldwide currently producing RC papers is not known.

Brownish Base-Staining in Developer-Incorporated RC Papers

In 1983 this author and Carol Brower made many hundreds of prints with Ilford Ilfospeed Multigrade RC paper; all of these prints now exhibit heavy brownish staining within the paper base itself. The discoloration is quite pronounced on the backs of the prints, but is much less apparent on the emulsion side of the prints because of the shielding effect of the white titanium dioxide pigmented polyethylene layer. This type of paper-base staining, which according to Ctein, a well-known photography writer, is caused by the developer incorporated in the paper's emulsion at the time of manufacture,[14] has never been observed with fiber-base papers. Apparently, the longer a developer-incorporated RC paper remains in storage prior to processing, the more severe the brownish stain may eventually become. During storage, the incorporated developer migrates from the emulsion, through the top-side polyethylene layer (and through the backside of the adjacent sheet), and into the fiber-base paper core of the RC paper.

Inherent Stability Differences Between RC Prints and Fiber-Base Prints

That fiber-base prints are not subject to the types of light-induced deterioration that afflict RC prints can probably be accounted for by two principal factors: **(1)** Barium sulfate — which, unlike titanium dioxide, is not photoreactive — is used as the pigment in the smooth, white baryta layer coated beneath the emulsion in fiber-base papers. **(2)** Fiber-base papers do not contain polyethylene, which, as mentioned previously, is a plastic long recognized for its poor stability in the presence of light and UV radiation (especially when compounded with titanium dioxide).

The thickness of the gelatin baryta layer in fiber-base papers can accommodate the relatively large amount of barium sulfate required to achieve a bright and opaque white coating. Barium sulfate does not, unfortunately, have a high enough relative reflectance or refractive index to make it suitable as a pigment in the small quantities permitted by the very thin emulsion-side polyethylene layer of RC prints. Of available white pigments, only titanium dioxide appears to have the optical properties required for RC papers. It would, of course, be possible to coat a conventional baryta layer on an RC base paper prior to coating the light-sensitive emulsion, but to do so would significantly increase processing, washing, and drying times — and thereby partially negate the principal advantage of RC papers.

There is also evidence that prints made on early Kodak Polycontrast Rapid RC Paper and Polycontrast Rapid II RC Paper — indeed, possibly *all* black-and-white RC papers — are unusually sensitive to the effects of atmospheric pollutants and/or contaminants in storage materials. In an article published in 1980, Gunter Kolf of Agfa-Gevaert suggested that one of the reasons why silver images on fiber-base papers appear to be more stable than images on RC papers is that the baryta layer and absorbent paper base of fiber-base prints act as a "sump" which absorbs airborne pollutants, contaminants from storage materials, and degradation products such as migrating silver ions, thereby preventing them from becoming concentrated in the emulsion layer, adjacent to the silver image grains.[15] With RC papers, the nonabsorbent polyethylene layer beneath the emulsion prevents migration of harmful substances away from the emulsion and silver image, and this, according to Kolf, can accelerate image discoloration and the formation of "silver mirrors" on the emulsion surface.

Kolf also stated that image silver accelerates the deterioration of the polyethylene layers in Agfa RC papers and that the cracking defect had not been observed in Agfacolor RC prints (this author recently examined a cracked Agfacolor RC print from the mid-1980's). This author has had little firsthand experience with early Agfa RC papers; but in Kodak RC papers from the 1970's, this author has encountered far more cracked color prints than cracked black-and-white prints. These differences possibly could be accounted for by differences in the formulations of Kodak and Agfa RC papers from that era.

Kolf's article was published primarily as a defense by Agfa-Gevaert against a vehement attack on virtually every aspect of RC papers by a group of fine art photographers led by the French photographer and gallery owner Jean Dieuzaide. In a document published by Dieuzaide in 1977 entitled *Appeal for the Preservation of Genuine Photographic Paper Which is Threatened by the Cessation of Production*, it was claimed, among other things, that the silver content of papers had been reduced and that "[RC] papers are of low quality, and tests have proved beyond question that the images fade in 15 years at the latest." It was also stated that "damage through flaking [RC cracking] is unavoidable; well-printed reproductions are virtually impossible since the gradations and black tones are insufficient; and [RC papers] are unpleasant to the touch."[16]

During 1977, Dieuzaide and other concerned European photographers collected thousands of signatures on petitions urging the major photographic manufacturers not to discontinue fiber-base papers. The group held two "summit conferences" in France with representatives of Eastman Kodak, Agfa-Gevaert, Ilford, and the French manufacturer R. Guilleminot Boespflug & Cie to discuss the situation. The eventual outcome of Dieuzaide's efforts — and a concurrent campaign in the U.S. led by David Vestal and Arthur Goldsmith of *Popular Photography* magazine — to prevent the demise of "quality" fiber-base papers will be discussed later.

While disputing nearly all of the practical and aesthetic criticisms of RC papers made by Dieuzaide, Kolf did acknowledge that Agfa black-and-white RC papers (and by implication, the RC papers of other manufacturers as well) were less stable than their fiber-base counterparts, both in terms of the permanence of the silver image and the stability of the RC base paper itself. Saying that more research was needed to find ways of retarding or stopping the light-induced deterioration of polyethylene, Kolf suggested that ". . . plastics other than polyethylene should be sought which while possessing the positive virtues of polyethylene exhibit fewer detrimental aging characteristics. So long as this work remains uncompleted, responsible manufacturers will continue to market a broad range of black-and-white baryta papers."

Kodak's Current Position on RC Papers versus Fiber-Base Papers

In Larry Feldman's previously mentioned article, he described the mechanisms of silver-image deterioration in RC and fiber-base prints and emphasized the damaging effects caused to silver images by peroxides and other oxidants from *external* sources such as oil-base paint fumes. Many readers of the Feldman article have been left with the impression that attack by external oxidants is the primary, if not the only, cause of image deterioration of correctly processed and washed RC prints.

Probably because of legal and marketing considerations at Kodak, Feldman's article made every effort to minimize the often large differences in image and support stability that have been observed in Kodak RC papers and Kodak fiber-base papers marketed in the 1970's (Feldman's article was first presented as a paper at an SPSE conference in 1980); and he did not address the topic of light-induced image discoloration of framed RC prints caused by reactions involving titanium dioxide and/or polyethylene degradation. (In the years since the Feldman presentation, Kodak has remained silent on this subject.) Feldman, however, in a carefully worded paragraph near the end of the article, did *allude* to the possibility of internally caused oxidation of RC images:

> In particular, black-and-white prints on resin-coated paper base that may be subjected to intense or extended illumination, exposed to oxidizing gases, or framed under glass or plastic should be considered for treatment with toners

> to extend image life. The toning of prints on fiber-base papers is likewise recommended for those applications requiring long-term keeping under adverse storage or display conditions.[17]

In a masterful attempt to further obfuscate the real cause of image deterioration in early Kodak black-and-white RC prints, the company included the following statement in its 1985 book *Conservation of Photographs*:

> Displayed black-and-white photographic prints on early versions of RC paper base, that were subjected to active oxidants at low concentration could, over a period of time, develop colloidal silver spots. This phenomenon can also occur on fiber-based papers. For some time, Kodak black-and-white papers on RC paper base have incorporated a stabilizer in the paper stock which prolongs the life of prints under display conditions. Nonetheless, treatment with toners is recommended to further extend the life of all black-and-white photographic prints.[18]

The Kodak book carefully avoided mention of the fact that the source of "active oxidants" in displayed prints made on early versions of Kodak RC papers most likely was the RC paper base itself. Especially in light of the admission that "This phenomenon can also occur on fiber-based papers," the statement can only be viewed as an attempt to divert the reader from the reality of the very large stability differences between Kodak fiber-base and RC prints from the early 1970's.

Conservation of Photographs also contained a similar, intentionally vague discussion of "emulsion cracking or mosaic cracking" of Kodak fiber-base and RC color prints. According to Kodak, "This effect may occur on either fiber-base or RC prints under adverse display and/or storage conditions."[19] Examples of cracked fiber-base and RC color prints are shown; judging from the amount of fading that has taken place and the nature of the cracks, the RC print appears to date from the early 1970's. The reader is given the impression that Kodak RC and fiber-base papers from this era did not differ appreciably in their tendency to develop cracks. This notion is obviously incorrect; examination of many Kodak RC and fiber-base prints from the 1960's and 1970's leaves no doubt that the RC prints have a far higher incidence of cracking.

Treating Prints with a Protective Toner to Help Prevent Image Oxidation and Discoloration

Feldman's article suggested treating RC prints (and fiber-base prints) with Kodak Rapid Selenium Toner, Kodak Poly-Toner, or Kodak Sepia Toner to increase their resistance to image discoloration. When a print is treated with Kodak Rapid Selenium Toner, for example, selenium metal — present in the toner solution in the form of sodium selenite — combines with the outer layer of the silver image grains to form silver selenide, a compound that is much more resistant to oxidation than is normal, unprotected image silver (see section below on new research on the protection afforded by various toners).

Feldman's advice to treat RC prints with a suitable toner (which could also be viewed as a legal disclaimer to help protect Kodak against possible lawsuits related to the very poor stability of its early black-and-white RC papers) soon appeared in Kodak RC paper product-information sheets, accompanied by the added recommendation: "Toned fiber-base papers continue to be recommended for those applications requiring long-term keeping under adverse storage or display conditions."[20] More recently Kodak has toned down its warnings; for example, the information sheets packaged with Kodak Polyprint RC Paper and Kodak Polycontrast III RC Paper now say only:

> *Print Storage and Display:* You can use Kodak packaged toners to extend the life of prints which may be exposed to oxidizing gases or subjected to adverse display or storage conditions. Kodak Rapid Selenium Toner, used diluted 1:20 for 3 minutes at 70°F (21°C), provides protection without changing the image color.[21]

The advice to use fiber-base papers for applications involving "adverse storage or display conditions" has now been eliminated on at least some information sheets for Kodak black-and-white RC papers.

It is this author's observation that it is virtually unheard of for a photographer to treat RC prints with a protective toner (or an image-protective solution such as Agfa Sistan or Fuji Ag-Guard). RC papers are chosen for their convenience and speed of processing, washing, and drying. Treatment with a toner requires an additional processing step along with an added wash, neither of which can be accommodated by automatic RC print-processing machines such as the Kodak Polymax processor or the Ilford 2150 or 2240 processors. Most photographers who are interested in permanence — and who might be willing to spend the time required for these additional processing steps — do not use RC papers in the first place.

Because of this, museums or archives should assume that black-and-white RC prints have *not* been treated with a protective toner solution, unless specific information to the contrary is available. In addition, it generally is difficult or impossible to identify the type and date of manufacture of an RC print, particularly if it has been mounted and the backside is not available for examination.

Kodak Rapid Selenium Toner and Poly-Toner Are Currently Recommended for Both RC and Fiber-Base Prints

For many years it was generally accepted that treatment of silver images with selenium, sulfiding, or gold toners offered substantial protection against peroxides, nitrogen oxides, ozone, and other oxidizing substances that frequently are present in polluted air and that may be evolved from particle board, plywood, wood, paints and varnishes, many types of plastics, poor-quality cardboard and paper, and a long list of other materials.

Selenium toner had been used for decades by the late photographer Ansel Adams to protect and intensify the images of his carefully made prints. This author has long been a vocal advocate of the use of selenium toner, especially for prints. Most contemporary fine art photographers now routinely treat their black-and-white prints with Kodak Rapid Selenium Toner. In the early 1980's Kodak published a series of articles that demonstrated its effectiveness and advocated its use for both prints and films.[22]

(The prohibitive cost of gold chloride, the key ingredient in gold toners, had long since rendered them little more than a laboratory curiosity — sometimes used as a benchmark with which to compare the image protection afforded by other types of toners.)

In 1988, James M. Reilly and his co-workers at the Image Permanence Institute in Rochester, New York reported that Kodak Rapid Selenium Toner afforded relatively *little* protection against oxidation to the extremely fine grain silver images of microfilms. Sulfiding toners were recommended instead.[23] As explained in a 172-page report on their studies released in 1991:[24]

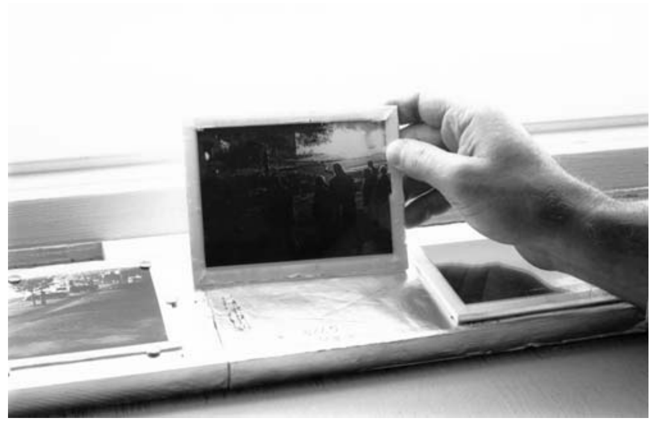
> Using a criterion of rigorous hydrogen peroxide testing, only gold and polysulfide treatment proved effective enough. Selenium, often recommended, does not protect the low density areas of microfilm. The evidence we have suggests that selenium does not convert the low density areas to silver selenide as readily as middle and high density areas. While the reason for this is not clear, it is a fact, and rules out selenium as a microfilm treatment, though it may function well with photographic papers. Gold and polysulfide protect all density levels; gold, however, is impractical because of its cost and the possible toxicity of the thiourea constituent of the most effective gold treatment formulas. Polysulfide seemed the most practical and effective choice.

For treating both RC and fiber-base papers, this author continues to recommend Kodak Rapid Selenium Toner (to simplify treatment of fiber-base papers, the toner can be mixed directly with Kodak Hypo Clearing Agent). If a greater degree of image protection is desired, Kodak Poly-Toner in a 1:10 dilution for about 2 minutes at room temperature is recommended. This gives a pleasing, near-neutral tone and a noticeable amount of image intensification with many current papers. Use of Poly-Toner with fiber-base papers requires a subsequent treatment with Kodak Hypo Clearing Agent (followed with Kodak Liquid Hardener if emulsion frilling proves to be a problem while the prints are wet), and a 30-minute wash. For RC papers, a 5-minute wash following toning should be adequate.

Kodak may modify Rapid Selenium Toner to improve the image protection it offers. A combination of Rapid Selenium Toner and Kodak Poly-Toner (which contains both selenium and potassium sulfide) might prove adequate.

Valuable Black-and-White RC Prints Should Not Be Displayed

It must be emphasized that *very little* information has been made public about the specific long-term stability characteristics of current and past black-and-white RC papers supplied by Kodak, Ilford, Agfa-Gevaert, and the other major manufacturers. Essentially nothing is available on the properties of black-and-white RC papers produced by the many smaller manufacturers in the field. At present it is not possible to suggest "safe" illumination conditions, display times, or even the best framing methods for any Kodak black-and-white RC prints, let alone for the RC papers made by other manufacturers. For these reasons, it is recommended that valuable black-and-white RC prints not be displayed; instead, copy prints should be made for exhibition purposes. Black-and-white RC prints known to date from the 1970's should *never* be displayed, even for short periods.


October 1992

Samples of "original type" Kodak Polycontrast Rapid RC Paper introduced in 1972 undergoing light-exposure tests in this author's temperature- and humidity-controlled high-intensity 21.5 klux fluorescent test unit. When this picture was taken, the tests had been in progress for 6 years and significant light-induced image discoloration and silver "microspot" formation had occurred. Under normal display conditions, a similar degree of image discoloration can occur after far less light exposure, indicating that there is a very large reciprocity failure in accelerated light-exposure testing of black-and-white RC papers.

Kodak's Early Claims Concerning RC Paper

When RC papers entered the market in the 1960's, they were a distinctly new type of photographic material. As with Polaroid SX-70 prints and some other color products, black-and-white RC prints exhibited entirely new types of image and base deterioration; the peculiar light-induced base cracking and garish image discoloration that soon occurred with RC prints had never been observed with fiber-base prints in the many years that they had been in use. Judging from early Kodak pronouncements about its black-and-white RC papers, the company itself was not fully aware of the stability limitations of the papers prior to introducing them to the market:

> Kodak Polycontrast Rapid RC Paper — medium weight — is the newest paper in the line. This new resin-coated paper, in either F or N surface, has many important advantages. It fixes in two minutes and washes in 4 to save you a lot of processing time. RC papers in F surface provide a high-gloss surface without ferrotyping. Prints lie flat, remain flexible and have long life. . . . Try this new product that offers you so much today.[25]

The above quote is from *Kodak Photographic Papers for the Professional,* Kodak Publication P4-73 (October 1972).

> The big saving in processing time for water-resistant [RC] papers occurs in the washing step. Instead of the minimum of an hour wash for conventional papers . . . a 4-minute wash time is recommended, in which time prints attain optimum stability.[26]
>
> *Faster and Better B/W Print Processing*
> Kodak Publication G-6 (July 1976)

In the early 1970's, all of this seemed like a panacea to many photographers. To be able to wash an RC print for only 4 minutes and obtain a lower level of residual thiosulfate than could be achieved in a fiber-base print after even 2 hours of washing seemed wonderful. And RC prints could be dried with a perfect gloss in a minute or less. After drying, RC prints stayed *flat*. With machine processing, RC prints could be completely processed, washed, and dried in *less than 60 seconds*, and the result, most photographers were led to believe, was a permanent print. It seemed too good to be true. And, as the unfortunate fate of many of these early black-and-white RC prints now clearly shows, too good to be true it was.

Evaluating the Stability Characteristics of Current Black-and-White RC Papers

No generally accepted accelerated tests have yet been devised to determine the stability properties of RC papers, and many questions remain unanswered about the tests used to assess the stability of RC base paper. Kodak has revealed only the barest details of how it evaluates the light-induced image deterioration characteristics of these papers.[27] Agfa-Gevaert, Oriental, Mitsubishi, Fuji, and Ilford[28] have disclosed little about their respective test methods, and comprehensive, comparative stability-test data from independent laboratories are not available.

As discussed previously, the light-induced discoloration of framed RC prints is difficult to simulate in accelerated aging tests in a way that can be extrapolated to normal display conditions. There also is evidence that image discoloration may in some instances first manifest itself in the dark *after* a print has been returned to storage following exposure to light on display. Likewise, if deterioration is already visually apparent in a displayed print, it may worsen in dark storage.

No ANSI standards currently exist either for the characteristics of the RC support material itself or for test methods to predict the useful life of the support and/or image in common conditions of display or storage. The current ANSI standards related to the stability of silver images on films do not include any tests which can be used to evaluate the four principal aspects of RC print deterioration: **(1)** susceptibility of the silver image of framed and displayed prints to fading and discoloration caused by oxidants from *internal* sources; **(2)** susceptibility of the silver image to fading and discoloration caused by airborne pollutants, harmful substances in mounting and storage materials, and other *external* sources; **(3)** light-caused cracking and other deterioration of the print support material; and **(4)** print cracking caused — or contributed to — by fluctuations in relative humidity.

Paper print materials in general have historically been rather neglected by ANSI; in the case of RC papers, the photographic industry — well aware of the stability shortcomings of these materials — has in the past been quite content to leave it that way. In 1980, however, a new ANSI subcommittee was established to develop a test standard for RC and fiber-base papers (this author has been a member of this subcommittee since it began). The meaningful evaluation of black-and-white RC papers using short-term, accelerated tests presents some formidable problems, but it appears that the new standard may be ready for publication in 1993 or 1994.

RC Papers Are Not All Alike

The reader should be aware that the information Kodak has supplied on the stability of its black-and-white RC papers — incomplete as it is — *cannot* be assumed to apply to RC papers made by Ilford, Agfa-Gevaert, Oriental, Mitsubishi, or other manufacturers (none of whom have published meaningful information on the stability of their respective RC papers). In recent years, some writers in the photographic press,[29] and even some people in the conservation field,[30] have tended to lump *all* black-and-white RC papers together and to assume that whatever claims Eastman Kodak has made about the stability of its RC papers apply to all RC papers, regardless of the manufacturer. Even the information about a particular Kodak RC product may not apply to other RC papers made by Kodak.

Unlike fiber-base black-and-white papers, the basic design of RC papers renders them *inherently unstable* when exposed to light on display. Once the serious stability problems of RC papers had manifested themselves in the early 1970's, and the mechanisms of image and base deterioration were beginning to be understood, the manufacturers made various modifications to the formulations of their RC papers in an attempt to increase their stability. Antioxidants, stabilizers, peroxide scavengers, and other protective substances were incorporated into the RC support material and, apparently, into the emulsion layer itself in an attempt to protect the silver image. These were measures that never had to be considered in the manufacture of black-and-white fiber-base papers.

As a result, modern RC papers have evolved into complex products made with proprietary formulations and manufacturing techniques which vary from one manufacturer to the next; for example, the system of incorporating polyethylene stabilizers into the porous paper core of Kodak RC papers (after manufacture, the stabilizers gradually migrate into the polyethylene layers) is covered by a patent granted to Kodak in 1974 (U.S. patents expire after 17 years). In another, earlier modification, Kodak changed the type of titanium dioxide in its RC papers to a less-reactive form of the pigment — Kodak has declined to reveal exactly when this improvement was made in its products.

Kodak also has refused to say exactly when the "stabilizer in the paper core" improvement was applied to its black-and-white papers; however, this author believes that this new technology appeared around the end of 1978, concurrent with the introduction of Kodak's type "II" developer-incorporated black-and-white RC papers (e.g., Polycontrast Rapid II RC Paper and Kodabrome II RC Paper). Because light-induced RC base degradation and image discoloration appear to be caused by the same oxidative reactions, it had been hoped that prints made on these and subsequent Kodak RC papers could tolerate longer display periods than earlier Kodak RC papers before image discoloration became evident. Unfortunately, a number of prints made in 1983 by this author and Carol Brower with Polycontrast Rapid II RC Paper began to exhibit image discoloration after only a few years of display — the resistance of these prints to light-induced discoloration appears not much better than that of the initial 1972 version of Polycontrast Rapid RC Paper.

Black-and-white RC papers sold by the many current suppliers of these materials are *certain* to have different stability characteristics; the differences between RC papers of various manufacturers likely are much greater than stability differences found among fiber-base papers. Further complicating the matter is the common industry practice of purchasing RC base paper from outside suppliers,[31] with the photographic manufacturer doing only the emulsion coating and packaging of the finished product. The source of RC base paper may change in time, and a plant in Europe, for example, may use a different supplier for RC base paper than the same company's factory in Japan.

This author has seen a number of truly dreadful black-and-white RC papers; among them is Forte RC paper manufactured by Photochemical Industry VAC in Hungary. In the course of normal handling and flexing, some samples of the Forte paper exhibited cracking of the backside polyethylene layer immediately after processing — and the prints had not even been displayed! This Forte paper also suffered from extreme edge-penetration and retention of developer and fixer in the course of processing.

