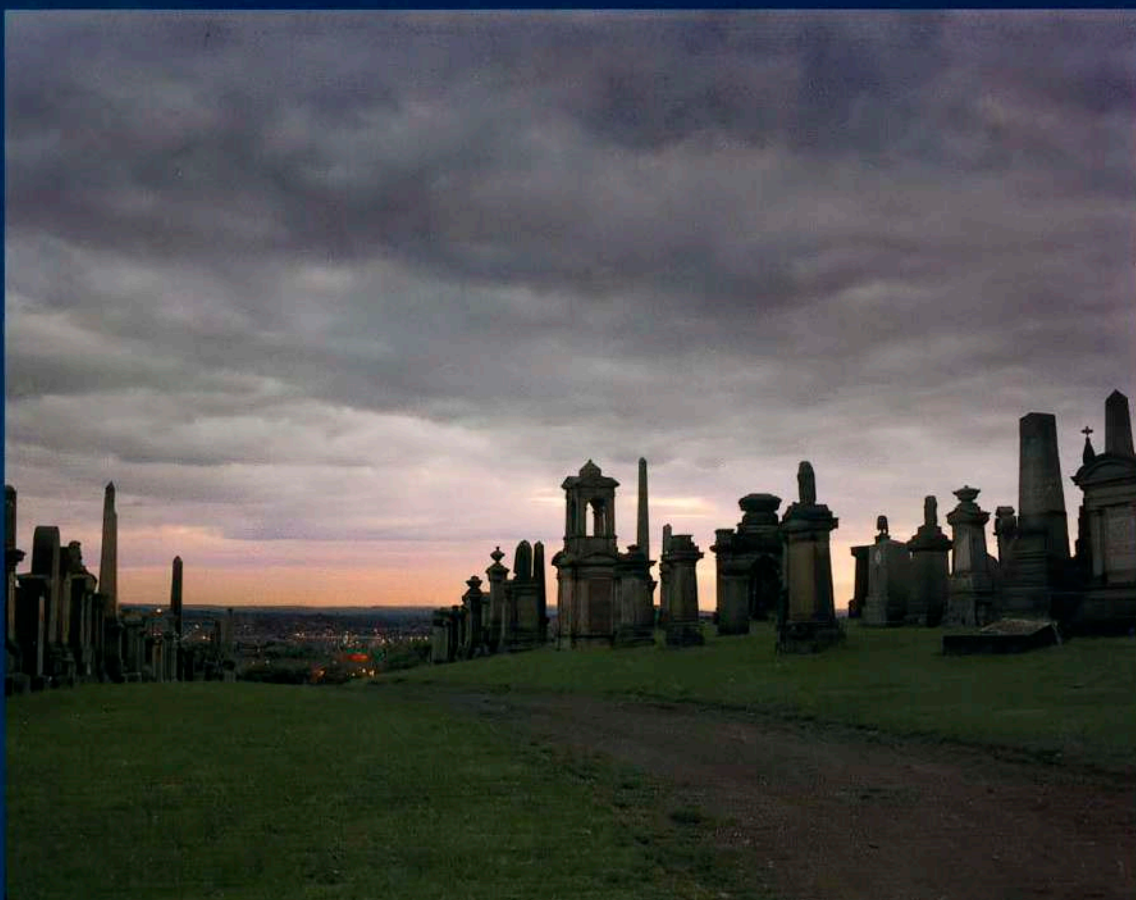
POST EXPOSURE

Advanced Techniques for the Photographic Printer

Second Edition



CTEIN

Focal Press

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Advanced Techniques for the Photographic Printer

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BOSTON OXFORD JOHANNESBURG MELBOURNE NEW DELHI SINGAPORE

You can reach me at ctein@pobox.com.

Thank you!

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This book is dedicated to Ray Bradbury,
without whose encouragement I would not have become the photographer I am today.

It doesn't matter how you get there, if you don't know where you're going.

—The Flying Karamazov Brothers

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Preface

Ansel Adams observed that the film is the score and the print is the performance. When I exhibit my best prints to an appreciative audience, I feel akin to the Wizard of Oz. Dorothy and her companions were supposed to see only that majestic head with the spouting flames and smoke and to ignore the little man behind the curtain pulling the levers. If I am successful as a printmaker, my viewers look at my work with joy at its beauty. They don't note the tricks, manipulations, and outright visual deceptions that go into making a print that inspires awe.

I've been doing serious photography for 37 of my 51 years. By the time I'd taught myself how to make dye transfer prints from my color negatives, back in 1975, I thought I was a pretty hot printer. Now I know I wasn't half as good as I thought. Twenty years hence, I'll look back and again be embarrassed by how much I thought I knew. Fine printmaking is an everlasting learning experience for all of us.

When I began my life in the darkroom, prints were still universally made on fiber-based paper, C-22 processing was standard for color negatives, E-3 was still common for some transparency films, and Cibachrome (now Ilfochrome) had yet to take its place in the darkroom community. Many materials available to the typical darkroom worker have improved immensely. We have also seen changes for the worse. Dye transfer printing was killed by Kodak in 1993. Although a few other printers and I still make these finest of prints, our supplies are limited and our prospects for ever getting more are uncertain.

Although materials have changed over the years, I've found the principles of fine printing haven't. Master printmaking is a discipline requiring both talent and knowledge and no small amount of legerdemain. The discipline doesn't come from the specific printing materials one uses or whether one prints black and white (B&W) or color or even whether one works in the darkroom or at a computer. The methods of fine printmaking are rooted in our own perceptions, the ways the human vision system sees the world, the ways that photographic materials see it differently, and immutable laws of optics and nature.

This book is not a primer on photographic printing. I'm not going to tell you how to develop a roll of film or process a print, and I assume you have a working knowledge of photography. Its purpose is to teach photographers the refinements of photographic printmaking, to take them from making those merely competent prints to making excellent ones.

This book brings together disparate fields of knowledge, distilled from my three decades of learning and experience in color and B&W photographic printing. In learning about both a human's and a film's perception of the world, you'll pick up some informational tidbits about color theory, the nature of the human visual system, information and measurement theory, neurophysiology, and other arcane topics. Still, most of this book is about tools, techniques, and darkroom procedures; I intend this to be a practical book, not one of difficult-to-apply theory.

Even novice printers can learn from this book. Some of what I say is pretty fundamental, but it is information most photographers don't know and won't find in the average photography book. I intend this book to be useful to anyone making color or B&W prints, including people working with a computer instead of an enlarger. One can't entirely fix an ineptly photographed image on a computer any more than one can fix it in the darkroom. If one doesn't understand the principles of good printmaking or have a real understanding of what the viewers truly see when they look at a print, one is no more likely to produce a truly fine print with the aid of a computer than with an enlarger. The tools change, but the principles don't.

Results speak for themselves. You can see several dozen of my finest photographs on your computer. I've created a Web site called Ctein's Online Gallery (http://www.plaidworks.com/ctein/), which contains very high-quality screen images of some of my dye transfer photographs. My site also includes a smattering of articles by me, including a lengthy one on dye transfer printing, and hints and tips for viewing images on your computer with the best possible fidelity. You can also reach me through my e-mail address (71246.216@compuserve.com). I do enjoy hearing from my fans!

Acknowledgments

So many people have helped me over the years that there is no way I can thank them all. I feel a special appreciation must go to Frank McLaughlin and Bob Nadler; their support and sage advice helped make me the fine printmaker and photographic writer I am today.

I am grateful to Tammy Harvey, whose very hard work made this book possible. I am equally grateful to Jodie McCune, whose equally hard work made it *real*.

For everything, from suggesting the structure of this book to suggesting its title, I owe an enormous debt to Laurie Toby Edison, a fine photographer and my finest friend, now and always.

Last, and most definitely not least, I thank my dear housemate, Paula Butler, for contributing unflagging love and support, helpful feedback and commentary, and a knowledge of grammar vastly superior to mine.

Introduction

A photographic print is not reality but interpretation, a mere mapping of reality. This simple core truth of photography is ill-understood and frequently ignored. The photographic map of visual reality is no more accurate than the familiar Mercator map of the earth, with its huge Greenland and diminished tropics.

At the beginning, there is a photographer looking at the real world; at the end, a viewer looking at a photographic print. In between lies a long, narrow, twisted pipeline called the photographic process, which stretches, squeezes, and rearranges the world. Each segment of that pipeline adds its own biases that emphasize its strengths and introduce new weaknesses. The photographer and printer direct the overall interpretation, but results are equally controlled by the characteristics and limitations of each of the components of that process—the film, the paper, and human vision. For photographers to make truly excellent prints, they need to understand how the entire photographic pipeline works and how they can manipulate it to their ends. To extend Adams's metaphor, although a master printer can produce a superb print from a less-than-masterful slide or negative, it's a lot better to have a great score and play in a good hall.

One can be an entirely competent printer yet still not know how to make quality prints. Understanding the twists and turns in the photographic pipeline, taking advantage of the components' strengths and knowing where the weaknesses lie is how one makes truly effective photographic prints. As photographers, we try to photograph what we see. Even if our ultimate objective is to utterly transform that vision in the darkroom or the computer, we usually begin with what our eyes perceive, and we always end with what the viewer sees in our images. Densitometric measurements do not define a superb print; the viewer's reactions do. Only a handful of printers know much about what viewers actually see when they look at a print. You must understand something of that or you won't be able to figure out what your printing objectives are; you'll be like a gourmet cook who doesn't know what tastes good. Consequently, the very first chapter is about human vision because that's critical to understanding how we choose to make photographs, how we need to print them and display them, and the ways in which those prints cannot live up to our expectations.

We're not talking about creating art, per se; we are talking about how the many steps in the photographic process confine the artist and about what those steps' potentials are so the artist can create art that speaks to the viewer in the way the artist wishes it to. Films simply don't see the world the way humans do; they do not reproduce color or tone as we see it. Few photographers really understand how the film sees light differently from humans; it's the next twist in the pipeline and the subject of the second chapter of this book. Most darkroom workers do not really understand how their print materials respond during printmaking—yet another bend and another chapter.

Although I hope that you will sit down and read this book cover to cover, I'm a realist. Each chapter stands on its own as much as possible. When chapters build on material that I have covered previously, I'll point this out and direct you to the appropriate portions of the book. I've put as much of the theory in the early chapters as I possibly could. If you just want to learn from my techniques and don't care (or already know) how and why they're important, you can skip ahead.

I believe that *why* you do something in the darkroom is perhaps even more important to knowing how to make truly fine prints than knowing *what* to do. Mere technique won't make you a great printer; you also need to understand your goals. This book will help you understand where you're going and how to get there.

CHAPTER 1

How We See

Sharpness

Photographers frequently underestimate the eye's ability to distinguish fine detail in a subject and just what it takes to make a truly sharp photograph. For instance, I once read an article by an outdoor photographer, promoting his handheld, long-lensed 35mm nature photos as utterly sharp 30" x 40" prints. I don't know what he meant by "sharp," but I'm sure it isn't what I mean by it. I want SHARP!

How much detail *does* it take to make such a print look sharp? For the purposes of our discussion, let's think about an 8" x 10" print held in the viewer's hands at a comfortable viewing distance of half a meter. There can be prints that are "adequately" sharp and those that are "perfectly" sharp. Adequate sharpness is the degree of sharpness in which someone looking at a print with nothing to compare it to says that it looks sharp. In practical terms, perfect sharpness means the point at which, if I increase the sharpness further, I can see no difference in side-by-side comparison prints.

You might think that these are indeterminate concepts, but we can pin them down. Sharpness is a combination of resolution (the finest detail we can see) and acutance (how crisp the edges look). We'll get to the subjective factors in a bit; first we consider resolution. Just as we describe any musical sound by a spectrum of audio frequencies, we can break down any visual image into a spectrum of spatial frequencies. We measure sound frequencies in cycles per second (Hertz); similarly, we measure spatial frequencies in line pairs per millimeter (lp/mm).

Figure 1–1 shows some bar patterns that vary in spatial frequency from 0.3 lp/mm to 0.6 lp/mm.

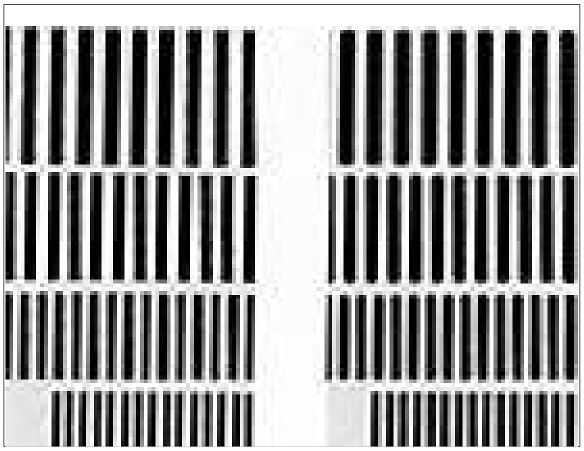

Figure 1–1 This is a pair of bar charts. The left half is tack-sharp; the right is fuzzy. The resolutions in both halves are the same, starting with 0.3 lp/mm for the top row of patterns and going to 0.6 lp/mm for the bottom row of patterns. If one views the figure from about 10 feet away, one will be able to resolve the lowest resolution patterns in both halves, but not the finest ones. One should see the same resolutions in both halves, but the left side should look sharper.

No one will question the sharpness of a print that displays detail down to 100 lp/mm. Going to 200 lp/mm will not make the print look any sharper; we can confidently call the 100 lp/mm print "perfectly sharp." However, no one will accept as adequately sharp a print that displays details no smaller than 5 mm in size (0.1 lp/mm). Adequacy lies somewhere between.

By testing and recording the observations of large numbers of people, we find that the point at which most viewers say "it's sharp" is when an 8 x 10 print displays 3 to 5 lp/mm resolution. For the sake of discussion, let's call 5 lp/mm adequate. (After all, we're assuming people with critical perceptions will be viewing our work, right?) The result changes under different viewing conditions. The level of detail needed goes down in proportion to the viewing distance; if you're standing 5 meters away from a very large print hanging on a wall, you certainly don't need 5 lp/mm in the print for it to look sharp. The sharpness requirement also drops if you're looking at a print under very dim light or in a situation in which there's a lot of glare.