It has been reported that thiosulfate and other chemicals retained in the absorbent paper core at the edges of a black-and-white RC print can produce localized image deterioration of an adjacent print when the edge of the print is in contact with the image area of another print during prolonged storage, especially under humid conditions.[32] To a greater or lesser extent, all RC papers are subject to edge-penetration during processing. How much danger this problem poses in normal, long-term storage is not yet known; the degree of edge-penetration varies among different brands of RC paper. Storing black-and-white RC prints in individual polyester sleeves, or trimming the outer ⅛ inch of all four edges of RC prints, will eliminate the possibility of this type of damage.

The Problem of "Veiling" of the Blacks in RC Prints: The Influence of Drying Method on the Appearance of RC Prints

A frequent and often vociferous complaint about black-and-white RC papers has been that after the prints are air-dried at room temperature, or after they are dried with a home-type electric hair dryer (the most common drying method employed by amateur darkroom workers), the blacks and other high-density portions of the image exhibit a disconcerting "veiling" of the image, and have a grainy "metallic" surface sheen.

This image defect is sometimes called "blooming," "surface backscatter," or "haze," and is especially noticeable on glossy RC papers. The dried prints have a distinctly degraded appearance compared with how they looked when wet during fixing and washing — the deep blacks are simply no longer really deep blacks. The effect is especially acute when a print is viewed at an angle with specular light reflected off the emulsion surface. This visual defect is peculiar to black-and-white RC papers and, in this author's experience, does not occur in any significant way in fiber-base papers. Surprisingly, it also does not occur in *color* RC papers. (Although the surface gloss properties of color RC papers vary depending on how the prints are dried, with a higher dryer temperature usually producing a higher gloss or sheen, the image quality itself is little affected.)

When black-and-white RC papers are dried with an Ilford 1050 RC print dryer[33] — a patented motorized dryer that employs powerful infrared heating elements placed both above and below the print, with a blower to force unheated, room-temperature air over the hot print surfaces to carry evaporating moisture away as the print passes between the heating elements — the degradation or veiling of the blacks in all brands of glossy RC papers is miraculously eliminated. (In 1990, the Ilford 1050 dryer was replaced with the Ilford 1250 dryer, an improved, variable-speed version of the 1050 model; all of the comments concerning the 1050 print dryer that follow are equally applicable to the 1250 print dryer.)

Infrared dryers function differently from conventional hot-air dryers in that in an infrared dryer, infrared radiation absorbed by a print heats it to a higher temperature than the surrounding cooler and comparatively humid air. A hot-air dryer, on the other hand, heats the air passing over a moist print to a significantly higher temperature than that reached by the print itself; the hot air has a very low relative humidity.

The Ilford 1250 RC print dryer, which costs about $1,990, squeegees and dries an 8x10-inch print in about 10 seconds. With a capability of drying two 8x10-inch prints at a time, according to Ilford, this machine can dry about 500 8x10-inch prints an hour. Both the automatic Ilford 2240 print processor ($13,545) and the table-top Ilford 2150 RC print processor ($7,695), which are high-speed machines for processing all types of Ilford, Kodak, and other black-and-white RC prints, have built-in infrared dryers and give the same excellent results as the Ilford 1250 RC print dryer.

Why the Images of Most RC Papers Are Affected by the Manner of Drying, and Why Fiber-Base Prints Are Not

Exactly why black-and-white RC papers exhibit the veiling problem, and fiber-base papers do not, has not been fully explained. Peter Krause, a former president of Ilford and a leading authority on photographic technology, speculated that several factors may be involved:[34]

- The very thin gelatin emulsion and surface coat of black-and-white RC papers contain latexes and other gelatin additives to impart flexibility and to reduce the tendency to curl in low-humidity environments. These additives cause the emulsion to have very different sur-

Wet RC prints being fed into an Ilford 1050 infrared RC print dryer (the 1050 dryer was replaced with the improved 1250 dryer in 1990). Drying black-and-white RC prints at room temperature, or with conventional hot-air dryers such as found in the now-obsolete Kodak Royalprint and Dektomatic RC print processors, results in degraded, “veiled” blacks (in this author’s tests, the only exceptions to this are the Oriental New Seagull RP [RC] papers, introduced in 1988–89, which give good results regardless of how they are dried).

July 1987

In the Ilford 1050 and 1250 RC dryers, electrically heated infrared tubes are placed above and below the print-drying zone. Infrared radiation rapidly heats the print emulsion, and fan-forced, room-temperature air carries the moisture off. In terms of image and surface quality, infrared drying appears to be the only satisfactory way to dry most current RC papers. Infrared dryers similar to the Ilford 1250 are employed in the Ilford 2240 and 2150 RC print processors. The Kodak Polymax IR print processor introduced in 1991 also features an infrared dryer.

face characteristics when rapidly dried under high heat than when slowly air-dried at normal room-temperature conditions.

- Fluorescent brighteners incorporated in a thin coating between the emulsion layer and the RC base tend to migrate to the surface of the emulsion during processing, washing, and drying. (With fiber-base papers, brighteners can be incorporated into both the paper base and baryta layer because barium sulfate, the white pigment used in place of titanium dioxide in fiber-base papers, is a substance that does not strongly absorb UV radiation and thus allows the brighteners to fluoresce.) The presence of even small amounts of a brightener in the image portion of the emulsion or gelatin surface coat can significantly degrade the appearance of the blacks. For reasons that are not entirely clear, rapid drying of RC papers apparently allows less brightener to migrate to the surface than when prints dry more slowly.

- The extruded polyethylene surface of RC base paper has a slightly rough, or “toothed,” texture, and this microscopic surface irregularity is imparted to the thin gelatin emulsion and surface coat of the print. High-heat infrared drying melts the moist gelatin the moment before drying is completed, leaving it with a smoother, higher-gloss surface. This results in less light-scattering by the silver image, and thereby increases the apparent density.

Krause said that the paper manufacturers have made improvements in black-and-white RC papers in recent years and that the veiling problem has been reduced. “At one time people just refused to use RC papers because they had such a very strong blooming — you really couldn’t get a decent black.”[34]

Experiments with Different Methods of Drying RC Prints

This author tried several different drying techniques with glossy (F surface), developer-incorporated papers including Kodak Polycontrast Rapid II RC Paper, Polycontrast III RC Paper, Ilford Ilfospeed Multigrade II RC Paper, Ilford Multigrade III RC Rapid Paper, and Agfa Multicontrast High Speed RC Paper. Conventional-emulsion (non-developer-incorporated) papers included Kodak Polyprint RC Paper (Kodak Polymax RC Paper, introduced in 1992, was not available at the time these tests were conducted), Ilford Multigrade III RC Deluxe Paper, Oriental New Seagull RP Paper, and New Seagull Select VC-RP Paper.

Included in the tests were air-drying at room temperature after careful squeegeeing to remove surface water; drying with a hand-held Gillette Promax 1200-watt hair dryer (this unit cost about $35 and is similar to the hair dryers found in many homes and darkrooms); and drying with an Ilford 1050 RC print dryer ($1,995), which is the predecessor of the Ilford 1250 print dryer. Samples of Polycontrast Rapid II RC prints processed and dried in a Kodak Royalprint Processor Model 417 (discontinued in 1991, the unit last sold for $14,800) and in an Ilford 2240 print processor ($13,545) were also obtained. In addition, Ilford Multigrade II RC prints dried with an Arkay RC-1100 dryer ($800) were examined.

A careful appraisal of image quality and surface characteristics of the prints led to the following conclusions:

1. With the exception of the Oriental New Seagull RP [RC] papers introduced in 1988–89, air-drying at room temperature (without a fan) produced the worst image quality of all the drying methods. The blacks were significantly degraded, and the surface gloss was somewhat sub-

dued (the reduction in surface gloss was quite pronounced with the earlier Kodak Polycontrast Rapid II RC Paper). Prints fixed in Kodak Rapid Fixer *with* the hardener added appeared slightly worse than those fixed without the hardener. With the exception of the Oriental New Seagull RP [RC] papers, this author considered all of these prints to be visually unacceptable. With respect to the veiling of the blacks and surface gloss characteristics, treating the prints with Kodak Rapid Selenium Toner as part of processing made no obvious difference in the appearance of the prints after drying.

2. Prints dried with the hair dryer (switched to the highest heat level) were hardly better than the prints dried at room temperature; with the exception of the Oriental New Seagull RP [RC] papers, all the papers were deemed visually unacceptable.

3. The Ilford 1050 dryer (replaced by the improved Ilford 1250 dryer in 1990) produced results that were far superior to the above methods on all papers. The blacks appeared to have no veiling whatever, and the surface gloss was very good. While the surface finish of the Oriental New Seagull RP [RC] papers was judged to be best when dried with the Ilford 1050 dryer, the improvement was surprisingly small when compared with Seagull RC prints air-dried at room temperature or with a hair dryer.

4. Prints processed and dried with an Ilford 2240 processor appeared identical to those dried with the Ilford 1050 dryer.

5. The Kodak Royalprint Processor Model 417 produced much better results than drying at room temperature or with an electric hair dryer, but the prints still exhibited some veiling and for this reason were not as good as those processed with the Ilford 1050 dryer or Ilford 2240 processor.

6. With glossy Ilford Multigrade II Paper, the Arkay RC-1100 dryer gave results similar to the Kodak Royalprint Processor — much better than room-temperature drying but not as good as results obtained with the Ilford units. The surface quality of pearl-surface Multigrade II Paper dried with the Arkay RC-1100 dryer was judged significantly inferior to the quality obtained with an Ilford 1050 dryer.

7. Regardless of how a print was originally dried, it could be re-wet and dried with an Ilford 1050 dryer to obtain the same excellent print quality of a print dried immediately after processing and washing. Conversely, prints dried with an Ilford 1050 dryer, Kodak Royalprint Processor, or an Ilford 2240 processor and then re-wet and slowly dried at room temperature had the identical degraded appearance of prints originally dried at room temperature.

This author has been unable to find any published account of the results of different methods of drying RC prints. Given the great differences obtained with different drying methods, this omission in the photographic press is remarkable. Surprisingly, Oriental has not promoted the superior drying characteristics of its RC papers, nor has the company revealed how it managed to solve the veiling problem with prints air-dried at room temperature.

Kodak, Ilford, and Agfa appear to have avoided discussion of this aspect of RC papers for fear that the many photographers who cannot afford to purchase a $2,000 print dryer might become discontented with RC papers. Ilford advertising literature says only that its infrared drying equipment produces “the best gloss in the industry.” Kodak avoided the issue completely until 1991, when the company introduced the Polymax IR Processor as a replacement for its Dektomatic Processor. According to Kodak, “The [Polymax] processor is equipped with an infrared dryer that provides higher surface gloss than normal air dryers.” Priced at $7,950, this is the first Kodak RC paper processor to use an infrared dryer (apparently licensed from Ilford).

In a conversation with this author, however, Barry Sinclair, Ilford’s national marketing manager for monochrome products and systems, said that despite improvements in RC papers during the past few years, “Infrared drying, quite frankly, is still the only way to get a decent gloss.”[35] (It may interest the reader that Ilford, an old-line British firm that had its beginnings in 1879, was purchased in 1989 by International Paper Company, a $10 billion American company based in Purchase, New York. Prior to being purchased by International Paper Company, Ilford was owned by Ciba-Geigy, a giant chemical and pharmaceutical firm headquartered in Switzerland.)

Discussing the matter with this author in 1987, *Popular Photography* magazine writer Bob Schwalberg noted that few home darkroom enthusiasts have access to an expensive infrared RC print dryer and, as a result, are “simply unable to make top-quality prints on RC papers because of the veiling of the blacks. Most of them are confused and discouraged by this and wonder if they are doing something wrong.” Schwalberg said, “They really don’t know what their problem is — their prints just don’t look as good as they did with fiber-base papers.”[36]

The Oriental New Seagull RP [RC] papers are likely to have great appeal to amateur photographers working in home darkrooms, and who generally do not have expensive infrared print dryers such as the Ilford 1250. These photographers must either air-dry prints or use a hand-held hair dryer to speed the process. The new Oriental RC papers for the first time allow these individuals to produce glossy RC prints with image quality that approaches that of glossy fiber-base papers.

Potential image and RC-base stability problems remain, however, and this author continues to recommend fiber-base papers for fine art prints and for all photographs of potential historical importance.

Kodak Black-and-White RC Papers, Especially Kodak Polyprint RC Paper, Are Currently Recommended

Since 1974, and perhaps earlier, Kodak has been acutely aware of the stability problems of black-and-white RC papers and apparently has devoted considerable effort toward minimizing them. Kodak has also published *some* meaningful technical information on the properties of its RC papers and in recent years has made an apparently sincere, if low-key, effort to inform photographers of the benefits afforded to displayed RC prints by protective toners. The other manufacturers have provided consumers with little or no meaningful information about the stability of their RC papers, and comparative data from independent sources are not available.

For these reasons — and if RC paper must be used because of time demands, such as with newspaper photography — this author currently recommends Kodak black-and-white RC papers. If, however, as previously discussed, a photographer does not have access to an Ilford 1250 RC dryer or other expensive RC print processing and drying equipment — and must air-dry prints at room temperature or use an ordinary hand-held hair dryer — the image and surface quality of Kodak RC papers may prove to be unacceptable. Should this be the case, Oriental New Seagull RP Paper and Oriental New Seagull Select VC-RP Paper are the only satisfactory alternatives (of these two Oriental RC papers, New Seagull RP paper, a graded RC paper, is recommended because it is made without a potentially stain-causing incorporated developer).

Included among current Kodak RC papers are:

Polymax RC Paper (conventional emulsion)
Polyprint RC Paper (conventional emulsion)
Polycontrast III RC Paper (developer-incorporated)
Kodabrome II RC Paper (developer-incorporated)
Panalure Select RC Paper (developer-incorporated)
Premier II RC Paper (developer-incorporated)

Kodak Polymax RC Paper and Kodak Polyprint RC Paper are particularly recommended by this author because the absence of an incorporated developer eliminates a possible cause of gradual brownish base-paper staining. The absence of an incorporated developer also allows a greater degree of control during development than is possible with Kodak papers such as Polycontrast III RC Paper (all Kodak RC papers with a "II" or "III" as part of the name are manufactured with a developer incorporated in the emulsion). Kodak Polymax RC Paper and Polyprint RC Paper also have a pleasing neutral image tone when tray processed with Kodak Dektol or a similar developer.

The preference for Kodak RC papers is based on admittedly scant data and could certainly change if any of the other manufacturers or an independent laboratory were to come forward with meaningful comparative test results. This author has made repeated inquiries to the major manufacturers about the stability of their respective products, examined numerous deteriorated RC prints, studied other available information closely, and believes that for now, at least, this is a valid recommendation.

RC Papers Are Preferable to Fiber-Base Papers for Some Applications

It is recognized that the speed of processing possible with RC papers makes them indispensable in some applications. In newspaper photography, for example, tight deadlines *require* the fastest possible processing of prints. This author recalls the days when he worked as a part-time high school sports photographer for the now-defunct *Washington Daily News* in Washington, D.C. Back then, in the late 1950's and early 1960's, RC papers had not yet appeared. With fiber-base prints, the general practice at the *Daily News* was to cut Kodak's recommended 1-hour wash time to only a minute or two — in a real rush, prints were sometimes rinsed for just a few seconds in hot water (although available, Kodak Hypo Clearing Agent was never used because the extra processing step was "too much trouble"). The prints were then dunked in a hygroscopic Pakosol "glossing-aid solution" which was always heavily contaminated with fixer from previous, poorly washed prints.

To dry the prints, they were placed on a heated Pako cloth-belt ferrotyping drum dryer with the temperature turned up as high as it would go without scorching the prints. Even if a print happened to become adequately washed (when it was left in the washer while the sports staff went out for a late-night hamburger, for example), it would subsequently reabsorb fixer from the stained and fixer-laden cloth dryer belt when the print was being dried.

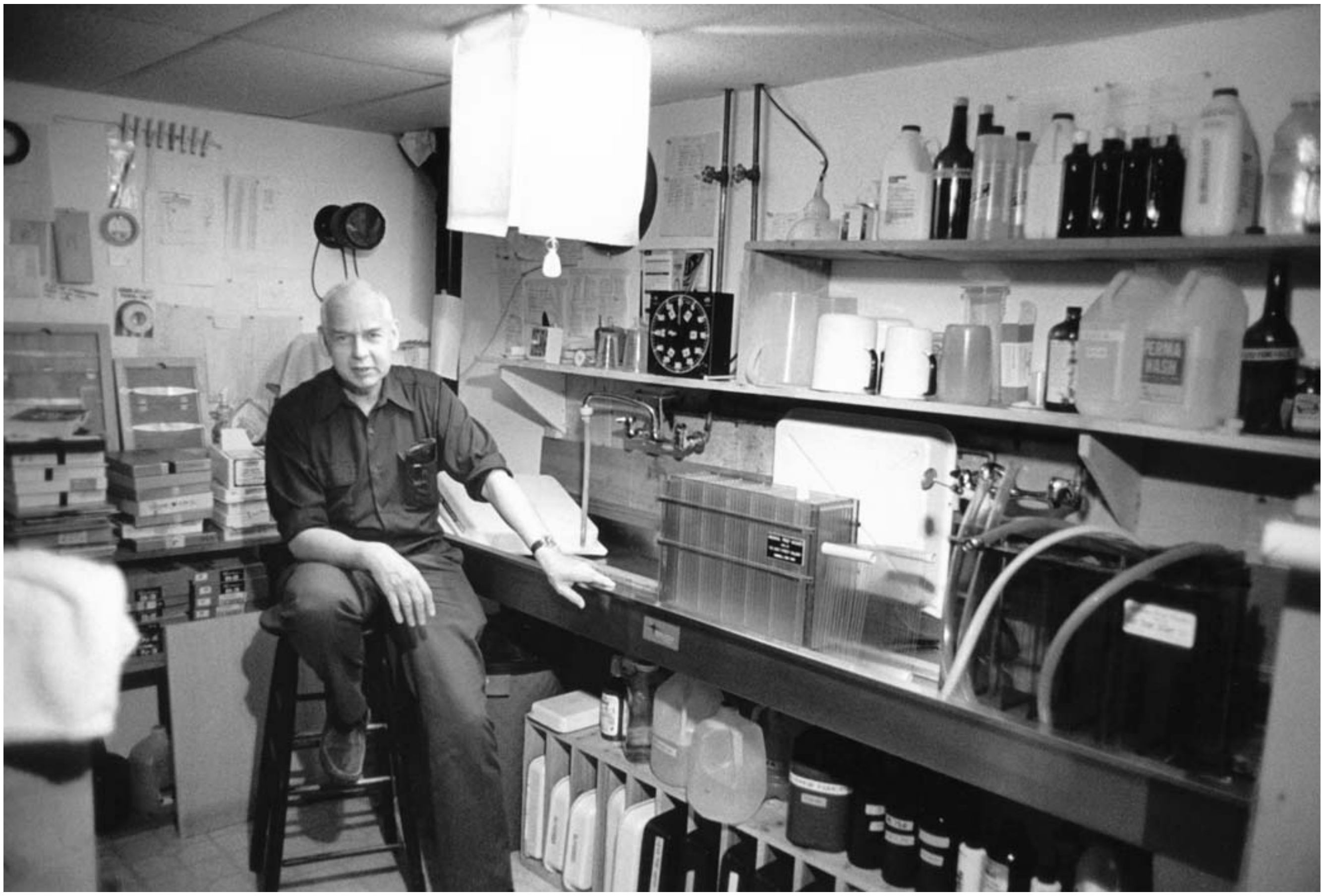
In situations like this, RC papers offer a decided advantage, especially with machine processing. The conversion to RC papers means that photographs in newspaper collections will for the most part remain in good condition far longer than they once did. It is suggested, however, that newspapers, magazines, and in-house commercial photo labs using RC papers at least have the *capability* of properly processing and washing fiber-base prints when the need arises for a "special" print, intended for long-term display or for donation to a museum, for example.

Black-and-White RC Papers Should Be Avoided by Museums, Archives, and Fine Art Photographers

In the fine art field, and for prints intended for museum or archive collections, this author *strongly* recommends that all black-and-white RC papers — including those made by Eastman Kodak — be strictly avoided. Instead, double-weight fiber-base papers, treated with a protective toner, should be selected. This is particularly important in the fine art field or in other applications where prolonged display of prints is even a remote possibility. Treatment of fiber-base papers with an image-protective toner such as Kodak Rapid Selenium Toner or Kodak Poly-Toner is an *essential* part of processing if the prints are to last as long as possible. Recommended high-quality, double-weight fiber-base papers[37] include (in alphabetical order):

Agfa Brovira Paper
Agfa Insignia Fine Art Paper
Agfa Portriga-Rapid Paper
Agfa Record Rapid Paper
Fuji Museum Paper
Ilford Galerie FB Paper
Ilford Multigrade FB Paper
Kodak Elite Fine-Art Paper
Kodak Polyfiber Paper
Mitsubishi Gekko Paper
Oriental New Seagull G Paper
Oriental New Seagull Portrait FB Paper
Oriental New Seagull Select VC-FB Paper
Zone VI Brilliant Paper

In 1976, apparently responding to concerns about the threatened demise of black-and-white fiber-base papers which had been expressed principally by David Vestal and Arthur



1981

David Vestal in the basement darkroom of his home in Bethlehem, Connecticut. In a series of articles in **Popular Photography** magazine in the 1970's, Vestal raised serious questions about the stability and image quality of the then-new black-and-white RC papers. A fine art photographer as well as a writer, Vestal was influential in persuading Agfa, Kodak, and Ilford not to abandon their black-and-white fiber-base papers (in 1976 Agfa-Gevaert had actually announced that it planned to discontinue all of its fiber-base papers). Vestal's impassioned pleas helped convince Ilford to develop Galerie paper, introduced in 1978 — the first of the new, "premium" fiber-base papers. Kodak followed with Elite Fine-Art Paper in 1984, and Agfa introduced Insignia Fine Art Paper in 1988. Other excellent fiber-base papers include Oriental New Seagull G paper, Oriental New Seagull Select VC-FB paper, and Ilford Multigrade FB paper.

Goldsmith in a series of articles, editorials, and a poll of readers' views on the subject in *Popular Photography*,[38] Eastman Kodak said:

> Until extensive testing and natural aging data indicate that prints on resin-coated paper base can be expected to last as long as prints made on conventional paper base, black-and-white photographic paper without a resin coat will be produced by Eastman Kodak Company for those customers requiring long-term keeping under adverse storage or display conditions.[39]

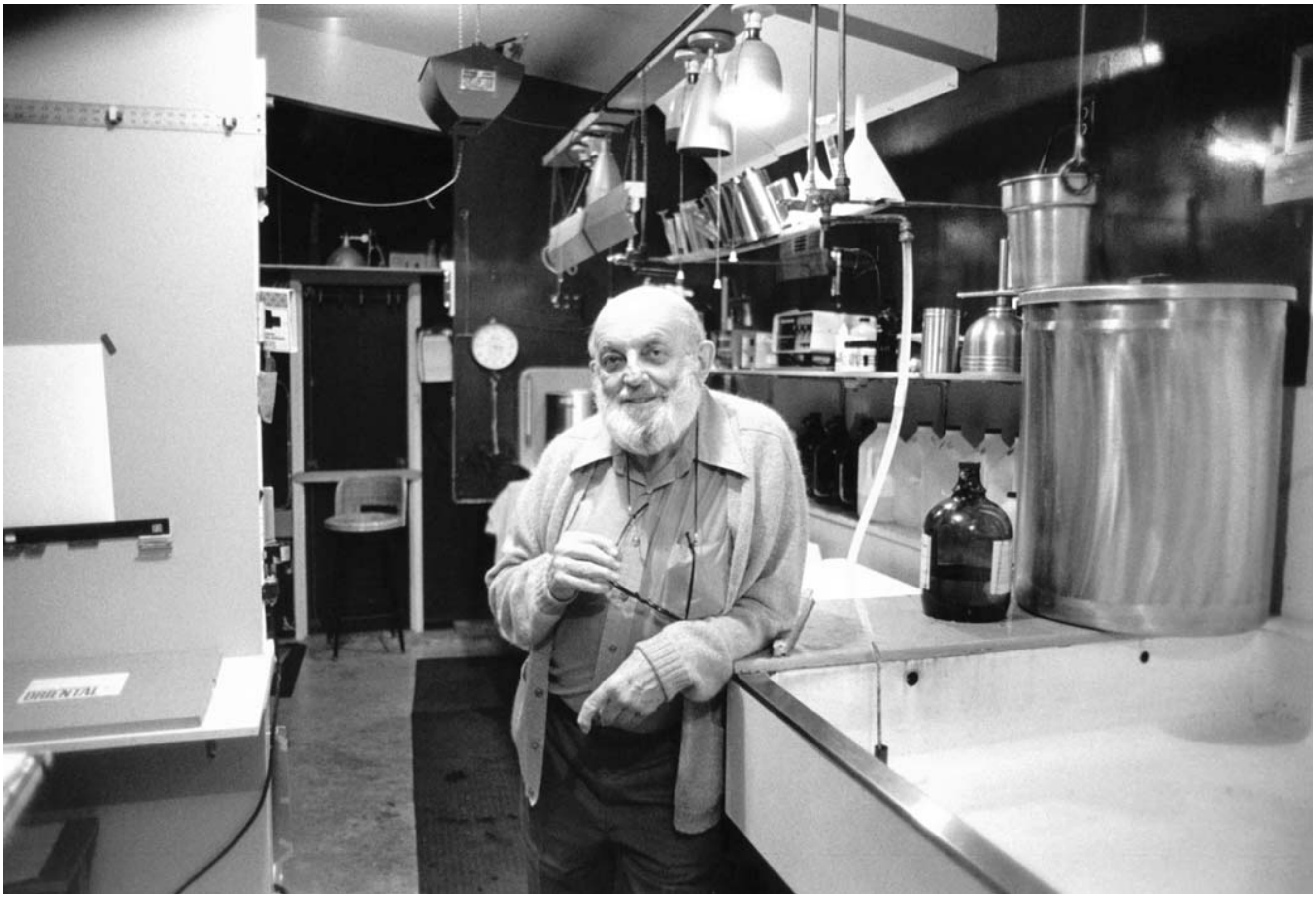
The Kodak statement was printed again in 1978 in *Kodak B/W Photographic Papers*[40] and was also included in *Preservation of Photographs*, published in 1979 by Kodak.[41]

In the 1985 Kodak book *Conservation of Photographs*, the company stated:

> Recently there has been concern over the continued availability of [fiber-base] papers. Concurrent with the manufacture of black-and-white RC papers, Kodak supplies a number of fiber-base products such as Kodak Elite Fine-Art Paper, Kodak Polyfiber Paper, Kodabromide, and Ektamatic Papers and will continue to provide the best products for photographic conservation purposes for as long as they are needed. Fiber-base papers are preferred for aesthetic reasons among many users of photographic papers.[42]

In their campaign to save fiber-base papers from extinction, Vestal and Goldsmith were concerned not only about the stability limitations of RC papers but also — reflecting the feelings of many of the world's finest photographers — about the decidedly inferior quality of RC papers versus the best fiber-base papers in terms of surface qualities, tone-reproduction characteristics, maximum density, and overall appearance of the image.

For an article published in 1977, Vestal interviewed a number of well-known photographers to get their views on the situation.[43] Ansel Adams told Vestal:


March 1981

Ansel Adams in the well-equipped darkroom in his home in Carmel, California. Adams was a prolific printer, and with the help of several assistants, he continued to work up until the time of his death in 1984.

> There is a definite deterioration in photographic paper. It is partially surface quality and partially inherent defects. It is heartbreaking to feel that the manufacturers are cutting down the availability of papers and apparently leading toward ubiquitous plastic-coated sheets.
>
> . . . I am preparing a letter to the manufacturers very strongly protesting the RC papers, largely on the basis of impermanence.
>
> Not only does fine creative work require permanence, but images of news character automatically become history and should be likewise treated archivally.
>
> While my strong feelings about RC papers were substantiated by the telephoned expression of opinion by a person very high in the photographic manufacturing world (*not* Polaroid) [at the time, Adams was serving as a paid consultant to Polaroid], I think it is very important that we be absolutely sure of the permanency factor. It would do our cause no good at all to find out that we had received bad advice.

W. Eugene Smith said: "If they go to the plastic papers, I think I will give up photography. . . . I'm also limping along with Polycontrast [fiber-base paper]. I can use it, but I don't like it. The paper is gray, and the surface doesn't have the brilliance it used to. I can no longer get the feel of cloth in the prints . . . . About the RC paper: it turns my stomach — and you can quote me on that."

Paul Caponigro wrote:

> Until roughly 10 years ago, a photographer could print on a wide variety of silver papers with beautiful surfaces and good working characteristics. Since then, the papers have steadily degenerated. My own experience is that they are becoming unyielding and difficult to manipulate.
>
> Each year, more of our remaining decent papers lose in quality, while others disappear. Today the situation is desperate. A bare minimum of usable papers remains. For the last six months I have found myself telephoning all over the United States and Canada trying to locate any leftover stocks of good discontinued papers on photo dealers' shelves.
>
> The replacements for the fine silver papers we have known are of course plastic-coated papers. Blech! I personally find them affronting: textureless, scaleless, and lifeless. I am told they will not even last.

Alan Ross – ca. 1978

Adams popularized the use of Kodak Rapid Selenium Toner to intensify the blacks and darker tones of fine art prints while at same time affording significant protection to the silver image from the damaging effects of air pollutants and other contaminants, thereby giving the prints added permanence.

March 1981

Bottles of Kodak Rapid Selenium Toner in Adams's darkroom. This large store of toner concentrate is evidence of the volume of his print production.

> Beauty is an important part of expression and communication. I think it a great pity to lose it, and a sad commentary on the producers of photographic papers that mediocrity and commodity should take precedence over excellence.

At the conclusion of his interview article, Vestal asked the readers of *Popular Photography*, "What do you think? I hope to hear from you, and I hope the photo industry hears from you — in no uncertain terms."

Ilford Introduces Galerie Paper

The following year, 1978, Ilford introduced Ilfobrom Galerie Paper (now called Ilford Galerie FB Paper), the first of a new generation of expensive, "silver-rich" fiber-base papers intended for those specialized markets for which the best visual quality and longest-lasting black-and-white prints are more important than convenience and price. The paper is supplied in only two surfaces — and only on double-weight paper base.

Ilford's decision to develop and market Galerie paper came in direct response to the campaign by David Vestal in the U.S. and Jean Dieuzaide in Europe to prevent the demise of "quality, high-silver-content" fiber-base papers.

Under the direction of Jacques Regent, Ilford's assistant product manager for monochrome products and systems, work on Galerie began soon after the "summit conference" between Dieuzaide and his supporters and representatives of the photographic manufacturers in the summer of 1977 at the international fine art photography conference in Arles, France.[44] Regent had attended a number of the annual Arles gatherings and had become aware firsthand of the sensitivities and expectations of fine art photographers. Prototypes of Galerie were demonstrated with rave reviews at Arles the following year, and the new paper was formally introduced at the Photokina trade show in Germany in September 1978.

Galerie soon became one of the favorite papers of Ansel Adams, who said: "This is a paper of very high quality which I use extensively. . . . It tones differently from any other paper I have used. Most papers intensify somewhat [in Kodak Rapid Selenium Toner], but Galerie does so to a greater extent, and without the marked color change that occurs with other papers. This ability to acquire some intensification during toning is a rewarding refinement of value control."[45]

In response to the renewed demand for high-quality fiber-base papers, Agfa-Gevaert — which in 1976 had actually announced plans to discontinue all of its fiber-base papers — took steps to correct the poor quality-control that for some years had plagued its popular Brovira and Portriga Rapid fiber-base papers and devoted more effort to marketing these products.

During this period, Oriental New Seagull G Paper, advertised by its Japanese manufacturer as the "World's Finest Baryta Paper for Exhibition Prints," also became popular with many fine art photographers. Brett Weston, whose work has been featured in advertisements for Oriental, said, "Quite simply, the best paper I've ever used." Ansel Adams stated: "This paper has had exceptional quality and consistency. It tones very well in selenium. . . . I have

March 1981

The paper-storage cabinet in the print-finishing room outside of Ansel Adams's darkroom. When this photograph was taken in 1981, Adams was using Ilford, Agfa-Gevaert, and Oriental papers to make his prints. He had largely abandoned Kodak papers because of their inferior image quality. Discussing the merits of various papers with a visiting photographer is John Sexton, Adams's technical assistant. Sexton later served as a paid consultant to Kodak in the development of Elite Fine-Art Paper, and his photographs appeared in advertisements promoting the product after its introduction in 1984.

found that Seagull Grade 4 gives me a better print of my *Frozen Lake and Cliffs* than I was able to get on Agfa Brovira Grade 6, and the tone is magnificent."[46]

Zone VI Studios, a small mail-order company in Vermont run by Fred Picker, a photographer and workshop teacher, has been importing a premium-quality, double-weight fiber-base paper made by the French firm of R. Guilleminot Boespflug & Cie; the paper is sold under the Zone VI Brilliant name.[47]

With Well-Known Photographers Abandoning Its Fiber-Base Papers, Kodak Finally Becomes Concerned

During the 1970's, Eastman Kodak had concentrated its efforts in the expanding black-and-white RC and color RC paper markets, and by 1980 found itself in the rather embarrassing position of having the worst fiber-base papers — from an aesthetic point of view — of any major photographic manufacturer in the world. Serious fine art photographers and top commercial printers had almost entirely deserted Kodak and switched to fiber-base papers supplied by Ilford, Agfa, and Oriental. For much of its long history, Kodak had prided itself on producing "the best of everything," and many Kodak employees seemed genuinely pained by this unexpected turn of events.

It was against this background that Kodak in late 1983 introduced Polyfiber Paper, an improved version of Polycontrast fiber-base paper, and, in 1984, Elite Fine-Art Paper, a premium-quality, premium-priced, graded, "silver-rich" fiber-base paper. Kodak hired John Sexton, a former technical assistant to Ansel Adams and a well-known photographer in his own right, to give the company's emulsion scientists and engineers advice on aesthetic considerations in the design of Elite Paper. Kodak later featured Sexton's photographs in advertisements promoting the new product. Said Kodak:

> Our goal with Elite fine-art paper was simple: create the best fine-art black-and-white paper requested by some of the world's best printmakers.
>
> Elite fine-art paper had to be so superior that its very touch stated there was no equal. So before we went to the lab, we went to users like you. People who are very serious about black-and-white photography and have the reputations to go with it. They told us what they wanted in the ultimate paper. We listened. Now, more than two years and untold hours of research and refinement later, we're ready.
>
> Whites and blacks are nothing short of superb. Images are alive. There is a richness of image that cannot be described. It's the brightest paper we've ever made. The emulsion delivers extraordinary exposure latitude: up to 240 seconds to control development. The extra-thick, fiber-base paper is a hefty 13.2 mils — heavier than double-weight. That means easier handling, less curl, better mounting.[48]

Eastman Kodak also stated: "With the recommended processing, Elite Paper has excellent image stability under normal storage conditions — the best of any paper we have made."[49]

Display Illumination Levels for Photographs

Very low illumination levels of about 50 lux have often been suggested for museum display of light-sensitive objects such as watercolors, textiles, and color photographs; suggested illumination levels for more stable materials such as oil and tempera paintings are about 200 lux.[50] In the 1986 Kodak book *Care and Identification of 19th-Century Photographic Prints*, author James Reilly concurs with the 50-lux recommendation for the more light-sensitive types of 19th-century prints, adding that only incandescent tungsten illumination is acceptable.[51]

Offering the opinion that "photographic prints can be adequately seen and appreciated when illuminated at the 50-lux level," Reilly recommends 50-lux illumination for the display of albumen prints as well as all 19th-century

February 1983

The main exhibition area for photographs at the Art Institute of Chicago employs incandescent tungsten track lights in the center of the room and recessed ceiling lamps along the outside walls. The vertical display panels can be rearranged to accommodate different exhibitions.

photographic print materials that have exposed paper fibers on the image side (among these are salted paper prints, gum bichromate prints, cyanotypes, platinotypes, and carbon prints). For 19th-century prints with baryta coatings, including gelatin printing-out and developing-out papers, and collodion printing-out papers, Reilly suggests that the illumination level not exceed 100 lux. Reilly points out, however, that "these illumination levels have not been experimentally established for each print process, but are extrapolated from the recommendations for works of art on paper and from experience with the individual components of prints rather than from the photographic materials themselves."

Most museums have light-level specifications to which they expect borrowing institutions to adhere; the limit of 50 lux of incandescent tungsten light, UV-filtered daylight, or UV-filtered fluorescent light is commonly specified. Enforcement of lighting specifications is often rather lax, however, and it has been observed that some museums routinely display photographs in lighting levels and environmental conditions which exceed their own lending-policy recommendations; indeed, some museums and archives have not even established formal lighting and environmental guidelines for exhibiting photographs.

Brian Coe — who was curator of the Kodak Museum in Harrow, England before Kodak closed the museum in 1984 and donated its collection to Britain's new National Museum of Photography, Film, and Television in Bradford — has reported that the Kodak Museum once loaned some vintage Dufaycolour transparencies for a 6-week exhibition in Cologne, West Germany; by the time they were returned they had faded severely.[52] Coe said the transparencies were back-illuminated on light boxes equipped with bright fluorescent lamps.

300 Lux Tungsten Illumination Is Recommended for Museums, Archives, and Galleries

This author believes that even under the most favorable viewing conditions, 50 lux is simply too low for proper visual appreciation of most color and black-and-white photographic images. At low illumination levels, details in the darker areas of a print are perceived improperly or in some instances are completely obscured, color saturation is reduced, and the apparent brightness range of the print is lowered. The perception of color in darker parts of a print may be eliminated altogether. In a 1986 publication, Eastman Kodak stated:

> The intensity of the light source influences the amount of detail that can be seen in a print. For good viewing, a light source should provide an illuminance of 1,400 lux +/– 590 lux.[53]

However, an illumination level of 1,400 lux — which approximates the most intense illumination ever encountered by this author in a tungsten-illuminated display area — causes fairly rapid fading of most types of color prints and cannot be recommended for museum applications. Examination of color and black-and-white prints on display in a wide variety of museum, gallery, and other display situations has led this author to conclude that, with incandescent tungsten flood lamps which concentrate light in the general area of the displayed prints (and if no windows or other sources of bright light are present), an illumination level of about 300 lux is a good compromise between adequate illumination for viewing and for minimizing the rate of fading. Short of total darkness, there is no level of illumination that is so low that no light fading occurs.

From the point of view of a museum, only UltraStable Permanent Color prints and Polaroid Permanent-Color pigment prints are sufficiently stable to permit permanent display. Fresson Quadrichromie prints, which have some significant shortcomings in terms of sharpness and accurate color reproduction — and which are produced only for a limited clientele in France — are also very stable and can tolerate prolonged display. As yet, however, very few UltraStable, Polaroid Permanent-Color, or Fresson Quadrichromie prints are found in museum collections; the great majority of color photographs are on much less stable materials such as Ektacolor, Fujicolor, Dye Transfer, and Ilfochrome (Cibachrome). For these prints, one should opt for short-term display at light levels high enough for proper visual perception. For the remainder of the time, the prints should be kept in the dark, and, if the material requires it, refrigerated in humidity-controlled conditions.

Infrared heating of prints by tungsten light at a level of 300 lux is not significant in most wall-display situations. Higher levels of tungsten illumination (in excess of 1,000 lux) are usually accompanied by significant infrared heating of the print emulsion and support; this results in dehydration and can produce physical stress in the emulsion which may in time cause cracks or other types of damage. In high-intensity applications, Cool Beam PAR (Parabolic Aluminized Reflector) lamps or special types of low-infrared quartz halogen equipment, or glass infrared filters over conventional lamps, can reduce heating effects by two-thirds or more.

If a luxmeter[54,55] is not available for light-level measurements, a single-lens reflex camera with a through-the-lens meter can be used to indicate the proper light level. Place a white sheet of paper in the same location and plane where prints are to be viewed and adjust the camera's ISO setting to 100 and the shutter speed to 1⁄30 second. Locate the camera so the white paper fills the entire viewfinder, being careful not to cast a shadow on the paper. A light intensity of 300 lux will register an exposure of about 1⁄30 second at *f*4.0.

Ansel Adams had recommended a light level significantly higher than 300 lux for proper viewing of prints:

> Although personal preference is a factor, I have found illumination levels of 80 to 100 ft-c [860–1,076 lux] at the print position to be agreeable if the walls and general environment are of a middle value.[56]

Eastman Kodak's Recommendations

Eastman Kodak Company generally recommends display illumination levels of 538 to 1,400 lux for both black-and-white and color prints. Until recently, the fading of color prints as a function of light intensity was not mentioned in most of the company's publications; where it has been discussed, Kodak's recommendations have generally been similar to this advice, given in a 1992 Kodak information sheet for Ektacolor Portra II Paper:

> Evaluate prints under light of the same color and brightness that you will use to view the final prints. A good average viewing condition is a light source with a color temperature of 4000 ± 1000 K, a Color Rendering Index (CRI) of 85 to 100, and an illuminance of at least 50 footcandles (538 lux).
>
> . . . Illuminate prints with tungsten light whenever possible. Display prints in the lowest light level consistent with your viewing needs.
>
> . . . Keep the temperature and humidity as low as possible.[57]

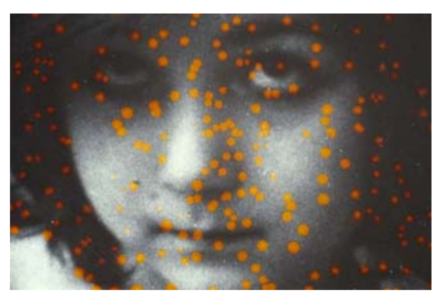
ANSI Recommendations for Viewing and Exhibiting Color Prints

ANSI PH2.30-1985, American National Standard for Photography (Sensitometry) – Viewing Conditions – Photographic Prints, Transparencies, and Photomechanical Reproductions makes illumination recommendations for "judging and exhibiting photographic reflection prints in competitions, salons, and other exhibitions":

> **Illuminance.** The illuminance at the center of the print surface shall be 800 lux +/– 200 lux and the luminance at the edge of the print shall be at least 60% of that at the center.
>
> **Spectral Power Distribution.** The spectral power distribution should [have] a correlated color temperature between 3000°K and 5000°K. The higher color temperature should be used [if possible]. Light of the same correlated color temperature shall be used for both judging and exhibiting.
>
> **General Color-Rendering Index.** The general color-rendering index of the light illuminating the prints shall be 85 or greater. . . .
>
> **Surround.** If the print is not associated with a given surround by a mat or mount, it shall be viewed against a gray background extending beyond the print on all sides at least one-third the print dimension in the same direction. If the print is associated with a given surround by mounting, it shall be judged and exhibited as mounted against a gray background extending beyond the mount on all sides at least one-fourth the mount dimension in the same direction. The surround should be spectrally nonselective and have a reflection density greater than 0.20.

© 1975 by Jan Saudek (Courtesy of Anne and Jacques Baruch of the Jacques Baruch Gallery, Chicago, Illinois)

This photograph by Jan Saudek, a Czechoslovakian artist, was printed with Kodak Polycontrast Rapid RC Paper in 1976. Introduced in 1972, this was Kodak's first general-purpose black-and-white RC paper. The print was framed under glass and after about 5 years of display it began to develop small reddish-orange spots in the image areas exposed to light (note that the outer edges of the print, which were protected from light by an overmat, are free of discoloration). This type of "self-destructive" oxidation of the silver image is caused by peroxides and other oxidants that are generated in the titanium-dioxide-pigmented polyethylene layer under the emulsion in RC papers; the reaction is initiated by exposure to light (see discussion beginning on page 581). Discoloration of this type does not occur with fiber-base prints. The Saudek print was sold by the Jacques Baruch Gallery, a Chicago gallery established by Jacques and Anne Baruch to exhibit the work of Eastern European artists. The print was returned to the gallery after the discolorations began to appear. By 1980, when the Baruchs learned the full scope of the RC paper problem, the gallery had sold more than 200 of Saudek's Polycontrast RC prints. Sale of the prints was immediately halted, and Saudek, who had printed much of his work from the early 1970's with Kodak Polycontrast RC paper, switched to fiber-base paper.



1983

A magnified view of the reddish-orange colloidal silver "microspots" that were caused by exposure of the Kodak Polycontrast RC print to light during display.

Henry Wilhelm – October 2, 1977

After 5 years of display, this Kodak RC print had formed reddish-orange "microspots" over its entire surface. The print was made by this author in 1977 with Kodak Polycontrast Rapid RC Paper purchased in 1974.

Light-induced image deterioration of black-and-white RC prints is usually characterized by reddish-orange or yellowish discolorations that are concentrated along image-density gradients. In the magnified view above, the severe discoloration that occurred on the fire hose on the left side of the picture is clearly evident. Discolored RC prints frequently exhibit surface silver-mirroring, which can be observed by viewing specular reflections from the surface of a print held at an angle to the light source. The photograph, at the left, of a fire that destroyed the Vosburg lumber yard near this author's home in Grinnell was printed with the "initial type" Polycontrast Rapid RC Paper introduced by Kodak in 1972. Sections cut from duplicate prints that had been processed together in 1977 were used in the author's accelerated light-exposure tests described on page 583. These tests revealed that there is an extremely large reciprocity failure in short-term, high-intensity image-discoloration tests with RC papers. Even very low illumination levels can — over a period of several years — be sufficient to initiate the reactions that cause discoloration of the silver image in black-and-white RC prints.

The black-and-white portrait (at the right) of Queen Elizabeth II and her husband, Prince Philip, Duke of Edinburgh, was presented to the people of Canada by Queen Elizabeth while she was visiting the country in October 1977 as part of her worldwide Silver Jubilee Tour, which commemorated her 25th anniversary on the throne. After only a few years of display at the National Archives of Canada in Ottawa, the photograph began to exhibit serious orange-brown discolorations in the silver image. In the photograph above (at the far left), studying the print, is Klaus B. Hendriks, the director of conservation research at the National Archives.

August 1982

The framed and inscribed photograph, which is believed to have been printed with Ilford RC paper in 1976 or 1977 by Her Majesty's Stationery Office in England, was removed from public display because of the light-induced discoloration of the silver image and is now in storage at the Archives.