Subjectively, a lot of other factors come into play. In particular, we perceive an image as being sharp if it has a lot of fine detail in it. The detail doesn't have to be informative—film grain will do! When viewers compare two equally sharp prints, one made from a grainy negative and the other from a very-fine-grained negative, they almost always pick the grainier image as being sharper. This is one of the reasons why any visible grain in your prints must be crisp. Viewers interpret mushy grain as being a fuzzy picture. The effect can be very subtle, and viewers may not be consciously aware that the grain is anything but tack-sharp. Nonetheless, they react to it!

Grain also acts as a type of visual noise, and our sensory systems tend to reject signals buried in the noise as being irrelevant. This has an odd effect on our perception of sharpness; a very-fine-grained print may reveal there is no subject detail beyond a certain level of resolution, which would be below the detection threshold in a coarse-grained print. We notice the lack of sharpness in the fine-grained print but unconsciously assume that everything must be sharp in the coarse-grained print, because we can't actually see the lack of sharpness because of the noise.

We also confuse high contrast or color saturation with high sharpness. That's why it is most important to have repeatable and reasonably objective ways to test your equipment. Unless you have a very well-trained and exceptionally disciplined eye, you cannot reliably judge sharpness from looking at photos of different ordinary subjects.

So much for defining "adequate." How shall we define "perfect?" The same kinds of viewer tests that determine adequate sharpness can find the limits of human vision. A viewer with very good eyes, looking at a contrasty bar chart under good light, is just able to resolve about 10 lp/mm at about a half-meter distance. This figure varies with distance, just as "adequate sharpness" did. Does this settle the matter conclusively? Unfortunately, no. There's more to sharpness than mere resolution; there's acutance.

Some of you will remember Kodak Ektaflex prints, discontinued in the late 1980s. Many pho-

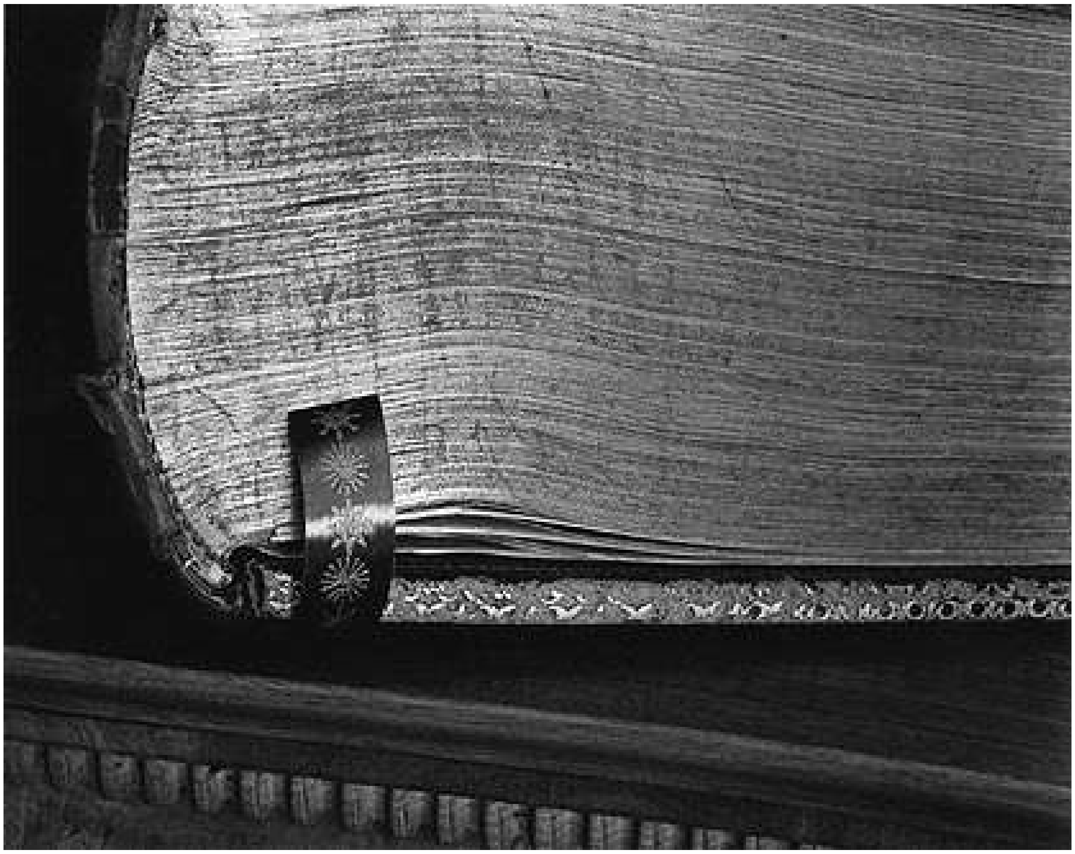

Figure 1–2 This photograph of a family bible, made on Kodak Panatomic-X 120, depends primarily on sharpness for its impact. The myriad fine transitions from bright to dark in the binding, pages, and wooden table impart a lively presence to this print.

tographers observed that these prints weren't as sharp as chromogenic ones. Viewers observe the same to be true of dye transfer prints. Objective testing showed that Ektaflex can display 20+ lp/mm; dye transfer does better than 15 lp/mm. A typical RA-4 color-negative paper can reproduce around 65 lp/mm. These numbers are all well above the 10 lp/mm visual limit.

What's going on? If the human eye can only resolve 10 lp/mm, why does a print that resolves 20 lp/mm look less sharp than one that resolves 65 lp/mm? It's because human vision doesn't just resolve fine detail, it selects for and analyzes edge detail. The human eye can see whether edges are blurry even in the finest observable detail. This is where acutance comes in. The human eye is even better at sensing acutance than resolution. At 10 lp/mm, we can readily see a difference in sharpness between crisply rendered lines with sharp edges and very blurry lines of the same resolution.

I'll spare you the math, which is beyond the scope of this book (it involves Fourier transforms, if you want to work it out for yourself). The difference between a sharp edge and a fuzzy one (a square wave and a sine wave) corresponds to a difference in spatial detail three times finer than the line spacing. In other words, the resolution difference between 10 lp/mm of sharp edges and fuzzy ones is way down around 30 lp/mm. When we notice a difference between those blurry and sharp 10 lp/mm lines, we are responding to detail at 30 lp/mm, even though we can't directly see it. That's why materials such as dye transfer and Ektaflex, which display about 20 lp/mm, look fuzzier than chromogenic prints with over 60 lp/mm. In a side-by-side comparison, you won't see any more fine detail in a chromogenic print, but you will perceive the detail you can see as sharper.

Figure 1–1 shows the effect of acutance. The bars in the left half of the picture have very high acutance—the edges of the bars go instantly from black to white. The bars on the right have blurry edges. Stand up the book about 10 feet away—far enough so that you can resolve the separate stripes in the top bar sets but not in the bottom ones. You should be able to resolve the same number of sets of bars on both the left and right sides. That's resolution. You also ought to be able to observe that all the stripes you can resolve seem sharper on the left than on the right. That's acutance, conveyed by spatial frequencies three times or more finer than the finest bars you can see.

Consequently, although our standard for "adequate" sharpness need be no more than 5 lp/mm in an 8 x 10 print, it has to be 30 lp/mm for "perfect" sharpness. As we'll see later in the book, achieving this is a daunting task. If you want to dive deeply into the topic and study the many techniques for maximizing sharpness, I recommend *Image Clarity,* by John B. Williams (Focal Press, 1990, ISBN 0-240-80033-8).

Digital printers are not exempt from these principles. It takes two pixels to make a line pair. The best of today's digital printers render about 400 square pixels per inch, or 16 pixels per mm. That corresponds to 8 lp/mm in the X and Y directions and 5.5 lp/mm on the diagonals. Hence, today's printers can produce prints that are more-than-adequately sharp, especially in the larger print sizes.

Our Vision of Tonality

If you were surprised to find out how well we can sense fine detail, you're going to be equally surprised to learn how poorly we see gradations of light and dark. This quality is what we think of as tonality and what scientists call the eye's psychophysical function.[1]

The average photographer doesn't understand tonality very well. If you've encountered the war over digital vs. analog images (almost as pointless as the Mac vs. the PC battle), then you've heard the assertion that analog systems, like our eyes and photographic materials, are superior to digital ones because they see "continuous" tones. We supposedly are able to see an infinite gradation of tones; similarly, we believe our films do the same. On the other hand, digital media assign a fixed number of bits to describe the brightness or tonal quality of a subject. For instance, an 8-bit system can assign only 256 different gray values to a subject. In fact, there are limits on our eyes' or our films' abilities to discriminate between tones. Our eyes distinguish a surprisingly small number of tonal steps—fewer than many films and digital sensors can. We don't notice this because our perceptual systems work to produce an illusion of continuity. We aren't aware of the steps in our gray response any more than we notice the "blind spot" in our retinas under normal circumstances.

Here's a thought experiment that will make that illusion clear. Imagine we are looking at a uniform square that has a fixed luminance (surface brightness) of 1.00 lamberts. A lambert is a unit for measuring luminance: 1 lambert is about the brightness of a middle gray on a slightly hazy day. Next to that square we'll put a similar square whose luminance we can adjust to any level we wish. If we make the brightness of the second square 1.00 lamberts, then the two squares will look like a single uniform rectangle. How much different in brightness do we have to make the two squares to see two distinct squares? If we make the second square only infinitesimally brighter than the first—say, 1.000001 lamberts—we certainly won't see any difference between the

1. H. L. Resnikoff, On the psychophysical function, *Journal of Mathematical Biology* 1975; 2: 265-276. This article is my primary source for information on the eye's psychophysical function. I recommend it highly, but only if you can cope with some set theory and basic calculus.

two squares; they'll still look like a single uniform rectangle.

After some trial and error, we would find that we need to make the difference in brightness between the two squares about 2% to actually be able to tell them apart. In other words, if we set square 2 to 1.01 lamberts, the two adjacent squares would still look like one uniform rectangle, but if we set it to 1.02 lamberts, we will see them as distinct. We've determined the just-barely-distinguishable luminance increase from 1.00 lamberts.[2]

We set square 2 to 1.02 lamberts. Now we add a third square and adjust it so that we can just barely distinguish it from square 2—say, 1.0397 lamberts—and then add more squares of just-barely-distinguishable greater brightness. Eventually, we will reach a point at which the squares are so blindingly white that we can distinguish nothing brighter. Now we go back to square 1; we add dimmer and dimmer squares of just-barely-distinguishable luminance differences until we have a square that is so dark that even a dark-adapted eye cannot distinguish it from a truly perfect blackness.

We have now constructed a gray scale that spans the entire range of brightness a human eye can see. This scale contains the maximum number of discrete tones we can see, because each square has the smallest detectable brightness difference from those around it. This scale defines the eye's psychophysical function. Remarkably, it has only about 650 squares in it. At best we can distinguish tonal differences as small as 0.006 density units (d.u.), about 1.5%. At the dark end of the scale we may need a brightness change of up to 0.15 d.u. (40%) to see any difference. Our ability to discriminate tones also deteriorates at the high end of the scale.

"Perfect" tonality for the average viewer requires only about 650 gray steps. You can always put more squares into the tonal scale. For example, you can put that 1.01 lambert square back between the 1.00 and 1.02 squares, but you won't be able to see it as a distinct square; it will blend perfectly into the squares on either side. No matter what you do to the gray scale, the average human will never see more than 650 squares. Visual artists frequently have better eyes than the average person, but the number of steps is still well under 1000.

Okay, if we can't squeeze squares in between the existing ones, could we start the whole series at a different point, such as 1.012 lambert, so that we could see the intermediate tones? No, it wouldn't work. Even if we started our gray scale with a value of 1.012 lamberts, we'd find that the next brightest distinguishable square would still be about 2% brighter than our starting square (about 1.032 lamberts). The new gray scale would still have only about 650 squares; they'd just be slightly shifted in density from our original scale.

Because the luminance of the new scale would differ from the old one by an amount too small for us to distinguish, we really wouldn't be able to tell the first scale from the second. If we put the two scales side by side, they would look like one double-width scale. It doesn't matter that a sensitive photometer can read smaller differences. We can't see them, and that means they don't count as far as photography is concerned. Visually, brightness is quantized, and intermediate values don't exist.

In truth, our photographic tonality is even more restricted than this. Those 650 steps span the entire range of human vision, from perfect blackness to blinding whiteness—a luminance range of about ten billion to one. A photographic image, whether it is a print or a slide, uses only a portion of that full gray scale. How many gray steps can we see in a good photographic print with a density range of about 2.3 (a brightness range of 200:1)?

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2. Exposure, *Photo Topics and Techniques*, Amphoto & Eastman Kodak, 1980 (out of print). This has a very intelligible description of luminance, illuminance, and reflectance for those who want to understand that arcane terminology and learn how to measure these things for themselves. Warning: there are a few insidious typos in the equations and text, but if you can follow the logic of the article, you'll also be able to tell where the typos are.

Figure 1–3 The human eye's ability to see an extremely long luminance range presents a major challenge to the photographer trying to produce "realistic" renderings of tone and brightness. I made this photograph of a half moon above the Pacific Ocean on Kodak TMAX P3200 film, a relatively low-contrast high-speed film. The print required extensive dodging and burning-in to simulate what I could easily see in the scene.

We can use our scale to answer that question. We first pick a "white" square. Which one we call white depends on how brightly we illuminate the print. Then we pick another square that is 200 times dimmer and call it "black." We count the number of squares between the two to determine the maximum number of tonal steps visible in the print for that illumination level.

We can try different starting points to see which one gives us the best tonality. We know it'll be poor under extremely dim or bright illumination. If we move the 200:1 range up and down the scale, there will be some point at which we will have bracketed the maximum number of squares. That tells us the ideal viewing light level and the number of tonal steps we can see in that print under such conditions.