> **Geometry of Illuminating and Viewing.** The lighting and print shall be positioned so that the amount of light specularly reflected toward the eyes of an observer on or near the normal to the center of the print is minimized. This may be achieved by placing the light source or sources 45° off the normal to the print surface.[58]

ANSI PH2.30-1985 is mostly concerned with illumination factors which influence color and tone perception. The Standard was written primarily for the graphic arts industry, and the illumination recommendations were arrived at apparently without consideration of the deleterious effects high light levels have on the stability of color prints. The section of the Standard quoted above is intended primarily for photography contests and short-term exhibitions and does not directly address the concerns of museums and archives. (It should be noted, however, that at one time ANSI recommended a higher illumination level for exhibit judging and display. The now-obsolete *ANSI PH2.41-1976, American National Standard Viewing Conditions for Photographic Color Prints* specified an illumination level of 1,400 lux,[59] which Eastman Kodak currently recommends for "critical viewing," and which is nearly double the 800 lux recommendation given in the current ANSI Standard.)

The main purpose of *ANSI PH2.30-1985* is to specify "standard" illumination conditions so that everyone involved with a publications project — photographers, art directors, editors, color separators, printers, and buyers of printing — can evaluate under *uniform* illumination conditions the color balance and density of original photographs, pre-press color proofs, and reproductions when a job is on press.

For graphic arts applications, the Standard specifies two illumination and viewing conditions "for critical appraisal of photographic reflection color prints and the comparisons of such prints with the original objects photographed or with reproductions." Light sources with a correlated color temperature of 5000K and a color-rendering index of more than 90 are specified:

> **2000-Lux Level.** For critical appraisal of the colors of reflection prints . . . when it is desirable to see detail in the darkest tones . . . the illuminance at the center of the print surface shall be 2000 lux +/– 500 lux as measured with a cosine-corrected illumination photometer.
>
> **500-Lux Level.** For critical appraisal of the tone reproduction and colors of reflection prints . . . when it is desirable to judge the way the print would look in what would be considered a brightly illuminated area in a residence, office, or library, the illuminance at the center of the print surface shall be 500 lux +/– 125 lux, as measured with a cosine-corrected illumination photometer.

Special photograph evaluation areas with illumination conforming closely to the 2000-lux condition specified in the Standard are provided in most graphic arts color separation houses and printing plants. The 500-lux illumination level is often used by color labs for evaluating portraits, wedding pictures, snapshots, and other photographs that will be displayed in customers' homes and offices.

Printing Photographs for Display

It is critical that the light for viewing prints in the darkroom be of the same spectral quality — and intensity — as that in which the prints will be displayed. The relative ultraviolet component of the light source is also important, because of its effect on the fluorescent brighteners incorporated in the base material of all current black-and-white papers (because of UV-absorbing emulsion layers to minimize UV-caused fading, and for other technical reasons, most color print materials do not contain active fluorescent brighteners on the emulsion side). In addition, the "surround," or the walls and other conditions in the darkroom or workroom viewing area, should be of approximately the same brightness and color as that of the intended display area. Eastman Kodak has offered the following suggestions:

> **Display Light Level:** The quality of prints made for display must be adjusted for the illumination level under which they will be displayed. The eye has a variable response to tones that depends on the level of ambient illumination.
>
> If a gray scale that has even density steps is viewed under a normal interior light level of 50 to 100 footcandles [538 to 1,076 lux], the eye sees the steps between the light tones as larger than steps between the dark tones. As the light level is reduced, the steps between the darkest steps disappear, while the tone separation between the light steps seems to grow larger. Under very low light levels, such as the light given by a full moon, only the light steps will be visible; all the medium-gray and dark gray steps will look black.
>
> On the other hand, if the gray scale is taken out into the full sun, the separation between two dark steps appears greater, while the tonal separation between the light steps appears to lessen.
>
> This means that prints made for display under high levels of illuminance should have slightly greater densities overall, while prints made for display under relatively low levels of illuminance should be somewhat lighter, overall, than normal.
>
> Good highlight rendition is important in all prints, and especially in prints for high illuminance display. The diffuse highlights should have enough tone so that they will not "wash out" when displayed.[60]

Color prints often appear to have significantly different color values when viewed under incandescent tungsten, fluorescent, or daylight illumination. Some types of materials show this effect more than others. In this author's experience, the appearance of Ilford Ilfochrome (Cibachrome) and Polaroid Polacolor 2 and ER prints in particular can be substantially altered when viewed under different types of light sources; most fluorescent lamps produce particularly

November 1985

Guy Stricherz, Kurt Rowell, and Karen Balogh of CVI Color Lab in New York City. Incandescent tungsten lamps were installed over the print-evaluation area in order to simulate an average museum display condition. CVI specializes in making Kodak Dye Transfer prints for fine art photographers. Most commercial labs evaluate color prints under fairly intense illumination from 5000K wide-spectrum fluorescent lamps, as recommended in **ANSI PH2.30-1985.** This is very different from the lower intensity and lower color temperature of the tungsten illumination found in most museums and galleries.

unpleasant effects. The altered appearance of color prints when viewed under different light sources is related to the spectral absorption characteristics of the cyan, magenta, and yellow dyes in the color image and to the spectral energy distribution of the particular light source. (For a discussion of the influence of different spectral sources on the appearance of oil paintings, see the informative article by Roy S. Berns and Franc Grum entitled, "Exhibiting Artwork: Consider the Illuminating Source."[61]) The image tone of black-and-white prints also varies when viewed under different types of illumination — this is especially true when the prints have been treated with Kodak Rapid Selenium Toner or other toners.

Unlike tungsten lamps and daylight, most fluorescent lamps produce light of irregular spectral distribution marked by a number of energy peaks in the narrow spectral bands of the mercury vapor discharge. The peak output of the widely used Cool White fluorescent lamp is in the green portion of the spectrum, with comparatively little red emission; the lamp also has pronounced mercury vapor emissions at 436 nanometers in the blue part of the spectrum, and at 546 and 578 nanometers in the green region. One result of this is that reds are "dulled" and appear to be much less saturated than when viewed with tungsten, daylight, Chroma 50 fluorescent, Deluxe Cool White fluorescent, or other "full-spectrum" fluorescent illumination.

Illumination for Evaluation of Prints for Gallery and Museum Exhibition

In the case of prints intended for museum and gallery display, it can be assumed that incandescent tungsten or glass-filtered quartz halogen lamps — usually of the reflector flood type — with a color temperature of 2800–3200K will be used for illumination.

It would benefit both photographers and museums if the major collecting institutions would agree on a "standard" display condition in terms of intensity, spectral energy distribution, lighting geometry, and characteristics of the surround, so that people making prints could evaluate them in the darkroom under the specified lighting conditions. This would be similar in concept to the previously mentioned *ANSI PH2.30-1985* Standard for the graphic arts and printing industries — though the specified viewing conditions for museums would of necessity be different.

For such a museum standard, this author suggests incandescent tungsten or glass-filtered quartz halogen illumination with an intensity of 300 lux on the surface of prints. Lights should be placed above displayed prints at a 30–45° angle. Windows or other extraneous light sources should be avoided. Walls or other backgrounds in display areas should be of a light, near-neutral, or gray color, with a reflection density of 0.15–0.30. Floors should be darker than walls.

UltraStable Permanent Color prints, Polaroid Permanent-Color prints, and black-and-white fiber-base prints treated with a protective toner (e.g., Kodak Rapid Selenium Toner or Kodak Poly-Toner) could of course be safely illuminated at levels much higher than 300 lux, but since most museum collections consist of photographs made with a wide variety of processes, including albumen and other 19th-century processes, untoned silver-gelatin prints, and many types of contemporary color prints, it usually is impractical to alter the display lighting every time an exhibition is changed.

The Effect of Display Lighting on Fluorescent Brighteners in Prints

Virtually all current black-and-white photographic papers have fluorescent brighteners added to the paper base (and the emulsion-side baryta coating on fiber-base prints) to give the appearance of added whiteness in many lighting conditions. UV radiation causes these brighteners to fluoresce in the visible portion of the spectrum, primarily in the blue region. If relatively little UV radiation is present, as is the case with conventional tungsten lamps or with UV-filtered fluorescent or UV-filtered daylight, the prints may appear to be subtly yellowish and less brilliant — somewhat "dull" is a good way to describe it.

The use of fluorescent brighteners in photographic papers is a fairly recent innovation. Ilford and Agfa began incorporating brighteners in their fiber-base and RC papers in the late 1970's, and Kodak started using fluorescent brighteners in RC papers at about the same time. But it was not until the 1983 introduction of Polyfiber paper that Kodak marketed a general-purpose fiber-base paper with a fluorescent brightener (Kodak Ektamatic SC Paper, a fiber-base paper intended for "stabilization" processing, has contained a fluorescent brightener since the mid-1970's, and perhaps earlier). Kodak Elite Fine-Art Paper, introduced in late 1984, also contains a fluorescent brightener. Kodak Polycontrast and Polycontrast Rapid fiber-base papers, which were replaced by Polyfiber paper, did not have fluorescent brighteners. Kodabromide, a graded-contrast fiber-base paper which has been manufactured by Kodak for a great many years, has to this author's knowledge never contained a brightener.

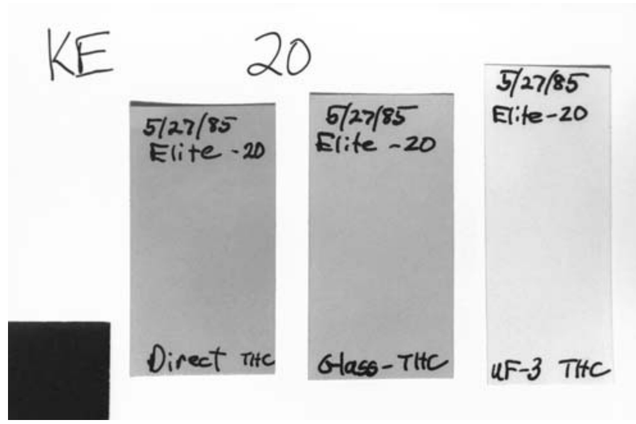
In a study of the effect of washing times on loss of fluorescent brighteners from black-and-white fiber-base and RC papers, Richard J. Henry reported that the brighteners in both types of papers were progressively leached out in the course of washing; depending on the type and brand of paper, the loss of brightener could be considerable with extended washing times.[62]

This author's accelerated light-exposure tests with Kodak Elite Fine-Art Paper also show that the brighteners gradually lose their ability to fluoresce during exposure to light and UV radiation on prolonged display.

Many modern artists' papers used for drawings and watercolors are manufactured with strongly fluorescing incorporated brighteners (in the paper manufacturing industry, fluorescent brighteners are sometimes called *optical bleaches* or *blancophores*).

Most color papers do not have *functioning* fluorescent brighteners in the base paper on the emulsion side because the UV-absorbing layers in their emulsion structure prevents the brighteners from fluorescing; brighteners found in the base paper of most RC color print materials are included only to make the backsides of the prints appear to be a brighter white (or possibly to allow the same RC base paper to be used with both color and black-and-white print materials).

In an attempt to partially compensate for the lack of a fluorescing base material, Kodak Ektaprint 2 Developer and similar color developer solutions for chromogenic papers, such as Ektacolor Professional Paper, contain a fluorescent brightener which mordants to the emulsion during development. Some of the brightener is lost in subsequent processing and washing steps, but enough remains to somewhat brighten the whites of the prints. There are limits to how much brightener can be used in this fashion — since the brightener is diffused into the emulsion itself (and is not located *underneath* the emulsion, as in the case of a base paper with brighteners), too much brightener would degrade the darker colors and blacks of a print.



1989

Samples of Kodak Elite Fine-Art Paper subjected to an accelerated fluorescent light test. After 100 days of exposure to 21.5 klux illumination (equivalent to about 25 years of display under average conditions — see Chapter 2), the fluorescent brighteners in the paper had lost considerable activity and the paper appeared perceptibly less brilliant. Of the three samples, the one on the left was exposed to bare-bulb illumination; the sample in the center was covered with glass during the test; and the sample on the right was covered with Plexiglas UF-3, a UV filter. The background is a freshly processed sheet of Elite paper, with full brightener activity. To illustrate the loss of brightness after the 100-day test, the samples were photographed under UV illumination. (Under normal illumination with visible light, the differences do not appear to be nearly as great, but are nevertheless readily discernible.) The development of more stable, longer-lasting brighteners would be a significant improvement in black-and-white papers.

Kodak Dye Transfer prints made with Kodak Dye Transfer Paper do not have UV-absorbing layers but at the time this book went to press in 1992, the paper continued to be manufactured with little or no fluorescent brightener. (In 1988 Kodak trade-tested an "improved" product called No. 45203 Dye Transfer Receiver Paper that incorporated an improved dye mordant for greater image sharpness and also had an effective UV-absorbing emulsion overcoat; however, difficulties in chemically bleaching the dyes in the course of retouching led Kodak to abandon the product.)

The ultraviolet component of a "standard" museum display illumination must be precisely defined — both for conservation reasons and because of the different visual effects various levels of UV radiation have on fluorescent brighteners. Incandescent tungsten lamps emit a relatively small amount of UV radiation and have less of an effect on the fluorescent brighteners found in many artists' papers and photographic materials than daylight or fluorescent illumination (glass-filtered fluorescent lamps have a strong mercury vapor emission line at 365 nanometers which effectively excites fluorescent brighteners).

To further complicate matters, at a given illumination level, glass-filtered quartz halogen lamps typically emit approximately twice as much UV radiation as incandescent tungsten lamps. Thus, the whites and lighter tones of prints made on papers containing fluorescent brighteners, such as Kodak Elite Fine-Art Paper, for example, look noticeably brighter when illuminated with a glass-filtered quartz halogen lamp than they do when illuminated with a conventional incandescent tungsten lamp of the same color temperature. If the lamps are fitted with Plexiglas UF-3 filters, the fluorescent brightener in the paper will not be activated and the prints will appear the same under both light sources.

Contrary to assertions by Kodak[63] and some others that incandescent tungsten illumination does not contain sufficient UV radiation to activate fluorescent brighteners, this author's examination of prints made on a variety of papers under daylight, fluorescent, and incandescent tungsten illumination left no doubt that tungsten illumination *does* visibly activate fluorescent brighteners. In the tests, some of the papers, including Kodak Elite Fine-Art Paper, contained brighteners while other papers did not. When the tungsten illumination was filtered with UF-3 to remove the ultraviolet component, the reduced "brightness" of the papers containing fluorescent brighteners was readily apparent. The visual appearance of Polycontrast and other non-brightened papers was not affected by the UF-3 filter.

Display Lighting — Incandescent Tungsten Lamps Are Recommended

Common incandescent tungsten 75-watt (75R30/FL) or 150-watt (150R/FL) internal reflector flood lamps are quite satisfactory for illuminating black-and-white and color photographs. The more expensive heavy-glass, internal-reflector PAR (Parabolic Aluminized Reflector) lamps, available in sizes from 40 watts to 150 watts, are supplied in a variety of beam-spread configurations (including several Cool Beam reduced-infrared types) and are equally satisfactory. With proper fixtures, conventional lamps without built-in reflectors can also be used. At a given level of illumination, incandescent tungsten lamps have a lower ultraviolet output than any other common light source, so there is little necessity for UV filters when using tungsten lamps to illuminate most types of photographs framed under glass.

With most organic materials, other things being equal, ultraviolet radiation and short-wavelength blue light are more harmful than the longer wavelengths in the green and red portions of the spectrum. Because of their relatively low ultraviolet radiation and blue light output, incandescent tungsten lamps are almost ideal from a general conservation point of view. Even though incandescent tungsten illumination has a low color temperature and a decidedly orange-red color balance, most people have lived with tungsten illumination all their lives and generally accept it in homes — as well as in museums.

It should be noted, however, that certain color photographic materials have cyan dyes which fade *more rapidly* when illuminated with tungsten lamps than they do with common fluorescent lamps of the same lux intensity. Ilford Ilfochrome (Cibachrome) print materials, Fuji FI-10 and 800 Instant Color Films, the obsolete Agfachrome-Speed reversal print material (marketed 1983–1985), and the initial versions of Kodak PR10 Instant Prints introduced in 1976 are among those materials that fade more rapidly under tungsten illumination.

For example, in Ilford Ilfochrome print materials, the fading rate of the cyan image dye is significantly increased when illumination comes from tungsten light instead of Cool White fluorescent lamps at the same intensity. That this is true can almost certainly be attributed to the higher relative red light output of tungsten lamps compared with the most widely used fluorescent lamps (e.g., Cool White lamps made by a variety of manufacturers). Cyan dyes have an absorption peak in the red portion of the spectrum; and with the cyan dye in Ilfochrome, this absorbed energy causes fading (UV radiation and other visible wavelengths also contribute to fading of the Ilfochrome cyan dye). Most of the literature concerned with dye fading suggests that the photochemical energy of red light is so low as to cause little or no damage to organic materials; with regard to some of the dyes used in color photography, this belief is obviously not correct. For further discussion of spectral influences on color print fading, see Chapters 2 and 3.

Quartz Halogen Lamps Are Also Satisfactory If Properly Filtered

Unlike incandescent tungsten lamps, bare-bulb quartz halogen lamps have a very high UV output, extending even below 250 nanometers, and should always be fitted with heat-resistant glass or UV filters. Exposure of skin to high-intensity quartz halogen lamps without a glass filter can cause reddening (sunburn). Even a glass-filtered quartz halogen lamp emits almost twice as much UV radiation in the 350–400 nanometer region as an unfiltered incandescent tungsten lamp. In terms of the deterioration of black-and-white photographs, gelatin, artists' papers, fabrics, and other organic materials, the significance of this difference in UV radiation levels is not yet known. The greater ultraviolet output of glass-filtered quartz halogen lamps is probably of little consequence in terms of the fading rates of Ektacolor, Fujicolor, Konica Color, Agfacolor, and most other current color print materials.

Quartz halogen lamps have tungsten filaments in a quartz envelope containing a halogen along with normal gases to fill the lamp. The lamps are made of quartz rather than glass because the very high internal operating temperatures (generally over 480°F [250°C]) can soften or melt ordinary glass. During operation of the lamp, the hot tungsten filament slowly evaporates; the tungsten vapor combines chemically with the halogen gas which then migrates back to the filament, where the high temperature causes it to decompose, redepositing the tungsten on the filament. This constant redeposition of tungsten on the filament prevents the lamp from darkening (which would occur if evaporated tungsten were deposited on the lamp envelope) and maintains a fairly uniform output and color temperature (typically with a drop of only about 50K) over the life of the lamp.[64] Quartz lamps, however, and most of the fixtures in which they operate, are expensive compared with incandescent tungsten lamps and fixtures.

Quartz halogen lamps last up to twice as long as conventional tungsten lamps, do not suffer a significant drop in light output during the life of the lamp, generate less heat and infrared radiation, and usually use electricity more efficiently. Quartz halogen lamps have a somewhat higher color temperature (typically 3100K) and produce a more visually pleasing light than conventional lamps, emitting a "whiter" light with comparatively greater blue and less red

November 1986

Because of their noticeably "whiter" light, high output, and compact size, quartz-halogen lamps are becoming increasingly popular in commercial galleries and museums. In the LIFE Gallery of Photography in the Time-Life building in New York City, quartz-halogen track lights provide the illumination; in this installation the compact size of the fixtures is of particular advantage because of the restricted ceiling height.

output. These features of quartz halogen lamps have made them appealing for museum display applications, and their use in museums is steadily increasing. The comparative effects of quartz halogen and incandescent tungsten lamps on the deterioration of photographs deserve further study.

Fluorescent Lamps

Fluorescent lamps consist of a glass tube coated on the inside with fluorescent phosphors, such as calcium halophosphate, and filled with mercury vapor and a small amount of certain other gases. In operation, the mercury arc produces ultraviolet energy which in turn is absorbed by the lamp phosphor, causing it to produce visible light. Not all of the UV radiation is absorbed by the phosphors, however; some of the remainder is absorbed by the thin glass walls of the tube and the rest, along with the visible light, is radiated from the lamp. The total radiation of fluorescent lamps is a combination of visible light emitted by the phosphors and ultraviolet radiation at the mercury emission lines of 313 and 365 nanometers; visible emission peaks are at 405, 408, 436, 546, and 578 nanometers.

In recent years, fluorescent lamps have almost totally replaced incandescent lamps in offices, schools, grocery stores, etc. because of their efficiency, producing up to four times as much light as tungsten lamps, and a correspondingly smaller amount of heat and infrared radiation, for a given amount of electricity. The reduced heat output of fluorescent lamps lowers air conditioning costs, further reducing costs when outdoor temperatures are warm. Fluorescent lamps also last far longer than tungsten lamps, which results in additional savings.

Although there are many types of fluorescent lamps, the standard Cool White lamps, produced worldwide by manufacturers such as Philips, General Electric, Sylvania, Osram, Toshiba, NEC, and Hitachi, probably account for more than 80% of all fluorescent lamps sold. Some fluorescent lamps, such as the General Electric Chroma 50 and Verilux VLX/M, have a better color rendition. They are made with a mixture of phosphors and rare gases to produce light of more uniform spectral distribution, but they are more expensive and give about 30% less light output for the same electrical consumption compared with standard Cool White lamps. These lamps constitute only a small part of the total market and are found primarily in clothing stores, meat counters in grocery stores, graphic arts firms, printing companies, photographic laboratories, and other settings where good color rendition is important.

In typical lighting installations, fluorescent illumination is usually much brighter than tungsten, with consequent increases in rates of color print fading. Indeed, it is the high level of illumination associated with fluorescent lamps that is their principal drawback; with respect to the fading rates of most color print materials framed under glass, the spectral differences between the two types of light sources are much less important. Because of the high illumination intensities associated with fluorescent lamps, and for a number of other reasons, this author does not generally recommend fluorescent lamps for illuminating photographs on display. Special-purpose fluorescent lamps with improved color rendering properties, or reduced ultraviolet emission, are likewise not recommended for most museum applications.

If fluorescent lamps are used to illuminate uncovered, UV-sensitive color photographs on display, it may be advisable to install a UV filter such as Plexiglas UF-3 over the fixtures, or to place UV-filter plastic tubes[65] over the individual lamps, or, as a last resort, to choose one of the available types of low-UV-emission fluorescent lamps.[66] Most fluorescent lamps have an ultraviolet energy peak at the 313 nanometer mercury vapor emission line; unless absorbed by a glass or acrylic plastic sheet, this UV radiation greatly accelerates fading of most types of color prints manufactured without a UV-absorbing emulsion overcoat.

The 313 nanometer emission does not appear to be particularly strong on the spectral power distribution curves of fluorescent lamps, but at this very photochemically active wavelength, its power is sufficient to have a devastating effect on Kodak Dye Transfer, Polacolor 2, Polacolor ER, pre-1982 Ektacolor prints, pre-1985 Fujicolor and Konica Color prints, and pre-1986 Agfacolor prints. Ultraviolet radiation of fluorescent lamps at the 365 nanometer mercury vapor emission line, which readily passes through glass and most clear plastics, has much less effect on the dyes used in most color photographic materials compared with ultraviolet radiation at the 313 nanometer emission.

In museums and archives, where a variety of photographic and other types of materials may be displayed, it is recommended that UF-3 sheets, cut to the proper size, be installed either above or below the diffusers in all fluorescent light fixtures; this is generally more practical, as well as less expensive in the long run, than installing UV-filter tubes over the lamps, or than purchasing special low-UV lamps. Particular attention should be given to fluorescent lamps in display cases; such lamps are likely to be installed without glass or plastic cover sheets.

Ultraviolet Radiation and UV Filters

In museums and archives, it is always good practice to keep ultraviolet radiation levels to a minimum in display areas. One should be aware, however, that with most types of color photographs displayed in typical indoor situations, the primary cause of image fading is *visible light*, so UV filters in place of glass, or in addition to glass, will do little if anything to extend the life of the prints. One of the most persistent beliefs in the photography field is that ultraviolet radiation is the primary, if not the *sole* cause of color print fading. This was indeed true with many early color print materials and is reflected in Kodak's 1970 statement that "Ultraviolet radiation in the illumination source is the chief cause of fading in color photographs."[67]

Beginning around 1970, Kodak and most other manufacturers of chromogenic print materials took various steps to mitigate the effects of UV radiation on displayed prints — principally by incorporating one or more UV-absorbing layers into the print emulsion structure — and with most current color print materials UV radiation is no longer the primary cause of fading; rather, it is *visible light* that causes most of the damage. A separate UV filter placed between the light source and prints made on current Ektacolor paper and similar products improves the fading characteristics little if any under most display conditions.

In the early 1970's, Ektacolor 37 RC and similar color negative print papers were made with an incorporated UV-absorbing layer between the topmost cyan dye and the underlying magenta and yellow dyes; this left the cyan dye layer without UV protection and resulted in rapid cyan fading when illuminated with direct fluorescent light or other high-UV light sources. Coating an additional UV-absorbing layer over the cyan dye is a relatively recent innovation. Kodak first added a UV-absorbing overcoat to Ektacolor RC papers about the beginning of 1982. Fuji, Konica, and Mitsubishi added the additional emulsion layer to the new papers they introduced during 1984 and 1985. Agfacolor Type 8 paper manufactured after mid-1986 also incorporated a UV-absorbing emulsion overcoat.

Kodak Dye Transfer prints made with Kodak Dye Transfer Paper do not have a UV-absorbing overcoat, and the cyan dye in these prints fades rapidly under high-UV illumination conditions. Plexiglas UF-3 "overprotects" the cyan dye, causing an increasing color shift toward cyan as fading progresses. Framing the prints with glass appears to give the best protection. This author's tests also suggest that glass, and not UF-3, is best for framing Polacolor 2 and ER prints.

A few color materials do benefit from the addition of a UV filter; however, in this author's tests, Ilford Cibachrome prints of all types (and presumably the Ilfochrome materials that replaced Cibachrome materials in 1991) showed worthwhile improvement in light fading stability when covered with Plexiglas UF-3. The protection afforded these prints by UF-3 is particularly striking in prints illuminated with north daylight coming through glass windows.

Elimination of UV radiation from illumination sources will somewhat lessen minimum-density yellowing of chromogenic papers such as Ektacolor and Fujicolor; but with most such papers in typical indoor display conditions, the small improvement in stain characteristics afforded by use of a UV filter is not very noticeable — at least not until the print has been displayed for so long that dye fading becomes rather severe. At that point, the presence of excessive stain may make little difference.

In accelerated light fading tests using this author's "General Home and Commercial Use" set of fading and staining limits, none of the current color papers reached the d-min stain or color imbalance limits as a first failure; in every case, dye fading or image color imbalances were reached first. This is not to say that UV filters should never be used, but with current Ektacolor papers, and similar products made by Fuji, Konica, and Agfa, displayed under typical indoor conditions, the benefits, if any, will be small. For further information on the effects of UV filters on the fading and staining of color prints, see Chapters 3 and 4.

Very high levels of UV radiation, such as occur with direct exposure of prints to light from unfiltered quartz halogen or fluorescent lamps (without a sheet of glass either over the lamps or covering the prints), should always be avoided with black-and-white prints, especially RC prints. High UV exposure may contribute to emulsion yellowing, image discoloration, and physical degradation of both the emulsion and paper base. The simple expedient of framing these materials under ordinary glass or acrylic sheet will eliminate the potentially damaging UV radiation at wavelengths below about 320 nanometers.

Instead of Framing Prints with Plexiglas UF-3, High-UV Illumination Sources Should Be Filtered to Remove UV Radiation

In museums and archives, where photographs, watercolors, paintings, fabrics, and a variety of other potentially sensitive materials may be displayed, it is strongly advised that an effective UV filter, such as Rohm and Haas Plexiglas UF-3 acrylic sheet, or DuPont Lucite SAR (Super Abrasion Resistant) UF-3 acrylic sheet, be permanently installed (indoors) over windows and skylights to keep UV radiation from both direct and indirect daylight to a minimum. As previously discussed, quartz halogen and fluorescent lamps in museums and archives should, in most cases, also be filtered with UF-3.

DuPont Lucite SAR UF-3, Polycast Technology Corporation Polycast UF-3, and CYRO Industries Acrylite OP-3 appear to have UV-absorption characteristics that are virtually identical to Plexiglas UF-3.[68] Contrary to some reports in the literature, the UV-absorption capabilities of

Plexiglas UF-3 do not diminish with age, even after many years of exposure to direct sunlight and outdoor weather.

Whenever possible, it is better to filter illumination sources with UF-3 than to frame photographs with the material. There are several reasons for this. UF-3 has a slight yellowish tint which is exaggerated when the plastic sheet is placed in contact with a photograph (and mount board) because the viewing light must pass through the UF-3 sheet twice — once to reach the print from the illumination source, and a second time when reflected from the print back to the viewer. The added "yellowness" of a print and mount board is readily apparent when compared with walls, glass-framed photographs, and other objects in the room. When a light source is filtered with UF-3, light passes through it only once; in addition, everything in the viewing area is equally affected by the yellowness of the UF-3 filter so the slight color change of the light is not noticed.

The yellowish tint of UF-3 is unavoidable; the UV absorber incorporated into the sheet during manufacture was selected to eliminate essentially *all* of the UV portion of the spectrum (wavelengths below 400 nanometers), and in the process also absorbs some short-wavelength blue light, resulting in the yellowish tint. The visible portion of the spectrum is between 400 and 700 nanometers; wavelengths below 400 nanometers, down to about 280 nanometers, constitute the principal ultraviolet region, insofar as the fading of color photographs is concerned. UF-3, like other UV absorbers, has a somewhat sloped absorption curve and does not reach 80% transmittance until about 420 nanometers. The design of UF-3 attempts to give the maximum protection against the damaging effects of UV radiation and visible light without being "objectionably" yellow.

An orange or red filter would offer much more protection with many organic materials, but this, of course, would be visually unacceptable for most applications. The U.S. Declaration of Independence, the Constitution, and the Bill of Rights, housed in the National Archives in Washington, D.C., have for many years been protected from the effects of the very-low-intensity tungsten illumination in which they are displayed by deep-yellow filters. This is in part as a consequence of grossly improper display of the Declaration of Independence earlier in its history; the document was written in 1776, and the ink inscriptions have faded so much as to now be nearly illegible.

UF-4 is an almost colorless grade of acrylic ultraviolet filter; however, it transmits significant UV radiation above approximately 385 nanometers and is thus a less effective UV absorber than UF-3. Standard grades of transparent Plexiglas (Plexiglas G) have UV-absorption characteristics which are somewhat better than glass, absorbing nearly all UV radiation below about 330 nanometers.

One should avoid framing valuable black-and-white prints with Plexiglas UF-3 and other types of acrylic sheet because over time the plastic might release trace amounts of peroxides or other substances which could harm sensitive silver images; long-term data on this potential hazard is not currently available. This concern probably does not apply to color prints, both because they appear to be less sensitive to low levels of peroxides than are black-and-white prints, and because color prints will have a necessarily limited life on prolonged display due to light-induced dye fading.

Other reasons to frame prints with glass rather than plastics are that glass is much more scratch resistant, less prone to develop dust-attracting static electrical charges, and less expensive than Plexiglas UF-3.

Even Low-Level UV Radiation Is Very Harmful to Albumen Prints

Albumen prints appear to be uniquely sensitive to even the low levels of UV radiation emitted by incandescent tungsten lamps. As illustrated in **Figure 17.1**, samples of newly processed albumen prints have a significantly reduced rate of yellow stain formation under incandescent tungsten illumination when protected with Plexiglas UF-3. For reasons not yet understood, the degree of stain formation in the glass-filtered albumen print was somewhat *higher* than in the uncovered test sample directly exposed to tungsten light.

Both the glass-filtered and direct-exposure samples stained less near the edges than in the center portions. Samples illuminated with indirect north daylight (through a glass window) for 2 years showed similar staining behavior, with the UF-3 sample staining much less than the glass-filtered sample. During the course of the tests, all of the prints also faded somewhat (red density was lost), with the prints unprotected by UF-3 fading less than the others. The gold-toned albumen prints in these tests were made in 1981 by James M. Reilly, currently director of the Image Permanence Institute at the Rochester Institute of Technology in Rochester, New York.

Although the staining behavior of these modern albumen prints under illumination may in some respects be different than that of historical albumen prints, it would seem prudent to filter light sources used to illuminate albumen prints with UF-3 or another equally effective UV filter. Because of the apparent high sensitivity of silver-albumen images to oxidizing gases, which could be evolved from acrylic plastics such as Plexiglas UF-3, this author advises against long-term framing of such prints with UF-3; glass should be used instead. Framing albumen prints with UF-3 for short periods (e.g., during shipping) will probably do no harm.

During manufacture, albumen papers were often treated with dilute solutions of pink, rose, mauve, or blue dyes to give a slight tint to the albumen layer of the paper; this was done in part in an attempt to counteract the inevitable yellowing suffered by albumen prints. Investigation by Sergio Burgi in 1981 revealed that many of these dyes have extremely poor light fading stability, some fading significantly after only a few months of exposure to low-level, UV-filtered tungsten illumination.[69] Burgi indicated that tinting dyes in albumen papers made before 1880 should be suspected of having particularly poor stability.

Albumen Prints Should Not be Displayed; Facsimile Color Copies Should Be Used Instead

Because of the high sensitivity of albumen prints to light, this author recommends that the prints not be displayed. Likewise, salted paper prints should not be displayed. Instead, high-quality Ilfochrome or other facsimile color photographic copies should be made and the copies

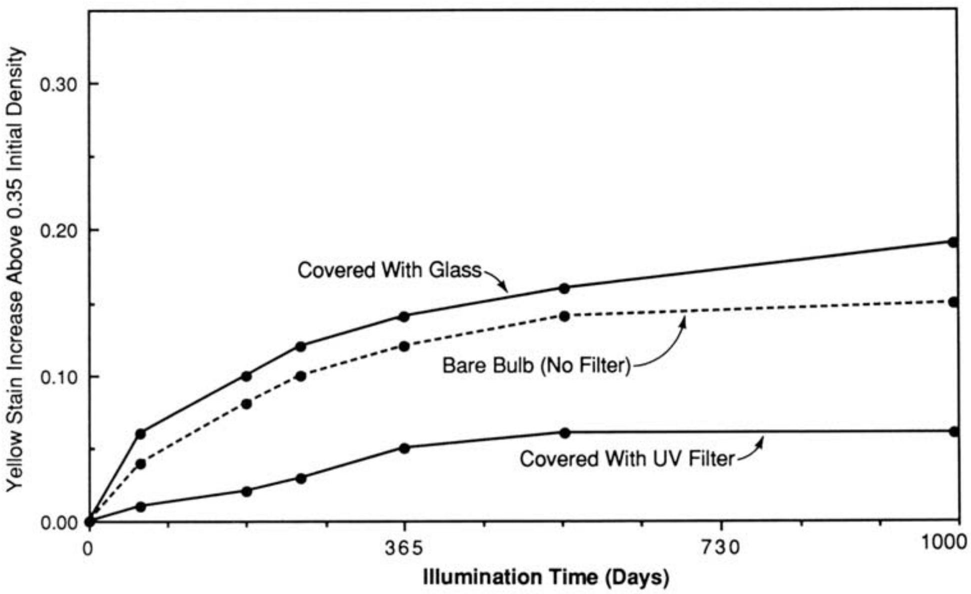


Figure 17.1 Freshly processed, gold-toned albumen prints exposed to 1.35 klux incandescent tungsten illumination. Yellowing was markedly reduced in the print framed with a Plexiglas UF-3 ultraviolet filter. (For unexplained reasons, the print framed with glass yellowed somewhat more than the uncovered print exposed to bare-bulb illumination.) The prints were made by James M. Reilly.

displayed. Black-and-white copies of albumen prints are not satisfactory because the delicate purple-black image tone and base tint of the prints are not reproduced.

If, however, it is decided to display albumen prints, it is essential that they be periodically densitometrically monitored, especially during and after periods of display and after prints shipped to other institutions on loan have returned. Display illumination levels should be kept low. To minimize staining and fading, Reilly has stressed the importance of storing and displaying albumen prints in conditions of low relative humidity (i.e., 30–40%). If albumen prints cannot be monitored, this author *strongly* advises that they not be displayed, even for short periods of time.

Caution should also be exercised and print monitoring employed when displaying other kinds of 19th-century photographs, such as ambrotypes, cyanotypes, platinum prints, palladium prints, and black-and-white prints that have been tinted or hand-colored with potentially unstable pigments or dyes.[70] It was common practice to add a little pink pigment to the cheeks of people in daguerreotype portraits, for example. Salted paper prints should never be displayed.

Albumen prints and other types of 19th-century photographs should never be loaned to other institutions unless they are sealed in vapor-proof packages and the temperature of the shipping containers can be maintained in the 60–75°F (15.5–24°C) range *at all times* when the prints are in transit; during shipment, the photographs should be accompanied by a representative of the loaning institution to make certain that these temperature conditions are adhered to.

Placement of Lamps in Display Areas

Within the limitations of the ceiling height, lamps illuminating photographs on a wall should be placed at a distance that provides as even illumination of the prints as possible. Given adequate ceiling height (about 15 feet is ideal), lights should be at about a 45-degree angle to the surface of the prints. Care must be taken to adjust the angle and placement of the lights — and the photographs on the wall — so that specular reflections and glare are minimized. Lighting at too narrow an angle will produce a shadow on the image from the frame or the beveled edge of the overmat; increasing the angle too much may produce a glare image of the lamp in the viewer's eyes or even cast a shadow of the viewer onto the photograph if the person is close to the print. Light fixtures should extend beyond the end of the lamp so that lights on opposite walls will produce a minimum amount of glare on framing glass; bare bulbs should be avoided.

Movable track lights, of the types commonly seen in museums and galleries, are excellent for lighting display areas, as individual lamps can be moved and redirected with ease.[71] Light intensities can be controlled by selecting the proper wattage of lamps, by installing light-absorbing black metal screens, and by using dimmer controls. Incandescent tungsten lamps darken somewhat and decrease in color temperature (about 100K) with age as a result of deposits of evaporated tungsten from the hot filament on the glass envelope. If necessary, this can be compensated for by selecting lamp wattages and re-adjusting the distance of the lamps from the photographs to achieve a somewhat higher light level than desired when the lamps are new; dimmers can be used to lower the light intensity to the desired level and then to maintain that level as the lamps age by gradually decreasing the setting of the rheostats.

Dimmers are also helpful for making minor adjustments in light intensity which may not be easily accomplished by the selection of lamp wattage and location. However, dimmers should be used with restraint, since the color temperature of the light is lowered, and the light becomes progressively redder, as the light intensity is reduced below normal. Low-voltage lamps operated by a transformer require special types of dimmers, and quartz halogen lamps cannot be dimmed beyond a certain point without interfering with the halogen cycle.

February 1983

Recessed incandescent tungsten lamps in a display area at the Art Institute of Chicago. Although less flexible than track lights, recessed ceiling lamps are unobtrusive and can be particularly advantageous in rooms such as this with low ceilings.

Design of Photograph Display Areas

In most display areas, flood lamps produce a pleasing, moderate concentration of light on the photograph; if the surrounding areas are somewhat darker than the photograph, the visual appearance of the photograph is enhanced. When walls are painted or covered with a material of gray or other near-neutral color, when flood lamps are used, and when no windows or other sources of bright light are present, photographs will appear to be more brightly illuminated than is actually the case. By comparison, the same level of light in a room uniformly illuminated by fluorescent lamps will not appear nearly as bright.

White or very light-colored walls should be avoided in display areas, since the bright surfaces will have the effect of reducing the apparent brightness of the print and will increase glare on the glass over photographs on opposite walls. For many reasons, prints on display should be framed or otherwise covered with glass (see Chapter 15 for a discussion of frames, nonglare glass, and plastic). Dark or black walls and ceilings should also be avoided since most people do not like the "cave" feeling of darkly painted rooms.

Windows and other sources of bright light should be eliminated in photograph display areas if at all possible. In buildings that were not designed to be museums, the presence of windows in display areas creates uneven lighting and difficult viewing conditions during daytime hours; in addition, unless special measures are taken, the light in-

February 1983

David Travis, curator of photography at the Art Institute, adjusts a lamp dimmer panel to obtain the desired overall feeling in the illumination of an exhibition.

February 1982

Outdoor windows present serious lighting problems in exhibition areas. In the upstairs galleries at the International Museum of Photography at George Eastman House in Rochester, New York, shown here before the building was closed for renovation in 1988, the glare from daylight through the windows made it difficult to properly view prints, and the intensity of illumination on prints in certain parts of the building during the day was far higher than recommended for proper display, particularly for albumen prints and other sensitive 19th-century materials.

February 1982

The same exhibition area at night. With incandescent tungsten illumination, display conditions were much better than during the day. George Eastman House was the home of George Eastman, the founder of Eastman Kodak Company, and, insofar as possible, the building has been preserved as it was when Eastman lived in the home. This precluded covering the windows. After 1988, the areas pictured here were no longer used to exhibit photographs from the permanent collection.

Jorge Gutierrez – March 1981

An Ansel Adams print on display in the upstairs exhibition area at Eastman House before the area was remodeled and no longer used for print display. The afternoon sun was shining directly on the print through a window. Although the selenium-toned image of this fiber-base print is very stable on exposure to bright light, heating by the intense sunlight could cause emulsion cracking, warping of the print and mount, or other forms of physical damage.

March 1981

At the Friends of Photography Gallery in Carmel, California, rows of incandescent flood lamps hung from the ceiling provided brilliant illumination, with an intensity at the print surface as high as 860 lux. This was in keeping with Ansel Adams's recognition that photographs are shown to their best advantage when brightly illuminated. In 1987 the Friends of Photography moved to new facilities in San Francisco.

tensities on prints in some locations can reach very high levels during certain times of the day or during a particular part of the year, depending on the angle of the sun (see **Table 17.1**) and the length of the day. Ideally, the windows in such a building should be closed off or otherwise made opaque in the exhibition areas; however, the desire to maintain the original architectural integrity of the structure may preclude such alterations. As a compromise, neutral-density glass or acrylic plastic sheeting can be used to reglaze the windows, or opaque curtains can be installed and kept closed during daytime hours. UV radiation from sunlight can most easily be reduced by using a UV filter such as Lucite SAR UF-3 or Plexiglas UF-3 in place of glass — or in addition to glass — in the windows. Various adhesive-coated plastic films are available which can readily be applied to window glass to reduce UV transmission and, if desired, to reduce transmission of visible light as well.[72]

Light levels should be reasonably uniform in display areas, as well as in the rooms or halls leading to the exhibition areas, so that viewers' eyes will have time to adjust to the lighting conditions. The photography galleries in the Art Institute of Chicago, which were opened in 1982, are examples of good gallery design and lighting-fixture placement; while walking to the photography galleries from other parts of the museum, the viewer passes through areas of progressively lower illumination.

Special Methods of Reducing Light Exposure of Displayed Prints

It is possible to display color photographs at normal room temperatures for extended periods if the prints are made on a dark-stable material such as Ilford Ilfochrome, Kodak Dye Transfer, or Fuji Dyecolor and if the photographs are protected from light except during the actual time that they are being viewed. Opaque cloth covers or curtains can be placed over the print, to be held aside by the viewer when the person is looking at the print, or the print can be placed in a horizontal box equipped with a door that can be lifted for viewing. If the photograph is located in a darkened area, a push-button (or timed) light switch can be actuated by the viewer to illuminate the print for a short time.

Special techniques of this type have been employed by a number of institutions to display light-sensitive albumen prints and other early forms of photography. Viewer-controlled lighting was used for some of the color photographs in the exhibition *Chasing Rainbows*, curated by Brian Coe of the former Kodak Museum in Harrow, England and exhibited at the Science Museum in London from November 1981 until February 1982. This exhibition contained examples of most of the forms of color photography that existed prior to the introduction of Kodak Kodachrome transparency film in 1935, which marks the beginning of the modern era of color photography. Many of the early color processes are extremely sensitive to light, and partly because of this the exhibition was not sent to other museums after it closed at the Science Museum.[73]

For the same reason, *Color As Form – A History of Color Photography*, curated by John Upton for the International Museum of Photography at George Eastman House, was not loaned to other institutions after it was exhibited at the Corcoran Gallery of Art in Washington, D.C. for 3 months beginning in April 1982 and for an additional 3 months at George Eastman House later that year. Because of the potentially very unstable dyes in many of the early color processes, originals of Autochrome, Finlay Colour, and some other materials were not exhibited; instead, modern Ektachrome transparency copies were substituted. In addition, many of the original photographs in the exhibition were monitored densitometrically by the conservation staff at Eastman House (see Chapter 7).

The Los Angeles County Museum of Art in Los Angeles, California has displayed old, light-sensitive books and works of art on paper in specially constructed cabinets fitted with

February 1982

Salted paper prints and other highly light-sensitive 19th-century photographs displayed at the Art Institute of Chicago are covered with black cloth to protect them from light except during the short periods when they are actually being viewed.

8-inch-deep, Plexiglas-covered drawers. For viewing, the visitor is instructed to gently open one drawer at a time.[74] This space-saving display technique protects objects from exposure to light except for the short periods when they are actually being viewed.

Facsimile Copies of Unstable 19th-Century Prints in the Historic New Orleans Collection

To avoid light-induced damage to salted paper prints, albumen prints, and other valuable 19th-century photographs owned by the Historic New Orleans Collection in New Orleans, Louisiana, the curatorial staff has made facsimile copies of the prints on Ektacolor paper for display purposes. The use of high-quality color facsimile copies of sensitive 19th-century prints as well as modern color prints inevitably will become more common — and more readily accepted by curators and conservators alike — as print monitoring becomes standard practice in museums and archives. It will then be clearly recognized that many types of photographs are inherently too unstable to survive long-term display, or the often uncontrolled environment of traveling exhibitions, and that facsimile copies provide the only safe means for these images to be viewed by the large audiences that want to see them.