The maximum number of tonal steps is between 250 and 300 when the print is viewed under 200 to 300 foot-candles (ft-cd) illumination. With more or less light than that, you'll see less tonality in the print. If you increase the density range of the print, you can distinguish more steps. If you could make a print with a 1000:1 range (3.0 d.u.), you'd see about 350 steps under about 500 ft-cd illumination.

Those are very high light levels for photographic display. A sunny day is about 7200 ft-cd, but a typical well-lit office or home interior during the day is only about 100 ft-cd. At night, home interiors run 20 to 40 ft-cd. What do you lose by viewing a print under 20 ft-cd instead of 200? You'll see only 75% as many distinct gray steps as you could before. Most of the loss is in the blacker tones. The darkest 25% of the density scale will lose at least 50% of its tonality; the lightest 25% of the density scale will lose almost nothing. Conversely, if you take one of your prints out into direct sunlight, you'll see great tonal separation in the deepest blacks, but the whites will be so blindingly bright you'll lose the ability to distinguish between highlight tones.

You can measure the brightness of the light (illuminance) that is illuminating your photographs with an ordinary light meter. Place a sheet of white paper where the photograph would be. Set your meter for a film speed of ISO 160 and take a reading off the white paper. Note the exposure time for an aperture of f/5.6. The reciprocal of that time is the illuminance in ft-cd (to within about 10%). For example, if your meter reads an exposure of 1/125th second at f/5.6, then the illuminance is about 125 ft-cd.

Color also affects our ability to distinguish tones. For example, we can distinguish less than half as many tonal steps in deep blue light as in white light. We also have considerable trouble seeing a change in brightness if it's spread out over a large viewing angle. Our ability to distinguish subtle tone (and color) differences is greatest when there's a sharp demarcation. Anyone who has ever tried to evenly light a backdrop

Figure 1–4 Good tonal rendition, a long recorded luminance range, and fine detail are all important in this photograph. Good tonal rendition with strong midtone separation is the key to bringing out the clouds in the sky and the subtle variations of tone in the upper part of the building. Without a long luminance range, the bright arc produced by sunlight reflected from the building columns would have printed as an uninteresting pure white. Fine, sharp detail with crisp edges is essential to emphasizing the windows and columns so that they stand out and define the shape of the building.

in a studio knows how hard it is to perceive large but gradual changes in brightness. As I'll discuss in Chapter 6, we don't notice the effects of gradual light falloff in printing until it produces a density change in the print of nearly 0.15 d.u. from center to corner.

Some of you who work with computer-assisted printing may wonder why your prints or screen images with 256 levels of gray in them sometimes show contouring and banding if only 250 steps are needed to make a "perfect" print. The answer is that those 250 steps have to be spaced perfectly to produce tone that looks continuous. The spacing between the tones in these images is not likely to match that of the ideal visual psychophysical function. Some tones will be closer together than they need to be, and others will have too great a difference in density. Consequently, the computer image may need more than 256 levels of gray to produce "perfect" tonality to fill in the gaps in the total scale. Even so, 8-bit black and white (B&W) images from a good computer printer look good; this is why they hold up so well compared to continuous-tone photographic prints.

How We See Color

Human vision is not a simple, three-color recording system. We still don't fully understand color vision, but we know enough details to know it's much more sophisticated. It's true that the human eye contains three types of color receptors, called cone cells, which are sensitive to red, green, or blue light. Cones respond primarily to bright light; this is called photopic response. The retina also has brightness receptors (rod cells), which respond mostly to blue-green light and function best in dim light (scotopic response). The cones don't work in dim light, which means that we don't see color in dim light because the one type of rod cell can't tell us about the relative amounts of each color in the light.

The basic light response of the rod and cone nerve cells never gets to our brains. The rod and cone nerve cells are wired together so that one retinal cell can change how strongly other cells respond to light. For example, cone cells inhibit rod cells—as light gets brighter, the cone cells send signals to the rod cells, causing them to become less responsive to light. This is good and necessary, because it prevents the supersensitive rod cells from being overwhelmed by bright light. The cone cells also interact with each other, so that each cell's response varies according to what the other retinal cells are seeing. All this happens before the nerve signals get to the brain; what the brain receives is the complex result of these cell interactions. The brain's visual centers do their own heavy-duty processing on the already modified incoming signals. Then we "see."

As a further complication, photopic and scotopic vision overlap in moderately dim light. In deep twilight, for example, both cones and rods will be active and our nervous system combines the rods' responses with that of the cones in a complex way. Human color response changes in some very odd ways at early dawn and late dusk and in dimly lit interiors.

You can experience these interesting changes in color perception for yourself the next time there's a full moon. Look at a standard color chart like a Macbeth ColorChecker chart and a Kodak Color Scale under the moonlight, which is very dim yet close to daylight in color balance. The most obvious difference you'll see is that the colors will appear considerably desaturated by moonlight. In my experience, the color patches seem to have a slightly grainy look as well. Most likely I'm actually observing the noise in the visual system.

You'll see most of the hues correctly, but reds should look more like magenta. The colors' luminance values will be highly distorted. This will be most obvious for the primaries. Under bright light, blue looks very dark, yellow looks very light, and the other four primaries—red, magenta, green, and cyan—are close together in the middle. Under moonlight, the magenta patch will be much darker (almost as dark as the blue), and it will look closer to purple. Green will look lighter than normal, and cyan will appear much, much lighter—nearly as light as yellow and much lighter than it would look under brighter light.

Under normal lighting, the "light skin" square on the Macbeth chart has higher luminance than the "blue sky" square. Under moonlight, that's reversed. Under bright light, the yellow-green and orange-yellow squares have very similar luminance. Under moonlight, the orange-yellow square looks distinctly darker. All these interesting changes are due to the influence of the rods on low-light color vision.

How does the neural processing affect what we finally see? Although we have red-, green-, and blue-sensitive cones in our eyes, we mentally perceive four primary colors—red, yellow, green, and blue. Yellow is a consequence of equal stimulation of red and green cones. Monochromatic yellow light, like that from a yellow light-emitting diode (LED), looks yellow because it stimulates both red and green cones. A mixture of pure red and green light with no yellow wavelengths in it looks yellow for the same reason.

Our vision also combines enhanced saturation with low contrast (more about contrast's connection to color saturation in Chapter 2). We can see only about 650 distinct levels of light intensity over a total luminance range of more than 30 stops. That is a surprisingly small number of tonal steps—a computer scanner with 30-bit color generates over 1000 gray levels over a luminance range of only 10 stops. Our eyes adjust for changes in luminance even within a scene, which further minimizes contrast.

In addition, our vision amplifies differences in signals between the different types of cone cells. For example, there is an antagonistic relationship between the red and green cones. The red and green cones work against each other, so what we perceive is more a differential signal than an absolute one. Under some conditions, a strong red cone stimulation can elicit what looks like a negative response from the green cones. They effectively "see" a light level less than nothing. This increases the response range of the cones and amplifies any differences, thus enhancing our perception of subtle variations in color and increasing perceived color saturation.

Color constancy is another trait of our vision. A red apple looks red whether we look at it under sunny daylight, shady blue skylight, or incandescent light. Yet the apple's red, its reflected color, is not an absolute and fixed characteristic. For example, the apple may always reflect 50% of the red light that hits it, 40% of the yellow light that hits it, and 30% of the blue light that hits it, but what we see is not the innate reflectance but the actual amount of light reflected back. To describe that reflected color, we need to describe the light producing it because we see the fraction of each color in the spectrum the apple reflects (innate color) times the amount of light of each color there is to reflect.

One way we describe the *visual* appearance of a light source is by talking about its "color temperature." A black-body light source emits light solely as a result of heat—there are no strong absorption bands or emission lines such as one finds in fluorescent, mercury, or sodium lamps. For example, a 3200 K photoflood lamp has a filament heated very close to 3200 Kelvins (K) (about 2900°C or 5300°F), and it simply emits black-body radiation. Sunlight has a color temperature of about 5500 K, which is near the sun's actual surface temperature—the sun is also a good black-body source. There are no incandescent solid-filament lamps that match sunlight because no known substance remains solid at 5500 K. Daylight incandescent bulbs filter light from the filament to balance it to near daylight.

Many common light sources are not true black-body sources. Daylight and skylight have many sharp peaks and valleys in their spectra. On average, the visual and photographic effects of these spikes are small enough that we can assign daylight and skylight a fairly accurate color temperature. Skylight, for example, varies from 12,000 K to as high as 18,000 K.

Figure 1–5 shows the relative amounts of the different wavelengths of light, from violet at 0.4 microns to deep red at 0.7 microns, for idealized daylight, skylight, and incandescent lighting. (In the figures, I've smoothed over the peaks and dips in the real curves to make them clearer.) Standard daylight has roughly equal amounts of red and blue light; skylight has twice as much blue as red, and incandescent has three times as much red as blue.

From the different spectral curves, we can see that the relative amounts of red and blue light vary greatly with the light source. It is even possible to have situations in which an apple reflects, in absolute terms, more blue light than red light. Yet we still see the apple as red. Our vision does that by using the entire range of perceived light intensities to estimate what the light spectra must really be. It then uses that knowledge about the light to compute how the perceived color must relate to the innate color. So, even though the raw light our eyes perceive indicates that the apple is reflecting blue, our vision system figures out that it must really be red, and that's the way we see it.

If the color temperature of the light remains between about 4000 and 10,000 K, we see colors as relatively constant. Below 4000 K, we see fewer of the cooler colors. When we get to the realm of candlelight (about 2000 K), we see almost nothing but oranges and yellows. Conversely, in the deep shadows on a clear day, when the color temperature of the blue skylight is about 12,000 K, we start to lose perception of reds and oranges. Our color constancy isn't perfect, but it works over a surprisingly wide range of light conditions before we start to notice its failings.

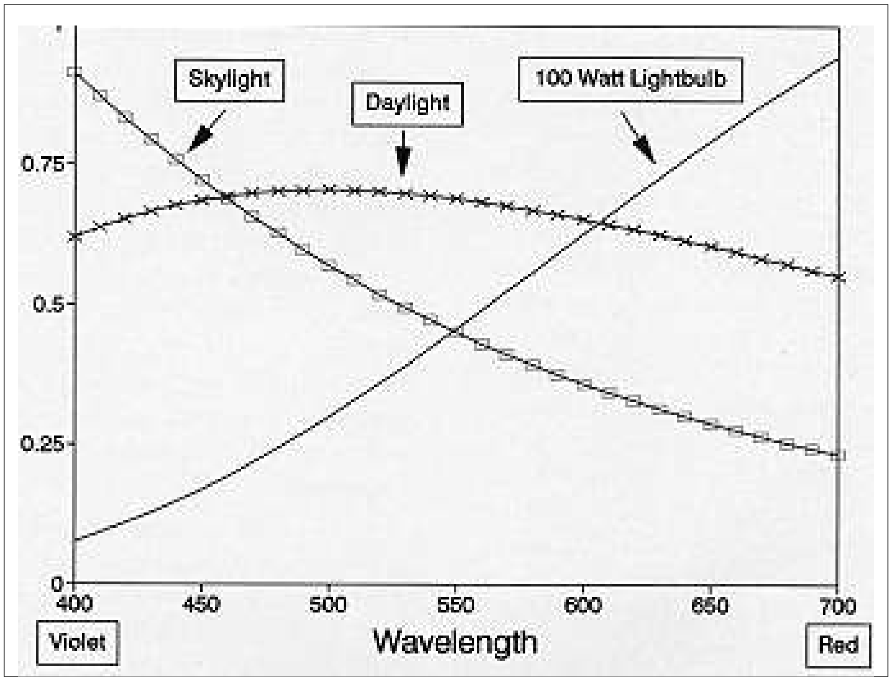


Figure 1–5 Idealized curves showing the relative amounts of each wavelength of light produced by three different light sources: skylight (color temperature of 12,000 K), daylight (5800 K), and a 100-watt lightbulb (2900 K). The *x*-axis is in nanometers; the *y*-axis is in arbitrary linear, not log, units to make the differences clearer. Notice how drastically the red-blue color balance differs among the kinds of light, although we see a full range of colors with good fidelity under all these light sources.

Photometamerism

Photometamerism is the little-known term for a well-known phenomenon—namely, that colors shift when the viewing light changes. Color constancy is not perfect; the bumpier an object's spectrum, the more likely that a lighting change will unduly emphasize some peak of transmission or valley of absorption. For example, remember the two different kinds of yellow? There's the spectrally pure yellow that corresponds to a small slice of the spectrum between orange and green, and there's the yellow we get if we mix equal parts of red and green light. Both kinds of yellow stimulate the retina in the same way, and we perceive them as the same color.

Consider two different patches of paint that look yellow under daylight-white light—one reflecting pure spectral yellow, the other reflecting red and green. Suppose we turn off the white light and turn on a yellow LED. The spectral yellow patch will reflect very strongly and look bright yellow. The red-green patch will reflect hardly any light and look very dark brown.

Let's make a "white" viewing light from pure red, green, and blue lights. To our eyes, this will look the same as the daylight-white light. If we illuminate the patches with mixed-primary light, the spectral yellow patch will appear dark brown because our light actually has little or no yellow in it, but the red-green patch will appear bright yellow, just the opposite of what we got when the yellow LED was the light source.