The use of facsimile copies of manuscripts, books, and other valuable artistic and historic objects is gradually gaining acceptance in museums and archives. For example, the Conde Museum near Paris, France has permanently withdrawn a number of rare manuscripts from public view. Speaking about one of the manuscripts, *Les Tres Riches Heures du Duc de Berry*, a 209-page book painstakingly produced by hand by four artists over a 75-year period beginning in 1410, Frederic Vergne, curator of the museum, said, "My overriding duty is to preserve the manuscript. No one will be allowed to see it again. . . . The public and scholars no longer have direct access." In an article entitled "Preservation Takes Rare Manuscripts from the Public," which appeared in *The New York Times* in January 1987, Paul Lewis wrote:

> The book is a work of astonishing beauty. Its yellowing vellum pages of handwritten text are exquisitely decorated with illuminated capitals and tiny brightly colored miniatures of religious subjects and scenes from 15th-century life. It is universally recognized as one of the two or three finest illuminated manuscripts in existence.
>
> But for the last couple of years the roughly 250,000 visitors who make their way to the Conde Museum each year have only been allowed to see a high-quality modern color reproduction of the original. . . . The Conde Museum's decision illustrates a trend by museums and libraries everywhere toward cutting down access to rare manuscripts in order to reduce the damage by handling and exposure to light. Increasingly, such institutions are offering scholars and the public high-quality and extremely expensive reproductions of the original that can cost up to $10,000 a copy.[75]

Notes and References

February 1987

At the Historic New Orleans Collection in New Orleans, Louisiana, albumen prints from the late 1800's have been copied with color negative film and printed on Ektacolor paper to retain the warm image tone and yellowed highlights of the original prints (copies made with modern black-and-white papers show little resemblance to albumen prints). The facsimile copies are displayed, allowing the original prints to be stored safely in the dark. With the realization that sensitive materials such as albumen prints cannot be displayed for long periods without harm, this practice is gaining increasing acceptance in museums.

1. Grant B. Romer, "Can We Afford to Exhibit Our Valued Photographs?" **Topics in Photographic Preservation – 1986** (compiled by Maria S. Holden), Vol. 1, pp. 23–30, 1986. American Institute for Conservation Photographic Materials Group, American Institute for Conservation, 1400 16th Street, N.W., Suite 340, Washington, D.C. 20036; telephone: 202-232-6636. Romer's article was reprinted in **Picturescope,** Vol. 32, No. 4, Winter 1987, pp. 136–137.
2. At present there are no reliable published data on the long-term effects of visible light and ultraviolet radiation on the images of fiber-base silver-gelatin prints displayed in normal conditions. It has long been believed that properly processed silver images on fiber-base papers are essentially unaffected by exposure to light; lending support to this notion are countless prints of this type which have been displayed more or less continuously for 50 years or more with little apparent deterioration. However, recent information published by Eastman Kodak indicates that light and ultraviolet radiation may indeed cause changes in black-and-white fiber-base prints. In **Conservation of Photographs** (George T. Eaton, editor), Kodak Publication No. F-40, Eastman Kodak Company, Rochester, New York, March 1985, Kodak states (p. 84): "Light has no significant effect upon the silver of an image in ordinary circumstances. However, light can reduce silver ions to metallic silver after oxidizing gases and moisture have acted upon the image. . . . Constant exposure to light can cause gelatin to turn yellow and tends to make it brittle. Paper also yellows with exposure, especially papers used in photographs prior to 1926. Any considerable discoloration is more likely to be caused by oxidation or by the decomposition of residual processing chemicals than by light."

   Kodak has suggested treating modern fiber-base and RC prints with Kodak Rapid Selenium Toner, or certain other toners, to extend the life of the image, particularly when the prints are subjected to prolonged display in a humid environment. For example, see: W. E. Lee, Beverly Wood, and F. J. Drago, "Toner Treatments for Photographic Images to Enhance Image Stability," **Journal of Imaging Technology**, Vol. 10, No. 3, June 1984, pp. 119–126. See also: Eastman Kodak Company, Kodak Polyfiber Paper, Instruction Sheet, KP 79673, May 1983, which says in part: "The life of untoned fiber-base prints that may be exposed to intense or prolonged illumination or oxidizing gases or kept under adverse storage or display conditions, can be extended by the use of Kodak toners." Kodak Rapid Selenium Toner, Kodak Poly-Toner, Kodak Brown Toner, and Kodak Sepia Toner, are recommended for image protection (see comments in the text of this chapter on the image protection offered by various toners and refer to a 1991 report by James M. Reilly and Kaspars M. Cupriks, cited in Note No. 24 below). See also: Eastman Kodak Company, **Quality Enlarging with Kodak Black-and-White Papers**, Kodak Publication No. G-1, February 1985, p. 103, which says: "Apparently light and ultraviolet radiation have no effect on the longevity of black-and-white print images that have been properly toned. . . . The prints can be displayed or kept in the dark with no difference in image stability. Untoned prints exposed to high levels of radiation for long periods of time may show image changes.

   "Such radiation seems to have little effect on the base of prints made on fiber-base papers. Processed and toned . . . prints made on fiber-base papers can be expected to last for generations, whether they are displayed or not."

   The silver images of negatives and transparencies made with the now-discontinued Kodak Professional Duplicating Film 4168 (initially known as Kodak Professional Direct Duplicating Film SO-015) are adversely affected by exposure to light. See: Henry Wilhelm, "Problems with Long-Term Stability of Kodak Professional Direct Duplicating Film," **Picturescope**, Vol. 30, No. 1, Spring 1982, pp. 24–33; and a related article: F. J. Drago and W. E. Lee, "Stability and Restoration of Images on Kodak Professional B/W Duplicating Film/4168," **Journal of Imaging Technology**, Vol. 10, No. 3, June 1984, pp. 113–118.

   The now-obsolete ANSI designation "archival," which was applicable only to silver-gelatin films (not prints), had a number of significant shortcomings that limited its usefulness. As an alternative concept, this author in 1987 proposed an additional, "ultra-stable" category of stability, which included black-and-white or color photographs that met the following requirements: **(a)** support material of polyester film or fiber-base paper (acetate-base films and RC paper are excluded); **(b)** black-and-white images that have been treated with a protective toner (untreated images are excluded); **(c)** color images with dark fading stability equal to or better than Ilford Cibachrome, Kodak Dye Transfer, Fuji Dyecolor, UltraStable Permanent Color, or Polaroid Permanent-Color; **(d)** color images with light fading stability equal to or better than UltraStable Permanent Color or Polaroid Permanent-Color. This definition of "ultra-stable" was discussed by this author in a presentation entitled, "Polaroid ArchivalColor: A Progress Report on a New, Ultra-Stable Color Print Process," presented at a meeting of the American Institute for Conservation Photographic Materials Group in New Orleans, Louisiana, February 7, 1987. (Subsequent to the New Orleans presentation, Polaroid changed the name to Polaroid Permanent-Color materials.) For further discussion of "archival," Life Expectancy (LE) ratings, and related terms, see Chapter 2. Because of the adoption by ANSI of the promising LE ratings concept, and because of possible confusion with UltraStable Permanent Color prints, this author decided in 1991 to drop his proposed "ultra-stable" designation for extremely stable black-and-white and color materials.
3. For information on UltraStable Permanent Color prints and Polaroid Permanent-Color materials, refer to the discussion in Chapter 1 and the comparative stability data given in Chapter 3 and Chapter 5. Pigment color prints made by the Fresson Quadrichromie process (commonly known in the U.S. as Fresson prints) are also extremely stable and can be displayed under normal illumination conditions for very long periods. In this author's accelerated light fading tests, however, Fresson prints were not as stable as UltraStable Permanent Color prints or Polaroid Permanent-Color prints. Fresson prints are made in a small, Old-World shop run by the Fresson family near Paris (Atelier Michel Fresson, 21 rue de la Montagne Pavee, 91600 Savigny-Orge, France; telephone: 33-1-996-12-60). Fresson prints are produced by hand in very limited quantities and generally have been available only to a select clientele in France (see Chapter 1).

4. Kodak's first RC (polyethylene-resin-coated) paper was called Kind 1594 Paper. First produced in the early 1960's, Kind 1594 Paper was a special-purpose product for U.S. military and aerial-mapping concerns. The paper was not sold in the general market. Kind 1594 Paper was a graded paper with an emulsion similar to that of Kodabromide fiber-base paper. Around the mid-1960's, Kodak converted its Kodak Resisto papers, previously coated with a solvent solution of cellulose acetate, to an RC base; Kodak Resisto papers are used primarily in the graphic arts industry.

   In October 1968, Eastman Kodak announced its first black-and-white RC papers for the commercial photofinishing field, Velox Unicontrast RC and Velox Premier RC Papers; placed on the market in 1969, both of the papers were supplied only in rolls. (1968 also saw the introduction of Kodak Ektacolor 20 RC Paper, Type 1822, Kodak's first RC color paper.)

   The first general-use black-and-white RC paper available in the U.S. was Luminos RD Rapid Dry Resin Coated Paper; distributed by Luminos Photo Corporation, Yonkers, New York, the paper entered the market about February 1972. Manufactured for Luminos by Turaphot GmbH in Germany, Luminos RD was supplied in several contrast grades and was packaged in 8x10- and 11x14-inch sheets. The paper was advertised to "wash in only 30 to 60 seconds — dries flat and dries quick." The paper had a "perfect" high-gloss surface without the need for ferrotyping, or "glazing," as it is referred to in Europe (at that time, a paper that did not require drying in contact with a chrome-plated metal ferrotype plate or on a polished, chrome-plated drum dryer in order to obtain a high-gloss surface was a totally new concept). Because of the general conversion to RC papers that has taken place since the 1970's, the practice of ferrotyping is now nearly obsolete; most photographers still working with glossy fiber-base papers prefer the tactile, lower-gloss surface which is obtained when these papers are air-dried.

   In part because the Luminos brand was not well known (Luminos Photo Corporation is a small company specializing in low-cost products, and Luminos papers have generally been shunned by professional, fine art, and advanced amateur photographers), Luminos RD Rapid Dry Paper initially was viewed as something of a curiosity and appealed primarily to home-darkroom hobbyists; this pioneering RC paper was, nevertheless, a very successful product for Luminos. This author has no information on the stability characteristics of this early version of Luminos RD Paper.

   Eastman Kodak's first general-use black-and-white RC product was Polycontrast Rapid RC Paper, introduced in October 1972 and widely available by mid-1973; this paper was supplied in sheets as well as rolls and marked the real beginning of the modern era of black-and-white RC papers. Shortly thereafter, Kodak introduced Kodabrome RC Paper, a graded paper, to supplement the variable-contrast Polycontrast Rapid RC Paper. In 1974 Ilford introduced its first RC paper, Ilfospeed, and followed that in 1978 with Ilfospeed Multigrade, an RC paper with an emulsion based on the original Ilford Multigrade fiber-base paper marketed in 1940. Agfa-Gevaert introduced Agfa Brovira-Speed in 1978, and by 1980 virtually all the world's manufacturers had introduced black-and-white RC papers.

   The "RC" name was first used by Kodak in 1968 and registered as a Kodak trademark in 1972. Apparently concluding that over time the RC name would evolve into a generic term to signify any polyethylene-coated photographic paper, Kodak decided in 1976 to abandon the trademark, thus permitting any company to adopt the term RC for its products. Kodak has continued to include RC in the names of its polyethylene-resin-coated black-and-white papers to distinguish them from fiber-base papers. Because fiber-base color papers have virtually disappeared from the market (Kodak Dye Transfer Paper and Fuji Dyecolor Paper are the only remaining examples), having been replaced by RC papers, Kodak no longer felt a need to designate products such as Ektacolor Professional Paper as RC papers, and by 1985 Kodak had dropped RC from the names of its color papers.

   Agfa-Gevaert calls its polyethylene-coated products "PE" papers; PE is the internationally accepted plastics-industry abbreviation for polyethylene. Konica calls some of its color products "PC" papers — signifying that they are polyethylene-coated. Oriental uses the term "RP" in the name of its New Seagull RC papers; RP stands for resin-protected. When Ilford introduced Multigrade FB Paper in 1985, the company included "FB" in the name to distinguish the paper from Ilford Multigrade II Paper, a developer-incorporated RC paper that had been introduced several years earlier. FB stands for fiber-base, and to this author's knowledge this was the first time such an abbreviation had been used with a photographic paper. Several years ago, when Kodak replaced the fiber-base Polycontrast Paper with a new paper, it was called Polyfiber Paper. Polyfiber Paper is the fiber-base counterpart to Kodak Polyprint RC Paper; both papers employ the same emulsion. It appears likely that the terms RC and FB will in time be adopted by all manufacturers.

5. Jack H. Coote, **Monochrome Darkroom Practice**, an Ilford book published by Focal Press, London England, 1982, p. 276.
6. Irvin H. Crawford, Roger E. Democh, and Robert J. Baron, **Highly Stable Resin Coated Paper Products and Method for Making Same**, United States Patent 3,853,592, December 10, 1974.
7. Eastman Kodak Company, "Keeping Characteristics of B/W Prints," **Kodak Studio Light**, Issue No. 1, 1976.
8. T. F. Parsons, G. G. Gray, and I. H. Crawford [Eastman Kodak Company], "To RC or Not to RC," **Journal of Applied Photographic Engineering**, Vol. 5, No. 2, Spring 1979, pp. 110–117.
9. Larry H. Feldman [Eastman Kodak Company], "Discoloration of Black-and-White Photographic Prints," **Journal of Applied Photographic Engineering**, Vol. 7, No. 1, February 1981, pp. 1–9. Originally presented at the **1980 International Conference on Photographic Papers**, William E. Lee, chairman, sponsored by the Society of Photographic Scientists and Engineers (SPSE), Hot Springs, Virginia, August 12, 1980.
10. Eastman Kodak Company, **Kodak B/W Photographic Papers**, Kodak Publication No. G-1, Eastman Kodak Company, Rochester, New York, April 1978, p. 28.
11. Klaus B. Hendriks, "A Discussion of Polyethylene Resin Coated (RC) B&W and Color Papers, Their Properties, and Factors Which May Affect Stability in Dark Storage and Under Display Conditions," presented at **The Permanence of Color – Technology's Challenge, the Photographer's and Collector's Dilemma,** Henry Wilhelm, chairman, a conference sponsored by the International Center of Photography (ICP), New York City, May 6–7, 1978.
12. David Vestal, "RC Report: The TiO_2 Blues," **Popular Photography**, Vol. 93, No. 4, October 1978, pp. 80ff. For a general account of the ICP conference proceedings, see: David Kach, "Photographic Dilemma: Stability and Storage of Color Materials," **Industrial Photography**, Vol. 27, No. 8, August 1978, pp. 28ff.
13. This author's prints were made on Kodak Polycontrast Rapid RC Paper purchased in 1974; the 100-sheet box of 8x10-inch F-surface paper had an expiration date of March 1976 and the emulsion number was 94801–73242X.
14. Ctein, "Agfa Multicontrast High Speed Paper," **Darkroom Photography**, Vol. 12, No. 6, June 1990, pp. 50–51, 64. Ctein wrote: "Like other developer-incorporated papers, Multicontrast is pretty insensitive to choice of developer and development; you can't manipulate the print by changing the amount of development without risking muddy blacks. Furthermore, Multicontrast may be prone to base-staining over time, as are other developer-incorporated papers." Also: Ctein, telephone discussion with this author regarding base-staining of developer-incorporated RC papers, September 4, 1990.
15. G. Kolf [Agfa-Gevaert AG], "Modern Photographic Papers – Part 2," (translated into English by A. J. Dalladay), **The British Journal of Photography**, Vol. 127, April 4, 1980, pp. 316–319. This article originally appeared in **Monatliche Fototechnische Mitteilungen**, Vol. 27, No. 11, November 1979, pp. 533–534.
16. Jean Dieuzaide, "Appeal for the Preservation of Genuine Photographic Paper Which Is Faced by the Threat of Cessation of Production," **Camera**, Vol. 57, No. 1, January 1978, p. 44. The document was originally distributed in 1977 at the Rencontres Internationales de la Photographie 1977, in Arles, France. See also: Andy Grundberg, "Arles Festival Ponders Future of B&W Papers, Photo Collecting and Color Imagery," **Modern Photography**, Vol. 41, No. 10, October 1977, pp. 54ff; Marco Misani, "Arles Meeting: Important Though Still Disorganized," **Print Letter** 11, September–October 1977, pp. 1–2; Geoffrey Crawley, "Comment," **British Journal of Photography**, Vol. 125, No. 6140, March 31, 1978, pp. 265–267; Martin Van Leeuwen, "Die Haltbarkeit Von PE- Und RC-Papieren," **Profi Foto**, Nr. 2, 1982, pp. 54–60; and M. Gillet, C. Garnier, F. Flieder, "Influence de l'environnement sur la conservation des documents photographiques modernes," chapter in **Les Documents Graphiques et Photographiques: Analyse et Conservation**, Editions du Centre National de la Recherche Scientifique, Paris, France, 1981 [translated for this author by Marcia Brubeck, June 1983.]
17. Larry H. Feldman, see Note No. 9, p. 9.
18. Eastman Kodak Company, **Conservation of Photographs** (George T. Eaton, editor), Kodak Publication No. F-40, Eastman Kodak Company, Rochester, New York, March 1985, p. 39.
19. Eastman Kodak Company, see Note No. 18, p. 40.
20. Eastman Kodak Company, **Kodak Polycontrast Rapid II RC Paper** (information sheet packaged with paper), Kodak Publication No. KP 73873f, Eastman Kodak Company, Rochester, New York, August 1981.
21. Eastman Kodak Company, **Kodak Polyprint RC Paper** (information sheet packaged with paper), Kodak Publication No. KP 80981a, Eastman Kodak Company, Rochester, New York, October 1984. See

also: Eastman Kodak Company, Kodak Polycontrast III RC Paper (information sheet packaged with paper), Kodak Publication KP 88196, Eastman Kodak Company, Rochester, New York, March 1988.

22. See Note No. 2.
23. James M. Reilly, Douglas W. Nishimura, Kaspars M. Cupriks, and Peter Z. Adelstein, "Stability of Black-and-White Photographic Images, with Special Reference to Microfilm," **Abbey Newsletter**, Vol. 12, No. 5, July 1988, pp. 83–88 (Abbey Publications, 320 E. Center, Provo, Utah 84601; telephone: 801-373-1598). The article is based on a presentation at the **Conservation in Archives Symposium** at the National Archives of Canada, May 1988. Reilly, director of the Image Permanence Institute, and his co-workers based their conclusions about the relative effectiveness of toners on results that they had obtained with microfilm samples treated with a number of toners and subjected to an improved accelerated peroxide fuming test they had developed during 1987–88:

    "Gold and selenium treatments provide protection against peroxide attack only in proportion to the degree to which the heavy metal is substituted for the original silver image. In the absence of sulfiding agents, even very high degrees of gold or selenium substitution do *not* provide complete protection. In actual practice, when used as recommended, the metal components of gold and selenium toners for microfilm do very little to protect against oxidation; their effectiveness is almost entirely due to the sulfiding action of other constituents of the toner formulas."

    Reilly and his co-workers discussed their findings with Kodak and Kodak "confirmed that in their own recent peroxide testing with microfilm, the selenium toner was depositing selenium, but not preventing oxidant attack, which it had done in tests performed as recently as one year ago. They suspected that small changes in [Kodak Rapid Selenium Toner] formulation made by the manufacturing area were responsible, but were not clear on exactly why."

    Sulfiding toners (e.g., Kodak Brown Toner and Poly-Toner), on the other hand, were found to be very effective in the Image Permanence Institute tests, even when used at low concentrations:

    "Excellent protection against peroxide attack can be gained by treating microfilm with solutions which lead to the partial **sulfiding** of the silver image. The best compounds to use, as well as methods of application and possible ill effects on physical properties, etc., are unknown at this point, but there are several promising candidates (in particular polysulfides), and the direction to be pursued is now clearly established.

    ". . .One of the strongest clues to the power of sulfiding agents to protect against peroxide came from experiments with gold toners. Kodak has recommended a formula known as GP-2 since the 1960's for the treatment of microfilm to prevent red spot attack. Because of the high cost it has seldom been used in practice, but it was always regarded as absolute protection. One of the ingredients of GP-2 is thiourea, a known sulfiding agent. In experiments [at the Image Permanence Institute], this formula was indeed completely effective in preventing peroxide attack. However, experiments with the same formula **without** the gold were completely effective. In both the gold toner and the selenium toner, it seemed to be the sulfiding agents, not substitution with gold or conversion to silver selenide, that was providing the bulk of the protection against oxidants."

    At the time of this writing, Reilly and his co-workers were continuing this work and could not yet recommend a toner formulation that would provide the aesthetically desirable image intensification afforded to most current fiber-base and RC papers by treatment with Kodak Rapid Selenium Toner, while at the same time providing the increased image protection of a sulfiding toner.
24. James M. Reilly and Kaspars M. Cupriks, **Sulfiding Protection for Silver Images,** Final Report to the Office of Preservation, National Endowment for the Humanities (Grant # PS-20152-87), Image Permanence Institute, March 28, 1991, p. 2. To obtain a copy of the report, contact: Image Permanence Institute, Rochester Institute of Technology, Frank E. Gannett Memorial Building, P.O. Box 9887, Rochester, New York 14623-0887; telephone: 716-475-5199; Fax: 716-475-7230. See also: J. M. Reilly, D. W. Nishimura, K. M. Cupriks, and P. Z. Adelstein, "Polysulfide Treatment for Microfilm," **Journal of Imaging Technology,** Vol. 17, No. 3, June–July, 1991.
25. Eastman Kodak Company, **Kodak Photographic Papers for the Professional**, Kodak Publication No. P4-73, Eastman Kodak Company, Rochester, New York, October 1972.
26. Eastman Kodak Company, **Faster and Better B/W Print Processing**, Kodak Publication No. G-6, Eastman Kodak Company, Rochester, New York, July 1976.
27. In presentations at the Rochester Institute of Technology, Rochester, New York, September 26, 1978, and at a conference at the Peabody Museum, Harvard University, Cambridge, Massachusetts, October 29, 1978, Glen G. Gray of the Paper Service Division of Eastman Kodak Company, in the course of discussing the light-induced chemical processes causing embrittlement and eventual cracking of RC papers, also briefly described some of the mechanisms involved in the discoloration of black-and-white images by oxidizing vapors, and mentioned that Kodak was conducting accelerated tests of light-induced image discoloration of framed RC prints illuminated with fluorescent lamps. Improvement in the resistance to discoloration was noted in the "stabilizer in the paper core" version of Kodak RC paper versus the earlier "improved-pigment" type of Kodak RC paper; behavior of the initial formulation of Kodak black-and-white RC paper was not discussed.

    Gray's two presentations were based largely on a talk given earlier (entitled, "To RC or Not to RC," by Timothy P. Parsons, Glen G. Gray, and Irvin H. Crawford) at the annual conference of the Society of Photographic Scientists and Engineers, Washington, D.C., May 1, 1978 (their talk was published by SPSE in 1979 – see Note No. 8). Unlike Gray's presentations at RIT and the Peabody Museum in the fall of 1978 (which were not published), neither the original SPSE presentation nor the published article included any discussion of image discoloration of black-and-white RC papers.
28. Rodney R. Parsons, technical services manager, Ilford Photo Corporation, letter to this author, June 13, 1988.
29. As an example, see: Alfred A. Blaker, "The Case for RC," **Darkroom Photography**, Vol. 8, No. 5, September 1986, pp. 22ff. Blaker cited only Kodak sources and quoted an unnamed Kodak scientist as saying: "There is no reason to believe or to suspect that RC black-and-white papers are inferior to conventional or fiber-based papers." In the article, there was no discussion of the possibility that stability differences could exist among RC papers made by different manufacturers. Blaker concluded the article by saying: "I will regard the two types of papers — conventional and resin-coated — as full equals. In fact, if a difference does exist, I've found that almost invariably it favors RC. And though I am withholding final judgment, I believe RC papers will eventually come to be accepted as the superior material." (p. 46).
30. For example, in a presentation by Klaus B. Hendriks, Debbie Hess Norris, and James M. Reilly entitled, "Photograph Conservation: The State of the Art," presented at the annual meeting of the American Institute for Conservation of Historic and Artistic Works, Chicago, Illinois, May 22, 1986, Reilly said: "Apparently, this problem [support cracking of RC papers from the 1970's] is now solved by the incorporation of stabilizers into current RC papers." No reference was given to a particular brand or manufacturer of RC paper. The actual presentation differed in some respects from the version in the conference **Preprints** published by the AIC before the meeting.
31. The principal manufacturers of RC base paper in Western countries are Eastman Kodak Company (USA); Fuji Photo Film Co. Ltd. (Japan); Mitsubishi Paper Mills, Ltd. (Japan); Felix Schoeller, Jr., GmbH & Co. KG (Germany, with a manufacturing division in Pulaski, New York); Oji Paper Company (Japan); and Wiggins Teape Ltd. (England). Kodak does not sell uncoated RC base paper to other photographic manufacturers; however, both Fuji and Mitsubishi do. Oji Paper Company began manufacturing RC base paper in Japan in 1986, with the Konica Corporation (known as Konishiroku Photo Ind. Co., Ltd. until October 1987) among its initial customers. Konica had for years obtained most of its RC base paper from Mitsubishi. Fuji is said to supply RC base paper to Oriental Photo Industrial Co., Ltd., among others. Kodak reportedly buys some RC base paper, made to Kodak's specifications, from Wiggins Teape for use with Kodak products manufactured in Europe. Wiggins Teape also supplies Ilford with RC base paper, and Felix Schoeller supplies RC base paper to Agfa-Gevaert, among others. The Pulaski, New York plant of Felix Schoeller supplied RC base paper to the 3M Company for its 3M High Speed Color Paper until 3M discontinued manufacturing the product in the U.S. in 1983 (3M continued to produce color paper until about 1988 at 3M Italia S.p.A., a 3M subsidiary in Ferrania, Italy).
32. Robert H. MacClaren [National Archives and Records Service], "Accelerated Test Methods and Factors Affecting Photographic Paper Permanence," a presentation at the **1980 International Conference on Photographic Papers**, William E. Lee, chairman, sponsored by the Society of Photographic Scientists and Engineers (SPSE), Hot Springs, Virginia, August 11, 1980. MacClaren reported on accelerated aging tests at the National Archives with processed black-and-white RC papers in which the edge of one RC print was placed against the image area of another. Image discoloration occurred in a line where the edge of the print had been in contact with the emulsion of the adjacent print. MacClaren attributed this to edge-penetration of processing chemicals and termed this type of deterioration the "picture-frame effect." For an account of the conference proceedings, see: Henry Wilhelm, "The 1980 Conference on

Photographic Papers," **Picturescope**, Vol. 29, No. 1, Spring 1981, pp. 25–27.

33. Ilford Photo Corporation, West 70 Century Road, Paramus, New Jersey 07653; telephone: 201-265-6000; toll-free outside New Jersey: 800-631-2522.
34. Peter Krause, telephone discussion with this author, March 10, 1987.
35. Barry Sinclair, national marketing manager for monochrome products and systems, Ilford Photo Corporation, telephone discussions with this author, April 21 and September 15, 1987.
36. Bob Schwalberg, discussion with this author, February 23, 1987.
37. Among fine art photographers and other discriminating users of premium, "silver-rich" fiber-base photographic papers, there is no general agreement as to which are the "best" products. Premium fiber-base papers are characterized by a very high maximum density (deep blacks) and clean, bright whites (all current premium papers contain fluorescent brighteners), and most are supplied only on double-weight, glossy paper stock. Among these papers, an individual's preference inevitably is based on a host of subjective factors, including: image tone; curve shape (tone reproduction characteristics in highlight, midtone, and shadow regions); tonal change and degree of image intensification when the paper is treated with Kodak Rapid Selenium Toner (this author considers toner treatment to be a mandatory part of processing); the tendency for the emulsion to "frill" or otherwise become physically damaged during processing and washing; surface gloss characteristics when the paper is air-dried naturally at room temperature; the degree of curl and cockle which develops during drying; the degree of curl which occurs as a consequence of storage in conditions of cycling relative humidity; edge-lift after dry mounting; consistency of image tone, surface gloss, and response to Kodak Rapid Selenium Toner among available contrast grades (and between emulsion batches); image "dry-down" characteristics; and other visual properties which may be difficult to quantify — or even verbalize — but which nevertheless can be very significant. Price and availability of a wide range of contrast grades and paper sizes may also be important considerations.

    Among many discriminating photographers and printers, the most popular papers at the time of this writing in 1992 were Ilford Galerie FB, Ilford Multigrade FB, Oriental New Seagull G Paper, Oriental New Seagull Select VC FB Paper, Kodak Elite Fine-Art Paper, Zone VI Brilliant Paper, Agfa Insignia Paper, and Agfa Portriga-Rapid (a specialized paper with a distinctive warm image tone which some photographers love and others hate). This author's personal favorites are Ilford Galerie FB, Ilford Multigrade FB, and Oriental New Seagull G. Both Ilford Multigrade FB Paper and Oriental New Seagull Select VC FB Paper are, in this author's opinion, distinctly better products than Kodak Polyfiber Paper. Kodak Elite Fine-Art Paper is an excellent product in most respects (the "premium-weight" paper base, which is thicker than normal double-weight paper, is particularly nice), but, in this author's opinion, the surface of Elite when naturally air-dried is not as appealing as the surfaces of Galerie, New Seagull, or Zone VI Brilliant. At the time of this writing, this author had not yet had an opportunity to evaluate Fuji Museum Paper, which was introduced in Japan in 1986 (this product is rumored to actually be Ilford Galerie FB Paper), or Mitsubishi Gekko Paper, which became available in the U.S. around the end of 1986 (Gekko has received excellent reviews in the photographic press — see, for example: Peter Moore and Rosalie Winard, "Modern's Great Paper Chase . . . Second Heat," **Modern Photography**, Vol. 51, No. 3, March 1987, pp. 48–51).
38. David Vestal, "Are Conventional B/W Papers an Endangered Species? – Will Waterproof Printing Papers Replace Other Types Soon? This Open Letter Says 'Proceed with Caution'," **Popular Photography**, Vol. 78, No. 1, January 1976, pp. 85, 132. In voicing his concern about potentially adverse effects of light on RC prints during long-term display, Vestal cited a letter, sent to him by Ilford, stating that up to April 1975, Ilford had made no tests for RC print permanence except those related to washing processing chemicals out of the prints. See also: David Vestal, "The Great Printing-Paper Crunch – A Plea for Old-Fashioned Quality in an Age of Mass-Production Values," **Popular Photography**, Vol. 80, No. 4, April 1977, pp. 91, 198; David Vestal, "The Paper War: Famous Photographers Speak Out on Old and New Black-and-White Enlarging Material," **Popular Photography**, Vol. 81, No. 6, December 1977, pp. 46ff; Arthur Goldsmith, "Editorial – A Voice from the Minority: Let's Save the Old-Time 'Fibre-Base' Papers from Extinction," **Popular Photography**, Vol. 80, No. 4, 1977, p. 10; David Vestal, "B&W Printing for Permanence," Photography How-To Guide, a **Popular Photography** publication, Fall 1977, pp. 6ff; Arthur Goldsmith, "Editorial – How You Can Help Save Quality Printing Papers," **Popular Photography**, Vol. 82, No. 6, June 1978, p. 102; and David Vestal, "Popular Photography Printing-Paper Poll," **Popular Photography**, Vol. 82, No. 6, June 1978, p. 103 (the results of the "Printing-Paper Poll" were conveyed to Kodak and other manufacturers). The tabulated responses of the more than 4,000 readers who responded to the poll were summarized in: David Vestal, "Paper Poll Answers: Here's What You Told Us About Your Need for Quality Printing Paper," **Popular Photography**, Vol. 84, No. 1, January 1979, pp. 85ff. Among the respondents, Agfa Brovira was the most popular paper, followed by Ilford Ilfobrom, Kodak Polycontrast, Agfa Portriga-Rapid, Kodak Medalist, and DuPont Varigam, in that order. RC papers were the favorite products among only a very small percentage of those responding to the poll.
39. Eastman Kodak Company, see Note No. 7. This article also stated: "Accelerated aging tests indicate that when storage conditions are carefully controlled (approximately constant 21°C [70°F], 50% RH, infrequent exposure to light), prints on resin-coated base should last as long as prints on non-resin-coated base. However, these tests also indicate that when prints are displayed for long periods (several years) or displayed in direct sunlight or stored under uncontrolled environmental conditions, non-resin-coated papers can be expected to have a longer useful life than resin-coated papers. Therefore, non-resin-coated papers are recommended for long-term display and for long-term storage."
40. Eastman Kodak Company, see Note No. 10, p. 28.
41. Eastman Kodak Company, **Preservation of Photographs**, Kodak Publication No. F–30, Eastman Kodak Company, Rochester, New York, August 1979, p. 5.
42. Eastman Kodak Company, see Note No. 18, p. 40.
43. David Vestal, "The Great Printing-Paper Crunch – A Plea for Old-Fashioned Quality in an Age of Mass-Production Values," **Popular Photography**, Vol. 80, No. 4, April 1977, pp. 91, 198.
44. William Messer, "Ilford at Arles," **British Journal of Photography**, August 11 1978, pp. 690–691. In addition see: David Vestal, "Ilford Galerie Enlarging Paper – Is This the Premium Fiber-Base Black-and-White Paper We've Been Waiting For?" **Popular Photography**, Vol. 84, No. 1, January 1979, pp. 88ff.
45. Ansel Adams, **The Print**, The New Ansel Adams Photography Series, Book 3, New York Graphic Society, Little Brown and Company, Boston, Massachusetts, 1983, pp. 49–50.
46. Ansel Adams, see Note No. 45, p. 50.
47. Zone VI Studios Inc., Newfane, Vermont 05345-0219; telephone: 802-257-5161.
48. Eastman Kodak Company, **New Kodak Elite Fine-Art Paper**, Kodak Publication No. P10-85G, Eastman Kodak Company, 1984.
49. Eastman Kodak Company, **Kodak Elite Fine-Art Paper**, Kodak Publication No. G-18, Eastman Kodak Company, Rochester, New York, November 1984, p. 11.
50. Garry Thomson, **The Museum Environment**, second edition, Butterworth & Co., London, England, in association with The International Institute for Conservation of Historic and Artistic Works, 1986, pp. 22–34. See also: Illuminating Engineering Society of London, **IES Technical Report No. 14**, London, England, 1970, pp. 1–7.
51. James M. Reilly, **Care and Identification of 19th-Century Photographic Prints**, Kodak Publication No. G-2S, Eastman Kodak Company, Rochester, New York, 1986, p. 105.
52. Brian Coe, telephone conversation with this author, July 27, 1983.
53. Eastman Kodak Company, **Kodak Color Films and Papers for Professionals**, Kodak Publication No. E-77, Eastman Kodak Company, Rochester, New York, March 1986, p. 49.
54. One recommended luxmeter is the Minolta Illuminance Meter, Model T-1 (the unit reads in both lux and footcandle units), which costs about $500 and is available from Minolta Corporation, 101 Williams Drive, Ramsey, New Jersey 07446; telephone: 201-825-4000; manufactured by Minolta Camera Company, Ltd., 30,2–Chome, Azuchi-Machi, Higashi-ku, Osaka 541, Japan. While not as precise nor as easy to read as the Minolta Illuminance Meter, also recommended is: Panlux Electronic Luxmeter (available with either lux or footcandle scales), about $350 (manufactured by Gossen GmbH, D-8520 Erlangen, Postfach 1780, West Germany), available from Bogen Photo Corporation, Gossen Division, 565 East Crescent Avenue, Ramsey, New Jersey 07446-0506; telephone: 201-818-9500.

    For determination of the proportion of total UV radiation present in ambient illumination, or in illumination from a specific light source, the Crawford U.V. Monitor, Type 760 is recommended. The instrument responds to total UV radiation in the 300–400 nanometer band and cannot indicate the percentage at any given wavelength. The Crawford U.V. Monitor is manufactured by the Littlemore Scientific Engineering Company, Railway Lane, Littlemore, Oxford, England 0X4 4PZ. In the U.S. the instrument is available from Qualimetrics, Inc., 1165 National Drive, Sacramento, California 95834; telephone: 916-928-1000; toll-free outside California: 800-824-5873. The standard model sells for about $620; a special, high-sensitivity version of the instrument is available for about $950.

55. R. H. Lafontaine, **Recommended Environmental Monitors for Museums Archives and Art Galleries**, Technical Bulletin 3, Canadian Conservation Institute, National Museums of Canada, Ottawa, Ontario K1A 0M8, July 1978.
56. Ansel Adams, see Note No. 45, p. 164.
57. Eastman Kodak Company, **Kodak Ektacolor Portra Papers**, Kodak Publication No. E-140, Eastman Kodak Company, Rochester, New York, January 1992, p. 4. See also: **Kodak Color Films and Papers for Professionals**, Kodak Publication No. E-77, March 1986, p. DS-64 ("Kodak Ektacolor Professional Paper"). On occasion Kodak has recommended lower levels of display illumination: **Conservation of Photographs** (George T. Eaton, editor), Kodak Publication No. F-40, Eastman Kodak Company, Rochester, New York, March 1985 (p. 109) stated, "For display purposes, tungsten illumination is preferred but whatever light source is used, it should be no more intense than is necessary to provide adequate viewing. An intensity between 54 and 160 lux (5 to 15 footcandles) of incandescent lighting is considered adequate."
58. American National Standards Institute, Inc., **ANSI PH2.30-1985, American National Standard for Photography (Sensitometry) – Viewing Conditions – Photographic Prints, Transparencies, and Photomechanical Reproductions,** American National Standards Institute, Inc., 11 West 42nd Street, New York, New York 10036; telephone: 212-642-4900 (Fax: 212-302-1286). This Standard is a consolidation and revision of **ANSI PH2.31-1969 (R1982), Direct Viewing of Photographic Color Transparencies; ANSI PH2.32-1972 (R1982), Viewing Conditions for the Appraisal of Color Quality and Color Uniformity in the Graphic Arts; ANSI PH2.41-1976 (R1982), Viewing Conditions for Photographic Color Prints; and ANSI PH2.45-1979, Projection Viewing Conditions for Comparing Small Transparencies with Reproductions.** These four earlier Standards are now obsolete.
59. American National Standards Institute, Inc., **ANSI PH2.41-1976**, **American National Standard Viewing Conditions for Photographic Color Prints,** 1972, p. 10. This Standard has been replaced by **ANSI PH2.30-1985**; see Note No. 58.
60. Eastman Kodak Company, **Quality Enlarging with Kodak Black-and-White Papers**, Kodak Publication G-1, Eastman Kodak Company, Rochester, New York, February 1985, p. 121.
61. Roy S. Berns and Franc Grum, Munsell Color Science Laboratory, Rochester Institute of Technology, **Color Research and Application**, Vol. 12, No. 2, April 1987, pp. 63–72.
62. Richard J. Henry, **Controls in Black-and-White Photography**, second edition, Focal Press (Butterworth & Co., Ltd.), Boston, Massachusetts and London, England, 1986, pp. 105–112.
63. Eastman Kodak Company, see Note No. 60, p. 16.
64. R. E. Birr and C. N. Clark, "Radiation Sources," Section 1 in **SPSE Handbook of Photographic Science and Engineering**, John Wiley & Sons, New York, New York, 1973, pp. 1–141.
65. UV-absorbing tubes and sleeves for fluorescent lamps can be obtained from a number of suppliers, including Conservation Resources International, Inc., 8000-H Forbes Place, Springfield, Virginia 22151; telephone: 703-321-7730. The tubes sold by Conservation Resources are made from Rohm and Haas UVA-7 acrylic resin which is said not to lose UV-filtration effectiveness with age. UF-3 sheets absorb somewhat more UV radiation than does UVA-7. Tubes are also available from Light Impressions Corporation, 439 Monroe Avenue, Rochester, New York 14607-3717; telephone: 716-271-8960; toll-free outside New York: 800-828-6216. Lower-cost sleeves are available from the Solar Screen Company, 53–11 105th Street, Corona, New York 11368; telephone: 212-592-8223.
66. A number of fluorescent lamps are available with low UV emission and improved color rendering characteristics. One such lamp is the Verilux VLX/M, available from Verilux, Inc., 626 York Street, Vallejo, California 94590; telephone: 707-554-6850; Fax: 707-554-8370.
67. Eastman Kodak Company, **Printing Color Negatives**, Kodak Publication No. E-66, Eastman Kodak Company, Rochester, New York, September 1970, p. 41.
68. Rohm and Haas Company, **Ultraviolet Filtering and Transmitting Formulations of Plexiglas Acrylic Plastic**, Plexiglas Design, Fabrication Data, PL-612d, 1979, pp. 2, 3, 5. Rohm and Haas Company, Independence Mall West, Philadelphia, Pennsylvania 19105; telephone: 215-592-3000. Plexiglas UF-3 should not be confused with Plexiglas II UVA which does not contain an ultraviolet absorber. UVA has about the same ultraviolet cutoff point as the standard grades of Plexiglas (which absorb somewhat more UV radiation than ordinary glass). The Plexiglas II series is made to much closer thickness tolerances, and is more expensive, than the standard grades such as Plexiglas G.

Polycast UF-3 and UF-4 are manufactured by Polycast Technology Corporation, 70 Carlisle Place, Stamford, Connecticut 06902. DuPont Lucite SAR (Super Abrasion Resistant) and Lucite SAR UF-3 are manufactured by the DuPont Company, Polymer Products Department, Lucite Sheet Products Group, Wilmington, Delaware 19898. (In April 1992, DuPont sold its acrylic sheet business to the British firm Imperial Chemical Industries P.L.C., also known as ICI. It is not known if ICI will continue to use the Lucite trademark in the U.S. in the future.) Licensing and purchasing agreements allow the Rohm and Haas UF-3 and UF-4 trademarks to be used by all three companies. Acrylite OP-2 and OP-3 are distributed by CYRO Industries, Inc., 100 Valley Road, P.O. Box 950, Mt. Arlington, New Jersey 07856; telephone: 201-770-3000. Similar materials in Europe are ICI Perspex VE (similar to UF-3) and Perspex VA (similar to UF-4).

UV-absorbing glass with an optical anti-reflection coating is supplied under the Tru Vue Museum Glass name by Viratec Tru Vue, Inc., 1315 N. North Branch Street, Chicago, Illinois 60622; telephone: 312-943-4200; toll-free: 800-621-8339. A UV-absorbing "safety-glass" version of anti-reflection coated Denglas is available from Denton Vacuum, Inc., 8 Springdale Road, Cherry Hill, New Jersey 08003; telephone: 609-424-1012.

Plexiglas is supplied with protective paper or polyethylene cover sheets on both sides to prevent scratches during cutting and handling. Plexiglas may be cut with a table saw equipped with a fine hollow-ground plywood blade such as those sold by Sears Roebuck, Rockwell, and others. Production shops cutting large quantities of Plexiglas should use one of the fine-toothed, carbide-tipped blades especially designed for cutting acrylic sheet. These blades, which may cost more than $200 each, are available from several companies, including Forrest Manufacturing Company, Inc., P.O. Box 1108, 461 River Road, Clifton, New Jersey 07014; telephone: 201-473-5236. Coarse-toothed saw blades or blades with teeth which have been "set" should not be used because a rough cut and edge chipping will result.

Pre-cut Plexiglas UF-3 sheets (⅛ inch thick) are available from a number of suppliers, including Light Impressions Corporation, 439 Monroe Avenue, Rochester, New York 14607-3717; telephone: 716-271-8960 (toll-free outside New York: 800-828-6216); Conservation Resources International, Inc., 8000-H Forbes Place, Springfield, Virginia 22151; telephone: 703-321-7730 (toll-free: 800-634-6932); Plasticrafts, Inc. ,600 West Bayard Avenue, Denver, Colorado 80223; telephone: 303-744-3700; toll-free: 800-800-7567. Light Impressions offers both pre-cut standard sizes for frames and custom-cut sizes.

69. Sergio Burgi, "Fading of Dyes Used for Tinting Unsensitized Albumen Paper," a presentation at the **International Symposium: The Stability and Preservation of Photographic Images**, Klaus B. Hendriks, chairman, sponsored by the Society of Photographic Scientists and Engineers (SPSE) and held at the Public Archives of Canada (renamed the National Archives of Canada in 1987), Ottawa, Ontario, Canada, August 10, 1982.
70. Douglas G. Severson, "The Effects of Exhibition on Photographs," **Topics In Photographic Preservation – 1986** (compiled by Maria S. Holden), Vol. 1, American Institute for Conservation Photographic Materials Group (AIC/PMG), pp. 38–42, 1986. Available from the American Institute for Conservation, 1400 16th Street, N.W., Suite 340, Washington, D.C. 20036; telephone: 202-232-6636. For a somewhat revised version of the article, see: Douglas G. Severson, "The Effects of Exhibition on Photographs," **Picturescope**, Vol. 32, No. 4, Winter 1987, pp. 133–135. Also refer to the discussion in Chapter 7 of the print monitoring program at the Art Institute of Chicago. For a related discussion of the hazards of displaying photographs, see: Grant B. Romer, Note No. 1.
71. Suitable lighting equipment for illuminating photographic display areas is available from many sources, including: Lighting Services, Inc., Industrial Park, Route 9W, Stony Point, New York 10980; telephone: 914-942-2800 (Fax: 914-942-2177); Edison Price, Inc., 409 East 60th Street, New York, New York 10022; telephone: 212-838-5212; and Wiedenbach-Brown Co., Inc., 435 Hudson Street, New York, New York 10014; telephone: 212-243-4500.
72. UV-filter and neutral-density-filter thin polyester plastic films with an adhesive for application to windows and display cases are available from a number of suppliers, including the Solar Screen Company, 53–11 105th Street, Corona, New York 11368; telephone: 212-592-8223; toll-free: 800-34-SOLAR. Also, Scotchtint Solar Control Films are available from the 3M Company, 3M Center, St. Paul, Minnesota 55144; telephone: 617-733-1110; toll-free outside Minnesota: 800-328-1300.
73. Brian Coe, see Note No. 52.
74. Anon., "Drawers Used to Exhibit Light-Sensitive Books," **The Abbey Newsletter**, Vol. 11, No. 2, March 1987, p. 33.
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June 1985

High ceilings permitted this unobtrusive installation of incandescent tungsten track lights in the Pace/MacGill Gallery, one of the leading fine art photography galleries in New York City. To show photographs to their best advantage, the gallery has much brighter illumination — averaging about 650 lux — than that found in most museum exhibition areas. Exhibitions at Pace/MacGill typically last about a month.