If we mix cyan with the two yellows, we make green patches that look identical under the daylight-white light. But when viewed under mixed-primary white light, the patch containing spectral yellow looks darker and more cyan; the

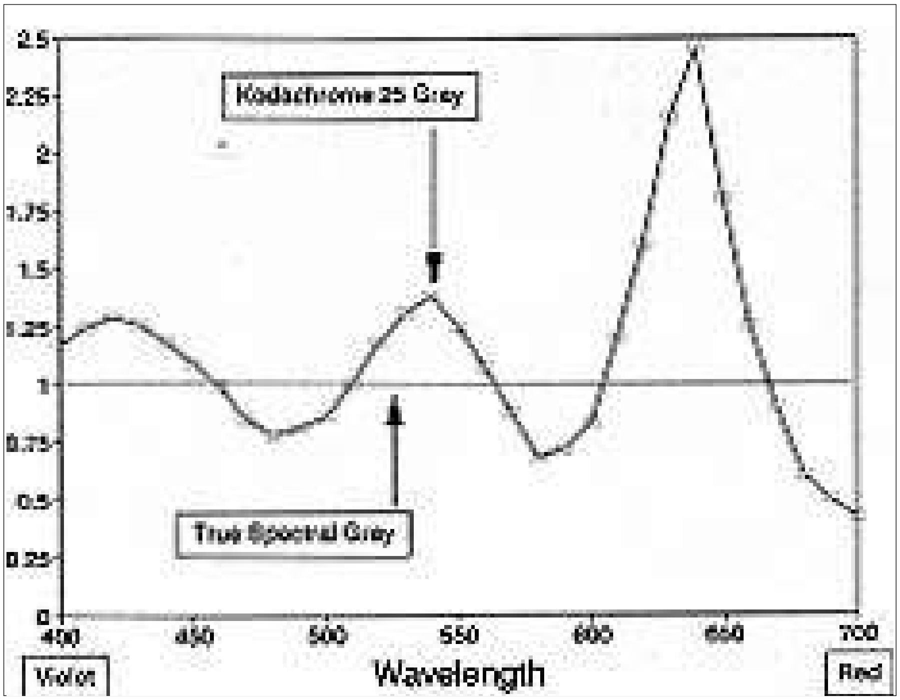


Figure 1–6 A plot of a photographic gray as rendered by Kodachrome 25 vs. a true gray. The *x*-axis is in nanometers; the *y*-axis is in arbitrary linear, not log, units to make the differences clearer. The eye sees these two kinds of gray as the same under standardized light.

one containing red-green yellow still looks properly green.

These are extreme examples of the kind of photometamerism that pops up when we look at color prints. Photometamerism doesn't come into play very much in B&W printing. A silver B&W print has close to a true gray spectrum: a flat line across the range of visible light, from red to violet. It looks close to gray under many different illuminations. But, color photograph gray consists of overlapping magenta, cyan, and yellow dye absorptions (Fig. 1–6). A color photograph gray that matches a B&W print under 5000 K viewing lights typically looks too red under incandescent light and too blue under skylight. Under fluorescent light, the gray becomes distorted in very strange ways because fluorescent spectra are so irregular themselves. Other colors shift too.

Computer prints made with inkjet printers will also exhibit photometamerism. The "black" ink in the printer is usually a mixture of colored inks. That means that pure B&W prints made with inkjet printers will take on color casts under different sorts of illumination, just as the grays in a conventional color print do. This will happen even when your print contains no cyan, yellow, or magenta ink.

Photometamerism also comes into play when printing slides. Frequently, slides from different films that looked identical to the human eye require very different filter packs, even when printed on the same print materials, because the paper's spectral response is not the same as that of our eyes. Like the eye's response, the paper's response curve has peaks and valleys across the spectrum, but they are not placed where our vision's peaks and valleys are. They also don't work quite the same way because the printed material doesn't do the elaborate signal processing that our vision does. Slides made on different films that look identical to humans rarely look identical to the print material. This is a strong argument for making proof sheets of your slides and/or printing only one type of slide film in a print session

Any time you compare objects that have different colorants in them, photometamerism will rear its head. A color print or slide will match the original subject under only one particular kind of viewing light, so we must define some standards for viewing. A 5000 K light with a Color Rendering Index (CRI) above 90 is the agreed-on standard for slide viewing. Whenever you use other lights, you'll get unexpected color shifts—a big problem if you're comparing a photo to someone's skin tone or to just about anything nonphotographic.

5000 K is also specified for viewing prints or display transparencies. This is a much less useful standard. The client's needs dictate the display conditions; if the client uses 5000 K for display, that's great. If the client wants a photograph to hang at home, though, you should balance the print for incandescent light. If the client wants to hang the photograph in the office, balance the print for fluorescent light (ideally, the same kind as is in the office). Fluorescent lights have such spiky spectra that it's often difficult or even impossible to make a perfect print for fluorescent lights, but anything is better than balancing the print for 5000 K lamps.

Choosing the Right Lighting for Viewing Prints

As I discussed on page 6, the optimum light level for illuminating prints so as to best show off their tones is extremely high by our usual living standards and in terms of what is good for the print. This situation puts collectors between a rock and a hard place! If you decide to run the light level high enough to show off your prints properly, you risk significantly increasing the rate at which they deteriorate due to light. You could cut anywhere from years to decades off their display life.

One compromise solution is to use special lights, such as track lighting or pin spots, for illuminating your artwork. There are several advantages to this approach, especially when you use lights that illuminate only the print and do not shine on the surrounding wall. You can control the intensity of the light hitting the prints independent of the overall light level in the room. Most of the time, you'll probably keep the light well below the optimum level. Since light deterioration is a cumulative effect, every hour less that the prints are exposed to high intensity light is an hour more of print life.

In addition, pin spots make artwork look brighter than it really is due to a combination of physical and psychological factors. In part, this is because the eye's iris is likely to be more open than it would be if the entire room were brightly lit. The brain also makes an adjustment for what it perceives as an overall lower light level. If you ever wondered why track lighting and pin spots made your prints look so much nicer, now you know that it's more than just dramatic effect.

Track and spot lighting have another advantage for displaying color prints. As I've said, the eye's "color constancy" isn't a perfect mechanism. There are subtle shifts in perceived color down to an illumination color temperature of about 4000 K. Below that color temperature, the situation gets worse rapidly. A typical quartz-halogen track or spot lamp has a color temperature of about 3200 K. An ordinary 100-watt incandescent light has a color temperature of about 2800 K to 2900 K. That 300 K to 400 K difference in color temperature makes quite a bit of difference in the color gamut we can see in a print.

For my dye transfer work, I find quartz-halogen light to be quite adequate, as long as I've made my prints with that kind of light in mind. Normal interior lighting is never better than marginal. If you're serious about the quality of your prints, you should be serious about how they're displayed. Viewing them under dim incandescent light such as you find in a typical living room is like listening to a very high-quality stereo system while wearing earmuffs.

CHAPTER 2

HOW THE FILM SEES

LUMINOSITY

Our vision characteristics present severe problems for film and paper makers. The nonadaptive systems used in modern emulsions are no match to our human vision. All photographic films, whether black and white (B&W) or color, reproduce luminosity in approximately the same way. They all have shadow tones where the contrast is low and the tonal separation is poor, midtones where the contrast is high and the tonal separation is very good, and highlights where the contrast and tonal separation decrease again. The major tonal differences between films have to do with how long that middle exposure range is, how much contrast falloff there is in the highlights, and how much exposure range the shadow region encompasses.

Print materials have a limited exposure range and usually cannot handle the entire density range of the film. The printer must decide what density range from the original film she wishes to place in the print and choose tonal characteristics of the print materials that best transform this density range into a print that fulfills their vision. I've worked out some pretty simple rules of thumb for dealing with this, but they require you to be comfortable with the idea of characteristic curves and shadow, midrange, and highlight regions on the curve. If these things are not clear from the abbreviated descriptions I give, it may be wise to review a basic photography book that covers them in more detail.

The easiest way to describe tonal qualities is with characteristic curves (Fig. 2–1). These graphs show the film density plotted against the exposure we gave the film to produce that density. Typically, we plot the exposure in stops or in log units (l.u.). A stop difference in exposure is 0.3 l.u. difference in exposure. If you've a characteristic curve whose *x*-axis is in l.u. instead of stops, multiply the numbers by 3.3 to get an exposure scale calibrated in stops. In Figure 2–1, the range of the *x*-axis is 10 stops and the *y*-axis 7.5 stops. The *y*-axis is the density of the film—the log of the film transmittance. For example, a film that transmits only 10% of the light has a density of 1.0.

Such a curve doesn't tell us everything about how a film responds to light, especially modern color films, whose response actually depends on the relative amounts of different color light that hit the film. Still, it's a good cognitive tool and a good guide to the general characteristics of a film. We can learn important things from these curves. The first thing we can learn is how the density range in the film is divided according to exposure. That is, we can find out how much of the exposure range winds up in the shadow densities, how much in the midtones, and how much in the highlights (see Chapter 4).

At any given point on the characteristic curve, we can find out what the film's contrast is; that is, how a change in exposure changes the film density. The ratio of change in exposure to change in density is called the film's *gamma*. For example, the dashed lines in Figure 2–1 mark a part of the curve where an exposure change of 1 stop (0.3 l.u.) produces a change in film density of 0.42 l.u. The film has an average gamma of 1.4 in this region. Unless the film's characteristic curve is very close to a straight line, the gamma will change along the curve (in other words, with the film's exposure). This is a very important characteristic of film and one we will return to as we try to figure out how to get the desired tonal rendition in our prints.

We call the low-density portion of the curve that is nearly horizontal the "toe" of the curve. (It's easier than saying "the low-density portion of the curve" every time one wants to refer to it!) We refer to the high-density portion of the curve (where the contrast starts to fall off and the curve becomes more horizontal) as the "shoulder" of the curve. Rolloff refers to the drop in contrast as one approaches the toe or the shoulder of the curve. None of the words refer to anything exotic;

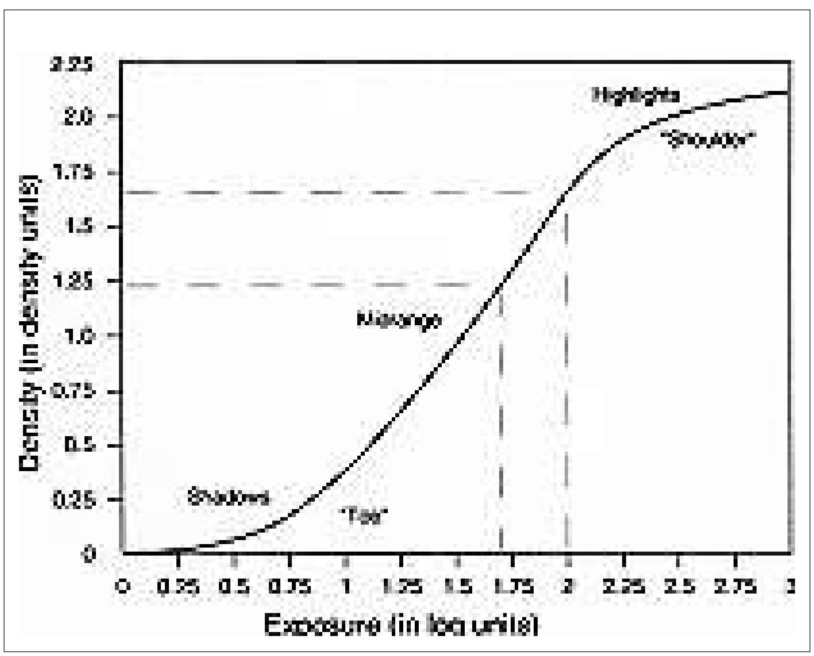


Figure 2–1 This is an example of a characteristic curve. The *x*-axis shows the exposure in log units (0.3 l.u. = 1 stop). The *y*-axis shows the resulting density in the photographic material in density units.

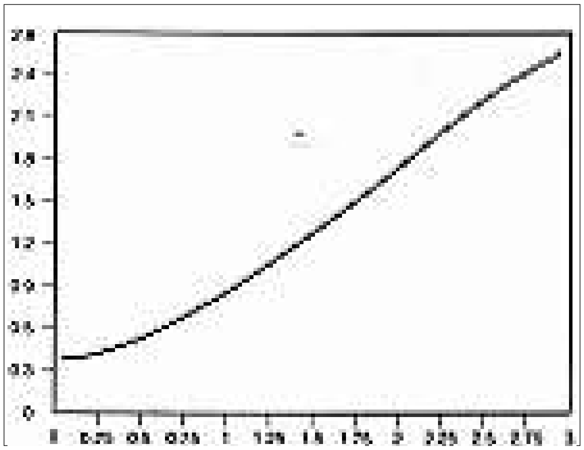


Figure 2–2 This is a typical characteristic curve for a color negative film. The film has a very long exposure range, and the resulting densities are roughly proportional to exposure for much of that range. B&W negatives also have these qualities.

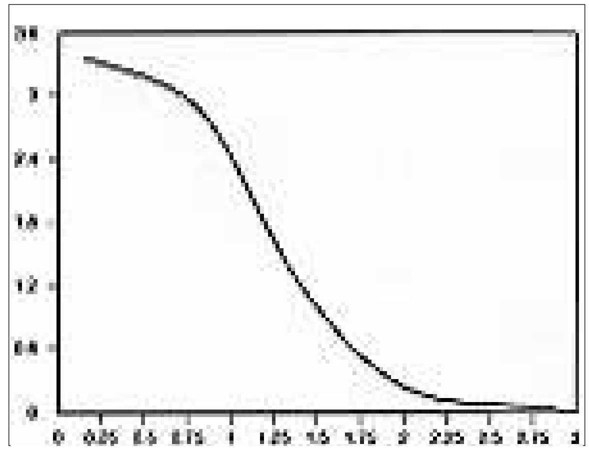


Figure 2–3 This is a typical characteristic curve for a transparency film. The exposure range is much shorter than for negatives, and the curve has a pronounced S shape. The film density is not proportional to exposure over much of the exposure range.

they're simply photographers' shorthand to make it easier to talk about these things.

In a negative, the low film densities of the toe correspond to the shadows in the photograph; the high film densities of the shoulder correspond to the highlights in the photograph. In a transparency, it's exactly the opposite—the clearest parts of the film (that is, the lowest densities) correspond to the highlights, and the highest densities correspond to the shadows. On average, negative films and transparency films have very different characteristic curves (Fig. 2–2). Negative films, both B&W and color, have a very long, straight midrange section in which each stop increase in exposure will produce approximately the same increase in film density and a gradual rolloff in contrast on the shoulder of the curve. Once you get off the toe of the curve, it's not uncommon for a negative film to have a usable exposure range of 10 stops.