Table 17.1 Survey of Lighting Conditions in Display Areas

These measurements of light intensity were made by the author between 1977 and 1987; a Gossen Panlux electronic illumination meter equipped with a flat diffuser disc was used for the measurements. On photographs and other works of art, the meter probe was placed over the most brightly illuminated portion of the image, next to and on the same plane as the surface of the object. In some instances, the lighting conditions found in a particular room or building are given as a range (e.g., 5000–8000 lux); in other cases, a number of individual readings represent high, low, and intermediate illumination levels.

In the past, the footcandle (fc or fcd) was the most common unit for measuring light intensity in the United States, Canada, and England; however, to conform with current international practice, the measurements reported here are given in lux units (1 lux is equal to 0.0929 footcandle; one footcandle is equal to 10.76 lux). Lux is sometimes abbreviated as lx. As a matter of convenience, illumination levels above 1,000 lux are frequently expressed in kilolux (klux) units; for example, 21,500 lux is usually given as 21.5 klux. For ease in making comparisons, however, kilolux units are not given in this table; all measurements are presented in lux units, regardless of how high a particular reading might be.

Light intensities on photographs were recorded over a very wide range — from a high of 32,000 lux (about 3,000 footcandles) on a Kodak Ektacolor RC print on display at the National Archives of Canada in Ottawa, Ontario, to a low of 8.5 lux (0.8 fc) on an 1872 Julia Margaret Cameron albumen print at the International Museum of Photography at George Eastman House in Rochester, New York; Eastman House also had display illumination levels as high as 5,170 lux (480 fc).

Tungsten illumination levels in museums and galleries ranged from a high of 2,100 lux (195 fc) at the Life Gallery of Photography in New York City, to a low of 8.5 lux (0.8 fc) at the International Museum of Photography at George Eastman House; tungsten illumination levels in photography display areas in museums and galleries typically were in the range of 130–300 lux (12–28 fc). The median intensity of all display locations in museums and archives in which tungsten lamps were the sole source of illumination was 160 lux (15 fc); in commercial galleries the level of tungsten illumination generally was higher, with a median intensity of 430 lux (40 fc).

When reviewing the measurements reported in this table, it should be kept in mind that the author has recommended that, in museums, archives, and galleries, photographs be illuminated with tungsten light at an intensity of about 300 lux (28 fc); some authorities have specified much lower light levels of about 50 lux (4.7 fc) for photographs and other works of art on paper.

The table is divided into four categories, with the median and average illumination intensities in the display areas listed below. The median intensity level is the middle reading of all the measurements when they are arranged in numerical order (if there is no middle value, which occurs when there is an even number of measurements, the median is calculated as the arithmetic mean of the two middle values). The average intensity is simply the numerical average of all the measurements in a group. The median intensity generally gives a better indication of "typical" illumination levels than does an average level; in three of the four groups, a relatively small number of measurements taken in extremely bright display areas caused the average intensity levels to be substantially above the median levels.

Because the fading rate of a color print is directly related to the intensity of the display illumination, the useful "lifetime" (defined as the length of time for a specified amount of fading and/or staining to take place) of a particular type of color print depends to a large extent on where it is displayed; with most modern color prints, the intensity of illumination is a much more significant factor in image fading than is the spectral energy distribution of the light source.

Location		Illumination Intensity: Median Level	Illumination Intensity: Average Level
A.	Museums and Archives	215 lux (20 fc)	1,057 lux (98 fc)
B.	Commercial Galleries	430 lux (40 fc)	549 lux (51 fc)
C.	Public Buildings (e.g., offices, libraries, hospitals, and airports)	1,325 lux (123 fc)	3,686 lux (342 fc)
D.	Homes	635 lux (59 fc)	3,213 lux (299 fc)
A, B, C, and **D** grouped together:		375 lux (35 fc)	1,808 lux (168 fc)

(continued next page)

A. Museums and Archives

The Art Institute of Chicago, Chicago, Illinois — New photography department galleries (1982); tungsten illumination controlled with dimmers.	130–160 lux
Dimmed tungsten through glass diffusers; “Paper & Light” exhibition in new galleries, 1982; calotype prints.	55–75 lux
Tungsten; 1543 Chinese handscroll, colors on paper.	375 lux
Photographic Print Study Room; indirect fluorescent reflected from domed ceiling, painted white.	540–860 lux
Fluorescent through plastic diffuser; photography room (Room 106).	240 lux
Tungsten; “Color photographs: Marie Cosindas, Eliot Porter.”	170 lux 160 lux 150 lux 125 lux 95 lux 60 lux
Tungsten; selections from the permanent collection.	130–240 lux
Watercolors and drawings (Room 108).	65–130 lux
Prints and drawings (Room 109).	85 lux
The Helen Regenstein Gallery.	55–65 lux
Fabric display durations: 3 months.	75 lux 45–55 lux
Museum of Modern Art, New York City — (new galleries — 1986) 30-watt incandescent reflector flood lamps; albumen, platinum, and other 19th-century prints.	65–160 lux
75- and 150-watt PAR incandescent reflector flood lamps; Ektacolor 74 RC, Ektacolor Plus, Ektacolor Professional, Cibachrome, Dye Transfer, and silver-gelatin prints.	175–380 lux
Museum of Modern Art, New York City — (old galleries — 1980) Tungsten lamps, with some diffuse daylight through glass; Ektacolor 37 RC, Kodak Dye Transfer, silver-gelatin, and albumen prints.	325 lux 240 lux 130 lux 85 lux
International Museum of Photography at George Eastman House, Rochester, New York — Diffuse daylight on a black-and-white photograph.	5,170 lux
Upstairs, northwest corner; diffuse daylight with some tungsten.	5,170 lux 1,600 lux 1,300 lux
Upstairs, southwest corner; diffuse daylight through glass with a small percentage of illumination from tungsten lamps; photographs framed with Plexiglas UF–3 or glass.	3,450 lux 1,940 lux 860 lux 650 lux 590 lux
Upstairs southeast corner.	1,560 lux 1,450 lux 1,400 lux
Upstairs; diffuse daylight through glass with some tungsten on color print (dye imbibition); print appears to have lost a significant amount of yellow dye.	1,300 lux
50% daylight, 50% tungsten; 1939 Nickolas Muray photograph.	1,300 lux
“Fashion Show” (photographs), October 8, 1977.	160–1,720 lux
Brackett-Clark Gallery; photograph display area; tungsten lamps.	1,400 lux 1,350 lux 850 lux 650 lux 590 lux 430 lux 370 lux
Brackett-Clark Gallery; tungsten, no daylight; 75-watt reflector flood lamps about 6–8 feet from prints; Eikoh Hosoe exhibit, 1982.	
Upper section of higher print on wall.	380 lux
Lower section of higher print.	270 lux
Lower print on wall.	95 lux
Average illumination.	160–215 lux
Brackett-Clark Gallery; Mark Goodman show; 150-watt reflector flood lamps approximately 8 feet from photographs.	270–325 lux
Tungsten illumination on Dye Transfer, Cibachrome, and Ektacolor prints.	240 lux
Tungsten; temporary exhibition, “The Photographers’ Hand” ; Dye Transfer and other color prints.	160–215 lux
Brackett-Clark Gallery; Pierre Petit salted paper and albumen portrait prints; 75-watt reflector flood lamps approximately 6 feet from prints.	130–160 lux
Brackett-Clark Gallery; exhibition, “Steichen – A Centennial Tribute.”	54–75 lux
Small room; tungsten.	32–54 lux
Permanent Exhibition Galleries (2nd floor) at night; tungsten.	32–65 lux
Permanent Exhibition Galleries (2nd floor); tungsten, 60-watt frosted lamps.	8.5–32 lux
Metropolitan Museum of Art, New York City — Stated museum policy is to not exceed 140–215 lux on photographs, displaying color photographs no more than 3–4 months every 5–10 years; UF–3 not used over color photographs. Tungsten; “Counterparts,” photography exhibit, 1982. Overall illumination.	45–160 lux
Illumination on 1979 Polacolor 2 print.	95 lux
Illumination on calotype print.	55 lux
Tungsten; illumination on Egyptian scrolls.	45 lux
The Historic New Orleans Collection, New Orleans, Louisiana — Tungsten reflector flood lamps and tungsten halogen lamps with glass filters. “New Orleans Now,” a 1987 exhibit of black-and-white photographs of modern New Orleans by Michael Smith; Ektacolor facsimile copies of 19th-century photographs; black-and-white photographs; manuscripts; lithographs.	130–320 lux
Corcoran Gallery of Art, Washington, D.C. — Tungsten; “Color as Form — A History of Color Photography,” exhibit, 1982.	32–215 lux
Museum of Fine Arts, Boston, Massachusetts — Daylight through glass; 1960 Morris Louis painting.	3,900–4,500 lux
Tungsten and daylight through glass in ceramics room.	3,000 lux
Daylight through white shade; John Marin oil painting.	2,700 lux
Daylight through glass mixed with fluorescent.	700 lux
Tungsten with some daylight; 1824 Gilbert Stuart oil painting.	460 lux

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Fluorescent; General Electric Warm White with UV-absorbing cover tubes; metal grid; Gilbert Stuart oil painting.	240 lux
Tungsten; 1757 oil painting.	130 lux
50% fluorescent mixed with 50% tungsten; Lewis Hine photograph, 1931.	130 lux
Tungsten; Lewis Hine photographs.	52–130 lux
Tungsten; Polaroid SX–70 print.	110 lux
National Gallery of Art, Washington, D.C. — New east building; daylight through tinted window glass; tapestry, paintings.	17,200 lux 1,900 lux 860 lux 220 lux
East building; gallery rooms; diffuse daylight with tungsten.	270–375 lux
East building; tungsten lamps; Picasso painting.	195–345 lux
Old building; mostly tungsten illumination and daylight through ceiling diffuse glass (skylights). Painting room; 13th-century paintings; 5:00 PM.	1,200 lux 775 lux 650 lux 590 lux 375 lux
Diffuse daylight; Claude Monet painting.	645–750 lux
Tungsten only; 15th–16th-century paintings.	110–130 lux
Hirshhorn Museum and Sculpture Garden, Washington, D.C. — Daylight through tinted glass on sculptures; no paintings or prints in this area.	2,700–21,500 lux
Second floor; tungsten spot lamps about 8–15 feet away from prints; "Grant Mudford: Photographs."	195–325 lux
National Museum of American History, Science, Technology and Culture, Smithsonian Institution, Washington, D.C. — Photography gallery, third floor; tungsten.	450 lux 345 lux 300 lux 195 lux 160 lux
Elvehjem Museum of Art, University of Wisconsin, Madison, Wisconsin — (Fluorescent tubes in skylights for night use.)	
Tungsten only.	240–540 lux
Tungsten and daylight (overcast day).	215–325 lux
Tungsten; skylight covered.	110–150 lux
Cleveland Museum of Art, Cleveland, Ohio — Diffuse daylight from full-roof glass skylight on very large fabric tapestry which is severely faded.	est. 5,400–8,600 lux
Diffuse daylight from full-roof glass skylight on Murillo oil painting (ca. 1660).	4,100–4,800 lux
Indirect daylight through windows.	3,450 lux
Tungsten lamp; black-and-white photographs.	200 lux
Tungsten.	130 lux
Yale University Art Gallery, New Haven, Connecticut — Mostly tungsten with some diffuse daylight.	1,240 lux
Tungsten exclusively; oil paintings.	1,130 lux
Tungsten exclusively; Fosburgh Collection; oil and watercolor paintings.	160–750 lux
Display case; tungsten illumination when case lid is open; early American miniature paintings.	340 lux

Tungsten and daylight; 17th-century Chinese drawings and paintings.	215 lux
1972 Dye Transfer print; tungsten.	195 lux
Lyndon B. Johnson Library, Austin, Texas — Display transparencies mounted on light boxes; yellow dye loss severe, also magenta dye loss, edge-fading effects; illumination measured on d-min film side. (These back-lighted display transparencies are intended to be replaced periodically.)	1,080–1,600 lux
LBJ Oval Office exhibit; fluorescent and diffuse daylight through windows; family photograph on display.	160 lux
Humanities Research Center, University of Texas, Austin — Vault area.	160–215 lux
Michener Gallery; tungsten spot lamps.	160–215 lux
Gutenberg Bible; case monitored.	325 lux
Museum of Art, University of Iowa, Iowa City, Iowa — Print room.	350 lux 170 lux 160 lux
Tungsten; photography exhibit; Ektacolor 74 RC prints and others.	300 lux 240 lux 170 lux
Tungsten, about 20% daylight.	240 lux
Oil painting.	170–260 lux
Tungsten, some daylight; photographs exhibited.	160 lux 120 lux 85 lux 65–75 lux 50–65 lux
Friends of Photography Gallery, Carmel, California — Tungsten; 150-watt reflector flood lamps, about 6 feet from photographs.	540–860 lux
National Archives, Washington, D.C. — Tungsten; exhibition area; exhibit, "A Matter of Identity."	100–160 lux
Tungsten, UV filter; Bill of Rights.	32 lux
Tungsten, UV filter; Declaration of Independence.	8 lux
National Archives of Canada, Ottawa, Ontario — Direct sunlight each morning on Ektacolor RC print framed behind glass.	32,000 lux
Print display area; fluorescent light through plastic diffuser.	540 lux
National Gallery of Art, Ottawa, Ontario — Gallery policy is to not exceed 50 lux (4.7 fc) on prints, drawings, and photographs.	
Photograph area; Ektacolor 37 RC and 74 RC prints, Cibachrome prints, Dye Transfer prints, and black-and-white prints.	55–85 lux
Tungsten lamp; illumination on oil paintings, watercolors.	300 lux 160 lux 150 lux 130 lux 85 lux 55 lux 32 lux

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Galeria de Arte Nacional, Caracas, Venezuela — Diffuse daylight; various rooms.	6,200 lux 3,300 lux 2,800 lux 2,600 lux 1,700 lux
One dark room; mostly daylight with some tungsten.	150–200 lux
Daylight only.	110 lux
Museo de Bellas Artes, Caracas, Venezuela — Tungsten.	160–430 lux
50% tungsten, 50% daylight.	215–325 lux

B. Commercial Galleries

Life Gallery of Photography, New York City — Time & Life Building, Room 28-58. Glass-filtered tungsten halogen lamps 4 to 6 feet from the photographs; November 1986 exhibit, "Life Photographs from the First Fifty Years: 1936–1986"; Ektacolor, Dye Transfer, Cibachrome, and black-and- white prints. (Illumination intensity in small areas near the center of some prints reached 4,800 lux.)	800–2,100 lux
Light Gallery, New York City — Tungsten; May 1982 exhibit of photographs.	860–1,900 lux
Pace/MacGill Gallery, New York City — Tungsten; June 1985 exhibit of Ektacolor, Cibachrome, Kodak Dye Transfer, and black-and-white photographs.	460–940 lux
Laurence Miller Gallery, New York City — Tungsten reflector flood lamps; November 1986 exhibit, "Real Pictures from 'True Stories'," by Len Jenshel; Ektacolor Plus prints.	325–430 lux
Tungsten reflector flood lamps; November 1986 photography exhibit, "Cherry Blossom Time in Japan," by Lee Friedlander; gravure prints.	215–270 lux
Witkin Gallery, New York City — Tungsten illumination on color and black-and-white photographs.	650 lux 540 lux 480 lux
Castelli Graphics, New York City — Tungsten reflector-flood lamps; graphics, color and black-and-white photographs.	325–430 lux
Photofind Gallery, New York City — Tungsten reflector flood lamps; November 1986 exhibit of Imogen Cunningham black-and-white prints.	430–540 lux
Marcuse Pfeiffer Gallery, New York City — Tungsten reflector flood lamps; November 1986 exhibit, "Illuminations: A Bestiary," by Rosamond Wolff Purcell; Cibachrome RC prints.	110–215 lux
A Gallery for Fine Photography, New Orleans, Louisiana — Tungsten reflector flood lamps; February 1987 exhibit of Dye Transfer, Cibachrome, Ektacolor, contemporary black-and-white photographs, and 19th-century prints.	120–300 lux
The Weston Gallery, Carmel, California — Tungsten, brightest area.	800 lux
Tungsten, overall.	130–430 lux
New West Gallery, Carmel, California — Tungsten.	160–325 lux

C. Public Buildings

Hopkins International Airport, Central Lobby, Cleveland, Ohio — (Semi-diffuse sunlight through acrylic skylights.)	
Bright areas of lobby.	21,500 lux
On fabric mural on wall for many hours each day.	19,400 lux
Diffuse daylight through skylights in darker areas of lobby.	4,100 lux
National Research Council Library, Ottawa, Ontario — Indirect daylight through very large tinted-glass window; winter day.	10,330 lux
Large wall; sunlight through tinted full-length window.	9,680 lux
Stack area; indirect diffuse daylight through full-length window.	5,160 lux
Reading room; diffuse daylight through full-length window.	1,500 lux
Diffuse daylight through glass, mixed with fluorescent lamps with plastic diffusers.	1,200 lux
Lambert International Airport, St. Louis, Missouri — Main terminal; daylight through tinted acrylic.	6,250 lux
Main terminal; diffuse daylight through glass; commercial Ektacolor prints on display.	5,600 lux 4,950 lux 3,450 lux 2,580 lux 1,180 lux
Houston Intercontinental Airport, Houston, Texas — Exhibit in main terminal of Ektacolor Professional prints by Gittings Studio entitled "The People of Houston." Illuminated by metal-halide lamps and indirect daylight through tinted glass; prints framed under glass (1987).	110–160 lux
Law Office, Des Moines, Iowa — Diffuse daylight through tinted window glass; wall area away from window; lithograph on wall very faded after about 2 years.	3,800–5,160 lux
Law Office, Des Moines, Iowa — Daylight through window glass and fluorescent light.	4,300 lux
Oberlin Art Conservation Laboratory, Oberlin, Ohio — Office area: diffuse daylight through glass and direct fluorescent (General Electric Cool White); Polacolor 1 print kept on desk for several years severely faded; estimated 20% daylight.	
Across from window.	3,450 lux
Wall near window.	1,130 lux
Direct fluorescent lamps through metal grid. Some daylight.	
On work desk.	2,360 lux
On lower wall.	540 lux
Laboratory; tungsten lamp illumination on Ektacolor print.	1,180 lux 345 lux 160 lux
Motel room, Oberlin, Ohio — Sunlight through window, at times directly on framed lithograph on wall.	56,000 lux

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Diffuse daylight through glass.	3,500 lux 1,800 lux 1,560 lux 970 lux
National Archives of Canada, Ottawa, Ontario — Office; diffuse daylight through large window onto shelf and wall area.	3,440 lux
Fluorescent lamp through plastic diffuser; work table; some daylight.	1,400 lux
Diffuse daylight and fluorescent through plastic diffuser; approximately 50% daylight and 50% fluorescent light.	1,180 lux
National Archives, Washington, D. C. — Office; fluorescent light through plastic diffuser above desk in alcove.	2,370 lux
Iowa State University Library, Ames, Iowa — Library reading room; daylight through glass, with some fluorescent directly through metal grid; oil painting on wall.	2,260 lux
Display case; direct fluorescent lamps; photographs not covered with glass.	860–1,300 lux
Reading room; direct fluorescent lamp through wide-spaced metal grid, with some daylight through glass.	1,180 lux
General illumination.	540–1,200 lux
Television office, Owings Mill, Maryland — Direct fluorescent lamps; no cover or grid; Westinghouse Cool White.	1,830 lux 1,290 lux 1,180 lux
Modern Photography editorial office, New York City — Fluorescent light through plastic diffuser; some indirect daylight through window glass; Ektacolor prints on display, covered with glass; older Ektacolor prints show significant magenta dye loss.	1,350 lux
Direct Cool White fluorescent light through metal grid (ceiling).	
On desk (some daylight).	590 lux
On wall (overcast day).	325 lux
Office wall; color print on display.	215 lux
University of Iowa Hospitals, Iowa City, Iowa — Exam room; direct fluorescent lamps through metal grid; Ektacolor print on display without glass; some daylight through window.	1,500 lux 1,300 lux 540 lux
Park Plaza Hotel, Boston, Massachusetts — Daylight through glass.	195–1,450 lux 320–860 lux
Time Inc., Time & Life Building, New York City — Office, Room 24-18; fluorescent illumination.	650 lux
Nassau Bay Resort Motel, Houston, Texas — Indirect daylight on wall through glass and solar control film.	430–650 lux

D. Homes

House, Grinnell, Iowa — Direct sun in room (not on a photograph).	86,000 lux
2nd floor room; snow on ground, indirect daylight.	2,800 lux
2nd floor room; nighttime, tungsten light.	75 lux
Kitchen; daylight, snow on ground.	1,350–1,700 lux
Kitchen at night, fluorescent light.	430 lux
Daylight through window glass.	1,290 lux
House, Ottawa, Ontario — Kitchen; direct daylight through glass.	23,670 lux
Kitchen; indirect daylight through glass.	1,720 lux
Bright, relatively small area on wall.	3,900 lux
Diffuse daylight through glass.	1,500–1,720 lux
Daylight through window glass.	1,180 lux 860 lux 540 lux
Apartment, Chicago, Illinois — Bedroom; indirect daylight through window glass; large window facing south; white walls; 11:30 AM.	4,850 lux 2,260 lux 1,940 lux
Living room; indirect daylight through window glass (and through screens in June); 11:30 AM.	3,660 lux 1,940 lux 620 lux
Modern house, Kennett Square, Pennsylvania — Diffuse daylight through glass in summer.	3,300 lux
Indirect daylight through window onto wall.	480–650 lux
Modern house, Laytonsville, Maryland — Living room; large windows; indirect daylight.	700–2,370 lux
Room where photographs of seven generations are displayed on a wall; indirect daylight.	485–1,670 lux
Older house, Iowa City, Iowa — Indirect daylight through window glass.	325–1,185 lux
House, Quebec City, Quebec Living room walls; indirect daylight through window glass.	375–970 lux
Kitchen; daylight through window glass mixed with tungsten.	215–485 lux
House, New Haven, Connecticut — Diffuse daylight through glass.	860 lux 485 lux 325 lux 215 lux
Old house (1896), Madison, Wisconsin — Daylight through window glass.	
Bedroom — near ceiling.	590 lux
Bedroom — near floor.	235 lux
Living room.	375 lux
Hall.	45 lux
Tungsten light at night;	
Dining room.	48–75 lux
Kitchen.	32–65 lux
Living room.	16–45 lux
House, Montreal, Quebec — Photograph display area; diffuse daylight mixed with tungsten.	32 lux 11 lux