On the other hand, slide films, whether B&W or color, have very different characteristic curves (Fig. 2–3). Their midrange section is relatively short, typically less than five stops, and fairly contrasty, with gammas usually in excess of 1.0. The low-contrast toe and shoulder of the slide film curve are very pronounced; we describe these films as having an S-shaped curve. Note that the exposure and density ranges are different in Figure 2–3 from those in Figure 2–2.

Qualitatively, it sounds like films don't behave much differently than our eyes do. After all, our vision has very poor tonal discrimination in the shadows, good discrimination in the midrange, and gradually deteriorating discrimination in the highlights. Quantitatively, though, it's another matter entirely. I coined a term for that: WTESIWYGS. It stands for What The Emulsion Sees Is What You Get, Sorta.

Our eyes are highly adaptive systems that deal with a huge luminance range, as I described in Chapter 1. At any one time, we can see only a portion of our total visual luminance range, but it's a portion well in excess of 10 stops. Negative films come closest to capturing luminance levels the way our eyes do. Mind you, I'm not saying they are better than slide films; they're merely more like our eyes. The biggest difference between the way films see luminance and the way our eyes see luminance is that our eyes have to deal with absolute light levels. Human vision does its best to adapt to different light levels, but moonlight, for example, always looks dim to us—we can't distinguish fine tonality under moonlight. Conversely, we suffer from snow blindness under bright sunny conditions in a light-colored landscape.

Figure 2–4 This photograph of the constellation Orion seen through high clouds does not represent the scene the way our eyes would see it. Under these extremely low light levels, film is much better at distinguishing tones, given sufficient exposure, than our eyes are. The clouds are rendered with a clarity and tonality unlike anything we'd see.

Film, however, only works with light levels over a moderate range. We vary our exposures to record extremes of light conditions as if they were moderately lit. This is, after all, the whole point of light meters and exposure adjustments—to ensure that the film always receives the same total amount of light regardless of the illuminance and luminance conditions in front of the lens. We can make a long exposure under moonlight that has great tonal separation and good contrast, which is something we never see with our eyes. In fact, as long as we strive to achieve a "well-exposed" negative or transparency and to print it on something resembling a normal grade of paper, it's just about impossible to avoid getting this unrealistically good tonal separation. "Unrealistic" isn't at all "bad," as Figure 2–4 demonstrates. It's merely different from the way we see.

Films lose sensitivity when exposed to extreme light levels; this is called reciprocity failure. It happens because silver halide crystals need several photons to make a stable latent image site. The intermediate excited states are not stable—they decay in a short period of time. My favorite metaphor for this is a house of cards. Stand one card on its edge and it will fall over quickly. Lean two cards against each other and they'll stand up for a while, but a light breeze will knock them over. When you have cards bracing the triangle on both sides, you get a stable base for the house.

Imagine someone is handing you the cards very slowly. It will take you much longer to get a stable four-card house built because something

Figure 2–5 The success of this aerial photograph of the slopes of Maui depends upon the linear characteristic curve of B&W negative film. If the film hadn't been able to record both extremes of brightness with good contrast, the printing task would have been hopeless. Even so, it took split-filter printing (see Chapter 11) to produce a good rendering of both the dark island and the bright cumulus clouds shrouding it.

will likely knock a card over before you get all four in place. That's like low-light reciprocity failure. It takes so long for the silver halide crystal to capture enough photons that many of the intermediate states decay first.

The dimmer the light, the higher the percentage of the intermediate states that decay before they get their minimum requirement of photons. For example, what would have been a Zone VII might be recorded as a Zone VI, at the same time that Zone V might be recorded only as Zone III. A 2-stop difference becomes a 3-stop one. Low-light (long-exposure) reciprocity failure produces a loss of film speed and an inherent contrast increase.

Bright-light (short-exposure) reciprocity failure is analogous to someone throwing cards at you very quickly. Odds are you'll drop some before you get the house built. Like card houses, latent image sites take time to build; the reactions don't happen instantly. If you dump a lot of photons into a silver halide crystal all at once, some of the light energy dissipates before all the necessary reactions to use it take place. Shoving photons in faster just wastes a greater percentage of the photons—the reactions can't speed up. Bright-light reciprocity failure causes loss in both speed and contrast.

Different emulsions have different degrees of reciprocity failure. You are always safe if you stay within the exposure limits the film makers put in their data sheets, but those limits are frequently very conservative. Before you reject a film, run your own tests rather than relying on data sheets. I have found that films that were "officially" unusable for exposures of more than 10 seconds produced little color shift with times of 40 minutes. I'll say more about the effects of reciprocity failure on color in the next section.

Another way in which film's response differs from that of our eyes is that our visual system does its best to create the perception that illumination remains constant. We look around a room and perceive it to be uniformly lit, but our film objectively records lighting variations of several stops around the room. Although our eyes can discriminate between very similar luminance levels when they're next to each other, when the levels become separated by more than a few degrees, our visual system's compensation kicks in and our ability to distinguish distinct luminous levels goes way, way down. Film, on the other hand, has no such spatial biases; it records differences in luminous levels the same whether they're separated by 20 degrees or 0.2 degrees.

Film, like our eyes, has only a limited ability to distinguish tones. The limit is set by the "noise" in the processed film. Noise comes from several sources: most obvious is the grain of the film. We have trouble picking out a subtle change in tone in a very grainy image. That is not merely a perceptual problem; it's a real fact of life and of measurement theory. You cannot meaningfully pull a very small signal out of a lot of noise in a small sample; there is simply no way to distinguish it from a random fluctuation in the noise.

The best way to suppress noise is to suppress the grain. You can do that by using a finer-grained film or by going to a larger film format in which you're enlarging less to make the print. Both theory and experiment tell us that the ability to discriminate tones in the film will improve in direct proportion to how much we suppress the grain. If we go to a film format that is twice as big, we improve the ability to discriminate tones by about a factor of 2 (it varies in proportion to linear dimension, not film area).

The biggest limitations in how we can render luminance range and tonality in a photograph come not from the film (assuming we're talking about negative film) but from the print materials. I assert that from a tonal point of view, our primary task is to circumvent the limitations and biases that print materials impose on the information recorded in the film. Figure 2–5 is a good illustration of this. Recording the subject's luminance range was not difficult; printing the resulting negative was.

A good color-negative film can record well over a 10-stop exposure range—in log units, that's over a 3.0 exposure range. Under some conditions, you can put as much as a 3.6 range onto the film. However, typical color-print material has a density range of about 2.2, and a considerable amount of the range is on the low-contrast toe or shoulder of the characteristic curve. In practical terms, the reasonably linear portion of the characteristic curve doesn't cover much more than a density range of 1.5.

If one attempts to make a print with reasonably good midtone fidelity, one can reproduce an exposure range from the original subject of perhaps 5 or 6 stops before one starts to push important image information onto either the toe or shoulder of the curve. In other words, the typical range in a print is not much different from the range one sees in any slide. Note that the problem lies with the print, not with the original negative. It's possible to record a remarkable luminance range in the original negative by using fairly simple techniques. The problem is finding ways to represent that luminance range in a print of limited density range.

Most B&W printers learn many tricks and techniques for accomplishing this at an early point in their careers. Even if they don't become devoted followers of an orthodoxy such as the Zone System, they still understand the idea of varying film development to expand or compress the density range in the negative for a given luminance range. They know about choosing different paper grades to match the luminance range they wish to convey in the print. Their knowledge may not extend much beyond that, but this is more control than many color printers exercise, and so

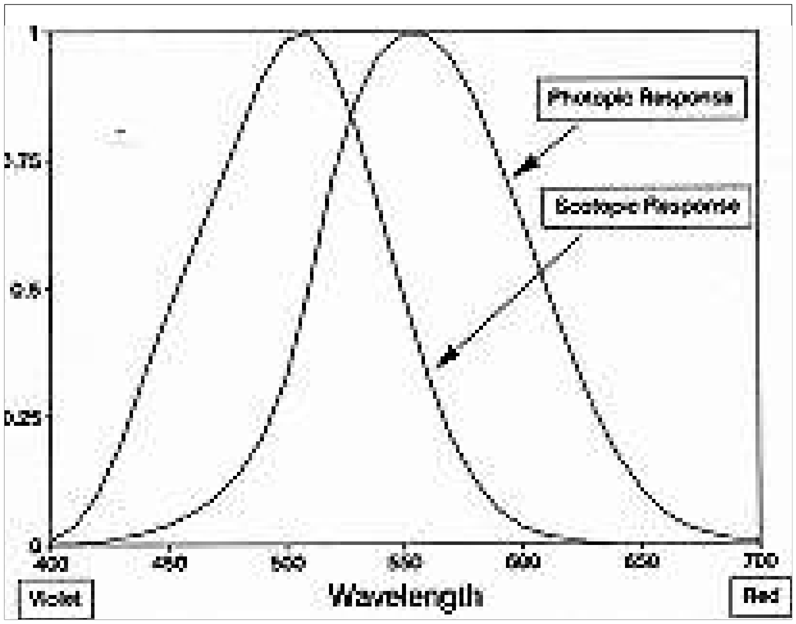


Figure 2–6 The curve on the right shows the bright-light (photopic) spectral response of the human eye. This is the collective response of the three kinds of color-sensitive cones. The left curve shows the dim-light (scotopic) response of the eye. This is the response of the rods. I've adjusted the height of the curves to fit on the same graph, but the rods are actually much more light-sensitive than the cones. The *x*-axis shows wavelength, from deep violet at 400 nm to deep red at 700 nm. The *y*-axis is linear to emphasize the response differences.

I devote more space in this book to talking about manipulating film and paper contrast for color photographers. In any case, color negative and B&W negative printers face essentially the same problem concerning tonal values and subject luminance—deciding what luminance range in the subject to convey in the print and deciding how that tonal scale will be distributed over the density range of the print.

For slide printing materials, a very different set of problems exists. We have the task of conveying a severely limited and highly distorted set of tonal information to the print paper without distorting it further. When printing slides, we want to get the most faithful print we can with as little loss of information from the original slide as possible. This is a very different objective than the one for printing from negatives, but both objectives point out the need to understand the tonal characteristics of the print materials we choose to use.

Color

All photographic films see color in a highly distorted fashion compared to the way a human eye sees color. Even B&W panchromatic films do not see colors the way our eyes do. One way of describing colors is by their hue (what we colloquially think of as "color,"—red, orange, mauve, etc.), chroma (that is, saturation), and value (how light or dark they are). The ideal panchromatic film has a flat response across the visual spectrum. In reality, no film meets that ideal. That response is nothing like the eye's response across the spectrum—the photopic response curve (Fig. 2–6). The eye is much more sensitive to yellows and greens than to other colors. Conversely, B&W films see blues and reds as having higher value than our eyes do.

This film characteristic lets us tailor a B&W film's spectral response however we wish by the

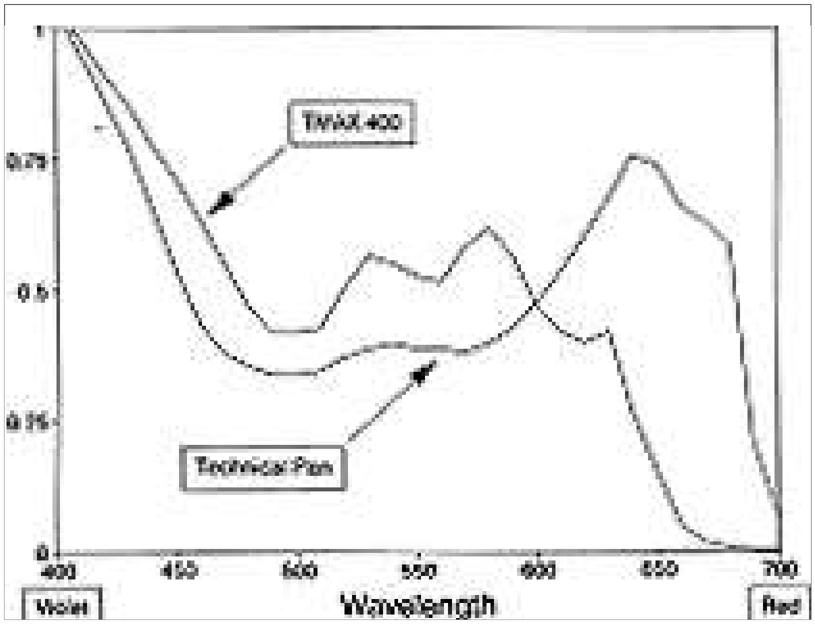


Figure 2–7 These are spectral sensitivity curves for two B&W films, Kodak Technical Pan and Kodak TMAX 400. They are analogous to the curves in Figure 2–6. Again, the *y*-axis is linear to emphasize differences.

use of appropriate filters, but it means that for highly saturated subjects, unfiltered B&W photographs invariably render colors' values differently from the way our eye sees them. Outdoor photographers commonly use a light green filter for scenic work because it emphasizes the yellow-green part of the spectrum at the expense of the red and blue and brings the film's response into a closer match to that of the eye, thus producing a more natural look. Oddly enough, no one seems to have shown much interest in tailoring B&W film's response to more closely match the photopic curve.

Under low-light conditions, the situation changes. When the light becomes too dim for us to see colors, our eyes operate with the rod cells in the retina, and they have a very different spectral response from the photopic curve. This is called a scotopic response. As you can see from the curve in Figure 2–6, it's a blue-green response with very little sensitivity to oranges and reds. Photographs taken under very dim light with B&W film not only show very different tonality from what we see, as I pointed out in the preceding section, but they also render the relative values of colors entirely differently from the way we see them. B&W photographers who wish to capture the way the luminances in such scenes look to our eyes should try using a cyan filter.

That is the ideal case. In reality, B&W films have anything but a flat spectral response. Basic, unadorned silver halide emulsion is sensitive only to blue light. To make it respond to a full spectrum, special dyes that can respond to longer wavelengths of light are added. Those dyes interact with the silver halide in a complex photochemical process that lets them contribute the sensitivity that the bare silver halides lack. Just how this sensitization is accomplished by the manufacturer determines the spectral response of the film.

For example, some films show enhanced red response and others show a truncated red response, as illustrated in Figure 2–7 by the curves for Tech Pan film and for TMAX 400 film, respectively. On the other hand, some films, such as Tri-X, have an enhanced blue response. The variations in sensitivity across the spectrum can be greater than half a stop. This can make a considerable difference in the appearance of sub-

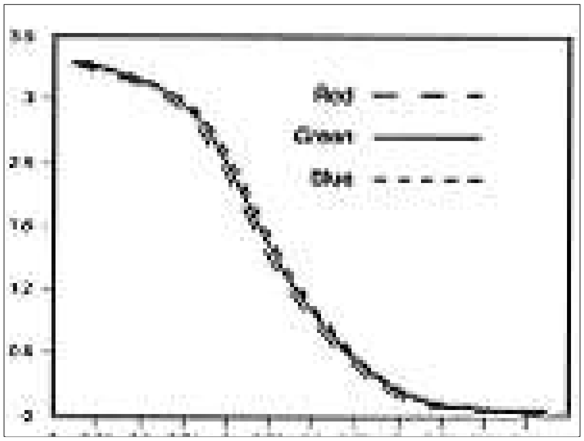


Figure 2–8 Characteristic curves for the three color images in a transparency. Ideally, they overlap perfectly; they are drawn adjacent to each other for clarity. The curve labeled "red" is produced by the cyan dye layer in the film; it corresponds to the effects of exposure to red light and the subsequent film density as seen by red light. Similarly, the green curve corresponds to the magenta dye image and the blue curve the yellow dye image.

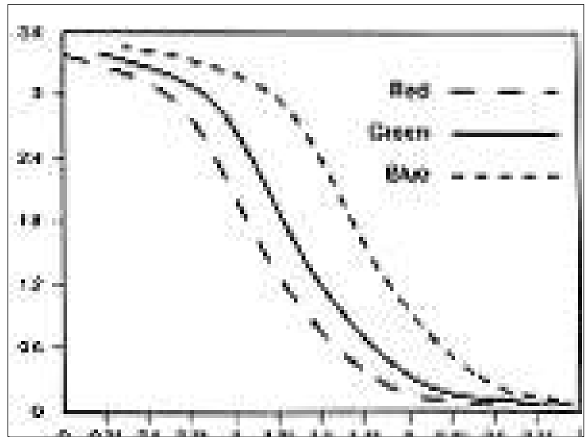


Figure 2–9 These curves show how the curves in Figure 2–8 shift when you expose slide film to light of the wrong color temperature (e.g., daylight film exposed by incandescent light). The red-, green-, and blue-light components of the illumination have different relative intensities. All three film curves have the same shape, but the curves are now separated horizontally because the exposures for the three colors are different.

jects in the print, especially in relatively high-contrast prints.

Color emulsions present a deluge of interesting, useful, but frequently annoying distortions. Modern color film does not record the actual spectrum of light it is exposed to, although an archaic process called Lippmann photography did just that. Films (and electronic cameras) encode the spectrum of the real-world image and intentionally throw away all the spectral and brightness information except for the red, green, and blue values. Computer folks would call this very lossy compression! Recording images in this way seems as unlikely to work as would taping a song by recording only three notes. The reason it works as well as it does is that our eyes also use a red-green-blue color-encoding system. But, the eye's extremely active and highly adaptive encoding scheme bears little resemblance to that of the film's and gives the eye many advantages.

Manufacturers must design color emulsions for a specific spectrum of light because films don't exhibit color constancy as our eyes do. For daylight films, the standard is 5500 K light. Tungsten films are balanced for 3200 K. You can use those films with other light sources as long as the light source approximates a black body. A meter can measure the amount of red vs. blue light and calculate the effective black-body temperature of the light. Special conversion filters reshape the spectrum to convert light of one color temperature to another with very good fidelity.

My tests indicate that with the appropriate conversion filters, daylight films produce excellent results under 3200 K light and tungsten films under daylight. Many photographers, including myself, like to standardize on one film's image qualities and use filters to balance it for different lights. If you have a film that you feel gives superior color and tone rendition, I believe you are better off using conversion filters than using other films.

Many times we make photographs under light that is not correctly color-balanced for the film we're using. You can correct the resulting color-balance errors to a greater or lesser extent in printing, but the correction is never perfect—sometimes it is very unsatisfactory. To understand why, look at the graphs in Figure 2–8, which show idealized sets of curves for a color-slide film. This film was exposed under perfect lighting conditions. Notice how all three curves overlap. What happens if we expose the film to light of a different color temperature than the one it was designed for—for example, daylight film exposed under tungsten illumination?

We can see the effect of that kind of exposure in Figure 2–9. The three curve shapes have not changed, but now they're separated along the *x*-axis because the tungsten light contains different proportions of red, green, and blue light than daylight does; we may find, for example, that the film is getting only one-fourth of a normal blue-light exposure when it receives the correct red-light exposure.

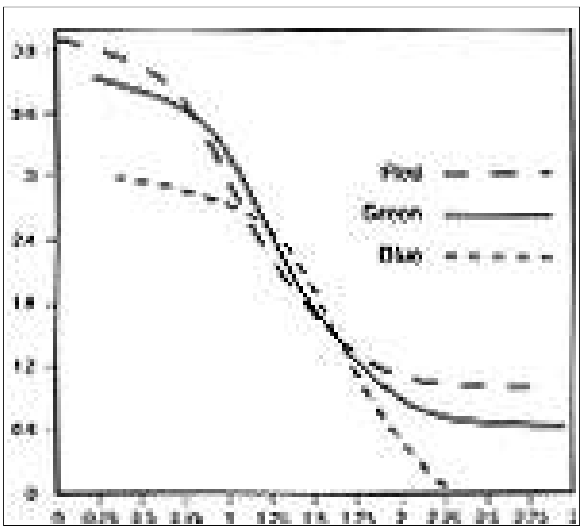


Figure 2–10 These curves show what happens to the curves from Figure 2–9 when you try to correct the color imbalance during printing. A change in the printing filter pack changes the density, so it moves the curves vertically. It does not undo the changes wrought in Figure 2–9.

When we go to print that slide, we can attempt to correct this color-balance error by changing the filter pack in our enlarger. By changing the filtration, we add or subtract density from each of the color curves, but that moves them vertically rather than horizontally. There is simply no way in printing to move the curves horizontally because we cannot alter the exposure they received to begin with. All we can do is adjust them up or down so that on average they overlap.

We can see the effect of doing that in Figure 2–10, in which we changed the filter pack to ensure that the middle gray is once again gray. Note that for a limited range of densities we've restored color balance, but we have problems in the highlights and the shadows. Because the curves have an S shape, they're not going to overlap perfectly after we translate them both horizontally and vertically.

This is color crossover. In the shadows on the shoulder of the curve and the highlights on the toe of the curve, the blue-light density is too low, which means a shortage of yellow dye in the image. In the darker midrange densities the effect is reversed; the blue curve is higher than both the others (i.e., the film is absorbing more blue light than any other color), so the darker midtones will be too yellow at the same time that the highlights and shadows are too blue.

A normal print from a slide will reproduce a density range of about 2.2 d.u., a little more than half of the entire 3.9 d.u. density range shown in these curves. No matter which 2.2 d.u. you choose to print, or what density value you choose to make neutral, prints from slides made under inappropriate lighting will always show some kind of color crossover.

The situation is much better with color-negative films. Because they have a very long straight portion to their characteristic curves, you can get a much better match in the curves when you translate them. When you expose the negative films under the wrong color temperature of light (Fig. 2–11), you end up with characteristic curves that look almost like three parallel straight lines, except for the toe portions of the curve. When you translate those curves vertically to bring the midtones into neutrality, the highlights track almost the same, and you'll see surprisingly little color crossover. The deep shadows are another matter. Because you're lifting the toe of the curve off the *x*-axis, you see the kind of crossover in the shadows that you would see in the highlights in a transparency (Fig. 2–12).

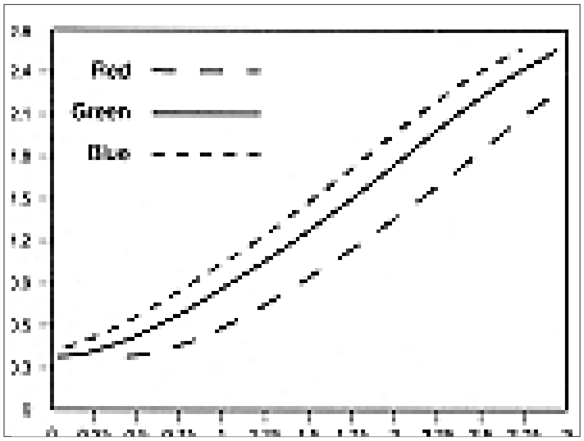


Figure 2–11 Characteristic curves for the three color images in a color negative when the film has been exposed to light of the wrong color temperature. The curves are spread horizontally, as in Figure 2–9.

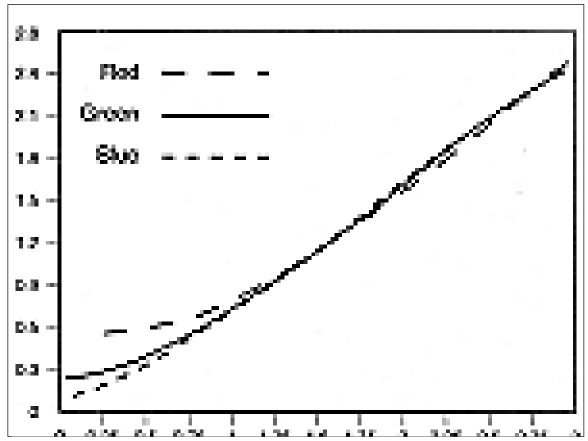


Figure 2–12 These curves show what happens to the curves from Figure 2–11 when you try to correct the color imbalance during printing. A change in the printing filter pack changes the density, so it moves the curves vertically. It largely corrects the changes wrought in Figure 2–11.

For example, if you expose daylight-balance color-negative film under tungsten light and attempt to correct the balance in printing, you get good color fidelity in midtones and highlights, but the extreme shadows turn very cyan-blue. You can avoid that by giving the negatives so much exposure that you're lifting all the printable shadow detail off the toe of the curve. Typically, that means overexposing the negatives by 1 to 2 stops. Fortunately, negative films have sufficient room in the highlights to allow this without losing highlight tone separation.

Photographing under extremely low light levels can also distort colors. If the three primary color emulsion layers in a color film have different reciprocity characteristics, two things happen to color rendition. First, there is a color shift that becomes progressively worse with more extreme exposures because one emulsion layer loses more speed than another (Fig. 2–13). Second, the different color layers wind up with different contrasts, which produces uncorrectable color crossover of the same type as the color shift. For example, a film that shifts toward magenta with decreasing light shows a green-highlight color crossover (Fig. 2–14).

By itself, reciprocity failure does not produce color crossover; it's the differential failure that messes up color. If you test an emulsion and find that it does not shift color significantly with extreme exposures, that emulsion will not exhibit color crossover, no matter how much speed it loses overall to reciprocity failure (Plate 1).

Many color photographers who make photographs at night attribute all odd colors to reciprocity failure. Usually, they're wrong. Most of the oddity in the color one sees in night photographs is due to the mix of unusual (from the film's point of view) light sources that illuminate the scene. That, combined with the fact that we see color poorly if at all under low light levels, lends an air of unreality to the color in night images.

Mistaking these conditions for reciprocity failure only leads to fruitless experimentation with color films. Different films render such colors differently, but the effects of reciprocity failure are usually less obvious than the effects of the odd light sources and our unfamiliarity with the colors they produce under such circumstances.

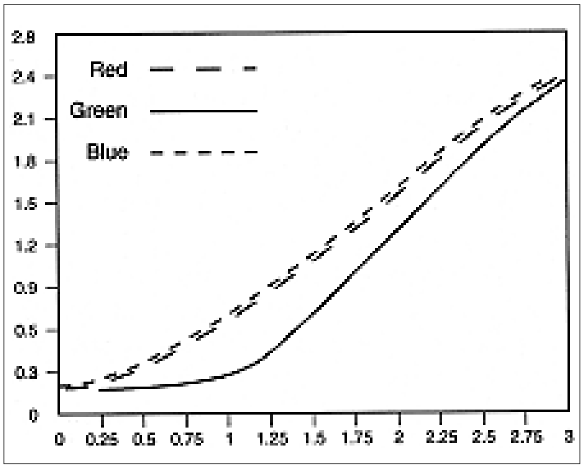


Figure 2–13 A film that has different degrees of reciprocity failure in the three colors will have characteristic curves something like these. In this example, the green-light curve (magenta dye image) shows more reciprocity failure than the red- and blue-light curves. It not only loses more average film speed than the other two curves, it loses progressively more as the exposure decreases.

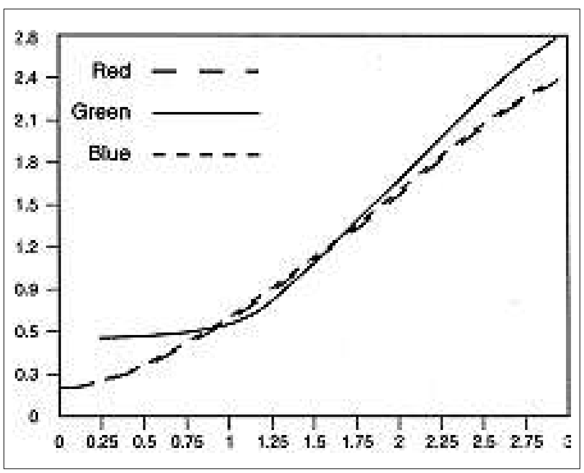


Figure 2–14 These curves show what happens to the curves from Figure 2–13 when you try to correct the color imbalance during printing. A change in the printing filter pack moves the curves vertically, but it cannot alter their different contrasts. It cannot correct the color crossover in Figure 2–13; there is too much green density in the highlights, which will print as green.

Saturation vs. Contrast

Our vision's characteristics of enhanced saturation and suppressed contrast have been especially vexing for film makers. Contrast and saturation go hand in hand in a linear system. For example, imagine you have a moderately saturated 90 CC green. CC are log-density measurements; 90 CC = 0.9 l.u. The green in question presents 0.9 l.u. more green light than red or blue light (that's 3 stops, or a factor of 8). Suppose we photograph the green with a film with a gamma of 2. Our green's 0.9 l.u. difference between green and red-blue light becomes a 1.8 l.u. difference in film density between the primaries. Our film shows the color as a much more saturated 180 CC green. However, a film gamma of only 0.5 would render the color as a low-saturation 45 CC green.

Because of the way our eyes enhance color differences, film manufacturers have found that a slide film needs a midrange gamma of 1.5 to 2 to produce a degree of color saturation that looks right. Films with high gammas can't record anything close to the luminance range that the eye perceives, and their tones look harsh to our low-contrast eyes. The limited tonal scale of slide films is obvious to anyone making photographs on sunny days.

Worse, the color qualities of hue, value, and chroma are not independent of each other. For instance, high chroma yellow always has a high value. There is no such color as a dark, saturated yellow. Crank down the value of a bright yellow and you get the color we call brown. Brown always has low saturation. If you crank up the saturation on brown, you usually get dark red.

A film that doesn't accurately preserve value distorts the hue and chroma of a color. A film must have a gamma of 1 to accurately portray values and, hence, hues. Accurately rendering hue conflicts with holding saturation. In real life the problem is worse because the film's spectral and luminance response curves aren't ideal. Color dyes are imperfect. For example, chromogenic color films and especially papers have less than ideal yellow dyes with noticeable magenta casts. An orangish-yellow looks dull, desaturates greens, and reduces color separation for all colors from orange through green.

What to do? Until about 15 years ago, film manufacturers could only refine the spectral response of the films, improve the dye colors, and push gammas as high as they dared without making the films too harsh. In the early 1980s, first Kodak and then others came up with a new breed of development-inhibiting couplers to improve color-negative films. Development releases the couplers that then act to suppress development—a kind of chemical governor. The new couplers also diffuse from one emulsion layer to another and slow down development in neighboring layers. There's an obvious analogy between a development inhibitor (DI) in films and the way cone cells in the eye inhibit their neighbors.

DIs improve saturation. For example, in an image of a bright-green leaf, the highly exposed, rapidly developing, green-sensitive film layer will release couplers that will slow development in the less exposed red- and blue-sensitive film layers. DIs will increase density differences between adjacent film layers whenever one layer has more exposure than another, boosting saturation without increasing overall film contrast. DIs even reduce overall contrast. If all three film layers have been heavily exposed, they all release DIs when developed and mutually slow down each others' development, thereby reducing the density in the highlights. That lets film manufacturers increase the internal contrast of the emulsion layers without having the overall contrast become garish.

Because slides are viewed directly by humans, any chemicals in the film other than the three primary color dyes must either be transparent or be removed in processing. E-6 films couldn't make use of development-inhibiting couplers until very recently. In 1994, Fuji introduced Provia 100, which was the first slide film, to my knowledge, to incorporate DIs.

Since the early 1980s, there have been many more refinements to color-negative films. Notably, Fuji created Reala film, which adds a fourth cyan-sensitive layer to the film. The primary function of this layer is to produce couplers that interact with the other film layers to refine color discrimination and enhance color separation (for example, red-green response), thus more closely matching how our vision works. A happy side effect of this layer is that Reala has almost none of the usual excess green response to fluorescent lights. Overall, Reala offers more accurate lower contrast and better color rendition and saturation than any other color film currently made (Plate 2). Fuji next revised their ISO 160 film, Fujicolor NPS, to incorporate most of the technological advances in Reala. The new NPS looks like an ordinary color-negative film, but it has Reala's special cyan-sensitive emulsion and the important DI enhancements. Today, Reala technology is found in most of Fuji's color negative films.

Contrast does not always go hand in hand with saturation. Very-high-speed films, both negative and slide, usually have higher contrast and lower color saturation than their slower cousins. Look to them when this is the look you want. For an extremely muted look, pull-process these films to further desaturate their color and bring their contrast down to normal (see Chapter 8).

Below ISO 400, there are modest differences in saturation and contrast among different films. For example, among color negatives, Fuji Reala is a low-contrast, high-saturation color-negative film; Kodak Portra 100 is a normal-contrast, moderate-saturation film. Among slide films, Fuji Velvia is noted for both high saturation and high contrast; Kodak Ektachrome 100 Professional (EPN) is lower than average in both saturation and contrast.

When exposing color negatives I recommend using lower-contrast films unless you know the subject is unusually flat. It is easier to boost the contrast by printing on a more contrasty color paper than it is to lower contrast by making a mask for the negative. For slides, I can make no general recommendation; this is an area in which every photographer's taste differs. I prefer the contrast of EPN but the color saturation of Fuji Provia. Because of the limited exposure range of slide films, you should think about matching film contrast to your intended subject or you'll only give yourself a big headache when repro time comes.

Many photographers prefer high saturation to accurate tonal rendition. EPN has the most linear exposure vs. density curve on the market, which gives it the most accurate tonal rendition but less midtone snap. Does everyone use EPN? Hardly—a majority of slide makers want higher color saturation than EPN provides. Ektachrome 100 Plus (EPP) is a noticeably snappier film with a more S-shaped characteristic curve. I like it much less than EPN, but I'm in a minority. Fuji used DIs to give Provia 100 the saturation of a "Plus" film but the uniform contrast qualities of an N-type film. Other factors, such as the overall film contrast and the dye set used in the film, may mask such subtle distinctions in real comparison slides.

One tool available to film manufacturers (besides improving spectral and dye characteristics) has been to give slide films a longer density range. The greater the density range of the film, the higher the film's gamma can be and still record the same luminance range in the subject. Over the past 20 years, E-6 films have increased by about 20% in density range, which has significantly increased the color saturation without sacrificing tone scale. Unfortunately, this does not translate into better prints. You're still limited by the density range the print is capable of. A high-density range slide may simply lead to a high-frustration printer!

Like our eyes, films are subject to photometamerism. If a change in lighting emphasizes any one primary color over another in a spectrum, films see some colors in the scene shift relative to other colors. The bumpier the spectrum (of either the object or the light), the more likely this is to happen. Skin tones of all hues and values have very bumpy spectra. Unfortunately, since our eyes and our films don't use spectral data in the same way and they don't sample quite the same bands, our eyes and the film are likely to see different shifts.

Fluorescent and other kinds of emission lamps cause problems; they don't come close to matching a black-body source. Measuring red and blue light levels tells little or nothing about the shape of the light spectrum, or where the nasty emission lines fall. That is why two-color temperature meters aren't reliable. A cool-white fluorescent lamp is visually about 4300 K.

Figure 2–15 shows idealized daylight and 4300 K spectra compared to that of a cool-white tube. There's not much of a match! A two-color meter that read the tube as 4300 K would tell you to use an 80D conversion filter (which looks similar to +15 CC cyan) to match it to daylight. Since fluorescent-lit subjects typically photograph very green without corrective filtration, you can imagine how bad your results would be if you added 15 CC cyan.

Three-color temperature meters measure red, green, and blue light levels. By comparing all three colors, they can determine whether a light source conforms closely enough to black-body to be acceptable. When it does conform, the simple color conversion and mired filter series work. When it doesn't conform, the meter guesses what type of light it is measuring (for example, cool-white fluorescent) and comes back with an exposure recommendation specific for that type of light (+30 CC magenta).

Since the meter response approximates the film's spectral response, the meter's guess is frequently pretty good. The filtration recommended for such uncooperative light sources usually makes true grays photograph as approximately gray. Unfortunately, there's no guarantee that other colors will be rendered correctly. Colors photographed under fluorescent lights are usually distorted in some manner.

There are non-black-body lamps ("high CRI" lamps) that produce good visual and photographic color. The Color Rendering Index (CRI) is a good predictor of color rendition because it is computed from measurements of how accurately the light renders eight colors across the spectrum. That's much better than a two- or three-color light measurement, and it's based on how the colors come out, not just what's in the light. CRI is the best guide to color accuracy. Daylight and tungsten lamps have a perfect CRI of 100. A CRI above 90 is a must for good color work.

This information applies just as much to those of you working at the computer as to those using the enlarger. Computer-assisted imaging is starting to play a role in printmaking.

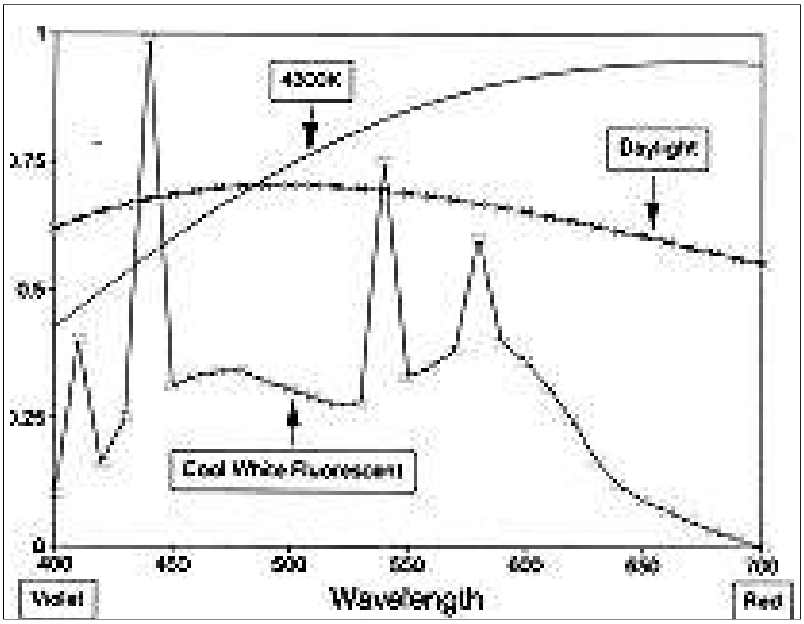


Figure 2–15 Idealized daylight and 4300 K spectra are plotted compared to a cool-white fluorescent lamp's spectra. The *x*-axis is in nanometers; the *y*-axis is in arbitrary linear, not log, units to emphasize the differences. Although the lamp has a visual color temperature of 4300 K, it doesn't look anything like a 4300 K black-body light source. Obviously, a simple color conversion filter will not fix the mismatch.

WYSIWYG software ("What You See Is What You Get"—a blatant lie if there ever was one) works on images after they are in the computer. Right now, inexpensive electronic image capture is significantly inferior to silver halide in color and tonal rendition (high-end digital equipment is another matter). That will eventually change, but for now you must start with an image on film to get the best image in the computer at a reasonable price.

The computer *can* help. Simple manipulations can attack the contrast vs. saturation problem, and some film deficiencies can be massaged out. Still, it's worth remembering that long before WYSIWYG became fashionable, we had GIGO (Garbage In, Garbage Out). I prepared a Web page to showcase my dye transfer photographs (http://www.plaidworks.com/ctein/) and I can testify that one can correct for all manner of deficiencies in the source images on-screen with great success. But it's a lot of work! High fidelity in an original film image is the best starting point for minimizing garbage in the final product, whether it is photographic or electronic.

Choosing Between Slides and Negatives

The battle between slides and negatives has been going on for many years and making about as much sense as the wars between Mac and PC users. If you're photographing for yourself rather than for a client, it's less important which film medium you choose than that you understand the pros and cons of the medium.

For years, photographers have heard that the only way to get good four-color magazine reproduction is to start from a color slide. That is an accident of history. When Ektachrome first appeared and commercial studio work began to turn seriously to transparencies, many printing houses complained that they couldn't get good press runs from chromes and that what they needed were color prints. Eventually printing houses learned how to separate chromes, and chromes came to dominate the professional market. Printers forgot how to make good separations from prints; it became hard to find a magazine that would accept anything other than a slide or a dye transfer print. Gradually, the pendulum has been shifting to center. Take a look at a well-printed photo publication, such as PPA's *Professional Photographer*; the reproduction quality from prints is just as good as that from slides.

In terms of purely technical considerations such as tone, color quality, sharpness, and so on, no one medium surpasses the others or is inherently more suitable for a given task.

Plate 3 was engraved from a Fuji Provia 100 slide and Plate 4 from a color print made from a Kodak Pro 400 MC negative. Composition aside, there are clear differences in the way the two films rendered the tones and colors, but there is little reason to declare one rendition superior to the other on technical grounds. If your objective is a "realistic" print (one that impresses the viewer as "looking like the subject"—which is, of course, an illusion), I feel safe in saying that negatives are far superior to transparencies as originals to print from. There is no question that one can make gorgeous prints from transparencies, especially if one is willing to put in some extra effort. I describe many of the techniques in later chapters.

If you are willing to go to truly heroic effort (e.g., printing methods such as dye transfer or UltraStable), it is possible to make prints from transparencies that look entirely as realistic as a print from a negative, but it's an uphill battle for lesser techniques. For equal amounts of effort and expense in the darkroom, there's no question that a negative is a better place to start because you are fighting far fewer distortions in the information that's been recorded by the film. If you're working on a computer, that's a different matter: superb results can be gotten from slides with no more effort than from negatives.

If you're more interested in working with what's in the film than in trying to reconstruct reality, a slide can produce a wonderful print. In particular, the very high saturation and contrast inherent to slide images is very difficult to create in a negative print; it depends on your tastes and your goals. Mine happen to be for a realistic-looking print, but I'm not the one to dictate your aesthetic!

What are legitimate grounds for choosing one form over another? When the exposing conditions are close to what the film was designed for, especially when you have control over the subject's luminance range, a slide is as close to WYSIWYG as silver photography gets. No interpretation is imposed by a custom lab's printing on the photographer's work, and the photographer need not rely on fallible memory to instruct a printer or advise an art director.

When exposure conditions are less than ideal, slides don't come close to what the photographer saw. In contrasty situations, negatives are better because they can record several stops more luminance range than a slide film can and with much better linearity. Slides also faithfully show every shift in light quality, regardless of whether one wants them to. In Plates 3 and 4, there is a modest difference in overall color because the slide more accurately recorded the late afternoon's yellow light. The print from the color negative more closely corresponds to what I actually saw.

In extreme cases, a slide film may totally fail, but a color negative may save your bacon. "Lehmann Caves" (Plate 5) is a fine example of this situation[1]. The cave was lit by very dim, yellow 7.5-watt lamps; I couldn't see the actual colors of the scene. Had I photographed the scene on any kind of slide film, even tungsten-balanced film, it would have come out pure red (the bulbs were as much redder than 3200 K tungsten light as 3200 K light is than daylight). The dim light made heavy corrective filtration unfeasible. By generously exposing my Vericolor 400 (VPH) negative, I was able to retain enough blue-light

1 This image is one you can see in its final form on my Web site (http://www.plaidworks.com/ctein/).

information to produce an acceptable print in the darkroom. There is still some crossover, which conventional printing couldn't deal with, although dye transfer can and did.

What to do if you absolutely must have slides of such an uncooperative subject? My preferred choice is to do a medium conversion. A Vericolor Print Film transparency made from the VPH negative would look at least as good as the Ektacolor print and be much better than anything I could achieve with a slide film.

Photographing for Reproduction in Color

So far, most of what I've related are immutable facts about films, papers, and our eyes. As a photographer, you choose the films and papers that provide you with the most palatable set of characteristics, but those characteristics are fixed. Once you've selected your medium, how you use it can greatly affect the quality of the tone and color you get. As a photographer, there are steps you can take during film exposure and processing to mitigate some of the material limitations. As a fine printer, you can take actions that compensate for many film idiosyncrasies and allow you to control how the print looks, rather than letting the film control it for you. The cost is often modest. The benefits are better prints, made more easily and reliably.

We've considered how the image qualities in our prints relate to those of our films and our subjects. We've noted that, especially with color-transparency film, we're often dealing with density ranges far beyond our ability to print easily. As we'll see in later chapters, there are ways to deal with this problem in the darkroom, but there's also a way for slide photographers to tackle this problem in the camera.

The technique is called photographing for reproduction. The photographer consciously limits the subject luminance range chosen to photograph so as always to work with a density range that the print materials can cope with. Once you run the tonal calibrations that relate your paper's exposure range to the film's density range and the subject's exposure range, you'll know what the ranges are and you will be able to photograph for reproduction.

At first this approach may feel unnatural, but it's a logical extension of what you already do as a photographer. You know that your prints won't usually reproduce the entire luminance range you saw. When composing a photograph, you make artistic decisions that certain luminances will print as pure white in the final print and others will become pure black, regardless of how you saw them with your eyes. All we're doing is making those decisions more rigorous and applying them to the print, not to the film. A slide made for reproduction usually looks flat on a light table because you don't use the entire density range of the slide; you'll probably use less than two-thirds of the range. You have to ignore how the slide looks to the eye and consider only how it will print.

Photographing for reproduction with slides gives you a unique tool for controlling placement of tones. A typical slide tone has a very S-shaped characteristic curve, with high contrast in the midtones and low contrast in the highlights and shadows (Fig. 2–3). When you photograph for reproduction, you can decide what portion of the S curve to use for your subject. For instance, if you want "normal" results with slightly higher contrast in the midtones than the extremes, you expose the film normally. In the processed slide, luminances that you intend to print white should come out as light gray, and those that you wish to print black should come out as dark gray.

If, on the other hand, you are recording a subject in which you want to hold good tonal separation in the highlights and are willing to give up some separation in the darker tones, you can reduce the exposure of your slide so that the subject highlights are recorded closer to a middle gray. That produces maximum separation in the print highlights and minimum separation in the shadows. Conversely, you can bias the film exposure to the higher side to increase tonal separation in the shadows at the expense of highlight separation.

You can use this tool in conjunction with the other tone and contrast manipulation techniques in this book. It's sole (albeit large) drawback is that you can't produce slides that both project well and print well. Photographing for reproduction lets you change the subject luminance vs. print density relationship in ways that are very hard to achieve otherwise.

CHAPTER 3

CALIBRATING FILMS AND EXPOSURE METERS FOR LIGHT AND FOR COLOR

HOW ERRORS CREEP IN

Meticulous photographers are very fussy about their exposures, as they should be. Slide photographers learn this early because they see the results of incorrect exposure immediately. Furthermore, the relatively limited exposure range of slide films demands accurate exposure. Even if you're lighting your scene (or selecting it) so that all the important tonal values can fit within the exposure range of the slide film, there is no margin for error; any sloppiness means unnecessarily throwing away some highlight or some shadow detail.

When one photographs under uncontrolled lighting conditions, the situation is worse because there is usually no way to obtain printable tones for all the luminance values in the scene. One has to do triage on the spot and decide which end of the tonal scale can be sacrificed. Again, any error in judgment or technique results in lost tonal information.

Negative photographers, feeling that the exceptionally long exposure range of their materials tolerates errors in exposure, may not be so sensitive to the situation. This is true to a point, but such errors still have undesirable consequences. One of the points of becoming a master printer is to learn how to tame the extreme luminance range of the subject and convey it effectively in a print of more limited density range. You may very well find yourself using most of the exposure range of the negative for printing when the subject warrants it.

Even when you make ordinary unmanipulated prints (a situation in which the negative film can easily record 4 or more stops more range than you can convey in the print), there are important consequences to varying the exposure. You can pull an excellent print from a modestly underexposed negative (assuming, of course, that the negative is not so underexposed that it lacks any important shadow detail). But, such a print has very different tonal characteristics from one made from a normally exposed negative. In the print from the underexposed negative, the shadows and darker tones derive from densities in the negative that come off the toe of the characteristic curve. Those tones will have lower contrast than the print's midtones and highlights, which come from the negative's density range that falls on the straight, relatively contrasty, midrange of the characteristic curve.

Conversely, in a print from an overexposed negative, the shadows and darker tones in the print come from negative densities that lay on the midrange of the characteristic curve. The highlights in the print come from densities on the shoulder of the film's characteristic curve. Hence, the highlights in the print have lower contrast relative to the midtones and shadows—just the opposite of the print from the underexposed negative. These effects are much more pronounced in slides than in negatives, and the savvy photographer can exploit them to advantage (see "Photographing for Reproduction in Color" in Chapter 2).

There's nothing wrong with any of these interpretations; they may all produce excellent prints! But over- or underexposed films do not produce prints with the same relative tonal placement as each other or as that of a print from a normally exposed negative. Even when all the tonal information is in the negative, exposure determines the relative distribution of the tones in the print. Uncontrolled or sloppy exposure results in lack of control of tone placement in the print, and that is not the mark of a fine photographer or a master printer.

However, the ways in which photographers obsess about their exposures are frequently unhealthy, often unproductive, and occasionally downright incorrect. Precise exposure is your goal: being able to keep that slop to a minimum so that your results are predictable.

Precision, though, is not the same as absolute accuracy. Whenever I hear photographers comparing their exposures on the one-third stop level, the first thoughts that come to my mind are whether they've had their equipment professionally calibrated or whether they're assuming (incorrectly) that everything operates so accurately that they can talk meaningfully about such small exposure differences. If you really want accurate exposures, the smartest thing to do is make sure that your equipment can deliver them.

Have you ever thought about how many places errors can creep into your exposures? I don't mean human error—I mean the kinds of errors that occur even if you're perfection embodied. Here's a partial list: errors in film speed, speed variations introduced in processing, errors in shutter speeds, errors in lens apertures, errors caused by not taking lens transmission into account, and all the possible errors in metering.

These kinds of randomly distributed errors compound according to the root-mean-square (RMS) rule. This is the same way that errors in sharpness compound (I discuss the math in Chapter 6).

When all the errors are comparable in size, the total expected error increases as the square root of the number of errors contributing to the problem. Thus, if you have six different possible sources of error like those I've just described, all of similar magnitude, on average you'll have a combined error 2.5 times as big as the individual errors. Of course, that's the *average* result. Sometimes everything cancels perfectly; at other times they all add up against you.

The errors in film exposure caused by your camera are the ones you should be worrying the most about. It's not at all unusual for camera shutter speeds to be in error by a quarter-stop. That's not much, but your lens apertures may also deviate markedly from what the inscription on the barrel says, especially for the largest and smallest apertures. Manufacturers frequently are a bit optimistic in their ratings of a lens's maximum aperture, in particular for complex zoom lenses and telephotos. The smallest apertures can be in error because of simple mechanical tolerances, most commonly with short-focal-length lenses. I've seen errors of a half-stop at both extremes, and errors of one-sixth to one-fourth stop aren't uncommon.

In truth, film manufacturers do not control the inherent emulsion speed to better than 0.15 stops. Your actual film speed depends upon processing as well; the tightest process specs don't guarantee better than 0.15-0.2 stops. In combination, you can expect to have random errors of 0.2 to 0.25 stops in film speed. Let's assume errors of 0.3 stops in shutter speed and 0.15 stops in lens aperture—a pretty common situation. The RMS error from all the errors combined would be about 0.4 stops.

Then there's the matter of the lens's actual light transmission. No lens transmits 100% of the light hitting it; in a well-designed optic, the light loss is less than one-fourth stop, which is usually insignificant, but all the effects compound. A shutter speed that is a bit too fast, a lens with slightly less light transmission than expected, and an *f/* rating that is biased to the low side can all add up to an error of more than half a stop in actual exposure. Even in a well-tuned system, you can expect to see errors of one-fourth to one-third stop.

Metering and the Myth of 18% Gray

I'm going to sidestep entirely the arguments over incident versus reflected-light meters, handheld versus in-camera, and averaging versus spot meters. If you know how to use your meter, any of these types and techniques of metering will serve you just fine. None is inherently better than the other; it's all a matter of personal skill and technique—but only if you understand just what it is your meter is measuring.

There's a long-standing photographic myth that exposure meters are supposed to be calibrated to read 18% gray cards. Yes, I know it's what we've been taught, and I know people who swear on a stack of Ansel Adams's diaries that it's true. This subject has caused no end of confusion and misinformation to be imparted to young and eager photographers, including myself. It wasn't until the late 1980s that Dick Dickerson at Kodak managed to drill the truth into my thick skull, and he had to send me a copy of the International Standards Organization (ISO, formerly the American National Standards Institute) document to do it. It's ANSI PH3.49-1971, in case you care to look it up. But take my word for it.

This document was created by the manufacturers to provide an industry standard for handheld meters—it's advisory, not mandatory, but it is what they agreed on. It specifies that meters should be calibrated to about 12% gray, with an allowable error of plus or minus 2%.

Why 12%? The light meter doesn't have any way of knowing how bright the subject really is; it sees only how much light the subject reflects its way. To make an exposure recommendation, the meter has to make an assumption about how reflective the subject is. A reflectance of 12% has no theoretical basis; it is merely the measured average effective reflectance for outdoor scenes in the middle latitudes in midyear. If light meters had been invented by folks living in Antarctica, they'd be calibrated to about 30%.

Have you ever wondered why Kodak's Professional Dataguides recommend that you hold a gray card at 45 degrees to the sun when you make a reading? Holding the card at 45 degrees to the light source reduces the apparent brightness of the card by 0.3; 18% times 0.7 is just about 12%.

Why then 18% gray? I've heard two explanations: (1) 18% gray approximates the brightness of a typical studio-lit scene; (2) 18% gray matches the Rochester, New York (where Kodak is headquartered) sky for at least 6 months of the year. I suspect the former has more technical validity, but the latter wins on charm.

As with many ointments, there is a fly in this one. Along with most photographers, most repair technicians don't know about the ANSI standard, and many camera manufacturers seem to ignore the standard they wrote. There's a fair chance your light meter has been adjusted to 18%. If so, it will read gray cards just fine. It will also overexpose the average outdoor scene by a half stop. I've also run across automatic cameras calibrated as low as 8% or 9%. They tend to underexpose average scenes. How do you find out what your meter is doing? Run some exposure tests.

What happens if you take light readings off a standard gray card, assuming that your meter is calibrated for it, when it's really adjusted for the ISO standard of 12%? An 18% card reflects about a half stop more light than a 12%-reflectance surface would, so the meter "thinks" the illuminance is a half stop greater than it really is. It recommends an exposure setting that is half a stop too low.

When you're exposing slide film, this will result in slightly dark slides, which many photographers feel look a bit richer than normally exposed ones. Negative film users may feel that their films are a bit on the thin side. From this, it is easy to understand why so many photographers feel that film manufacturers overrate the speeds of their negative films and come up with personal exposure indices (EIs) that are lower than the film's real ISO.

It's this business of personal EIs that saves us all. All serious photographers develop sets of customized film speeds for their favorite emulsions. Those speeds give them negatives and slides that they find ideal, and they hide a multitude of exposure errors and assumptions. No two of us take meter readings in exactly the same way, have meters that are calibrated exactly the same, or have equipment that performs identically. A custom exposure index takes all that into account for us.

This 12% standard applies only to simple meters. A meter that weights different parts of the scene according to their brightness, such as a center-weighted meter, must deviate from the 12% standard. It may give you a reading equivalent to 12% when it's measuring a uniformly illuminated field, but it's supposed to increase or decrease the exposure when some parts of the field are illuminated more brightly than others. Hence, it can't always function as a 12% meter. Of course, the more modern segmented or matrix meters in the latest cameras perform this trick even more effectively and extremely.

The final catch is the spectral response of the meter. This is not a big issue for color photographers, but some black and white (B&W) film photographers practically come to blows over it. This goes back to the issues we discussed in Chapters 1 and 2 on how we see and how the film sees. The B&W film doesn't see the spectrum the same way we do. The photodetectors in light meters don't see the spectrum the way either our eyes or the films do. It's necessary for the manufacturer to place filters in front of the photodetector to ensure that it has a response similar to that of the eye or the film. Without such filters, modern silicon detectors are most sensitive well into the infrared band, where neither we nor our films see anything.

At least one meter maker has placed customized filters in their meter to make it match the spectral response of a specific B&W film. The utility of this is dubious. As I discussed in Chapter 2, B&W films have greatly different responses to the visible spectrum. They may differ from each other in relative response by as much as a full stop. A meter perfectly calibrated to one film may not work well with another. Some argue that any kind of film-related calibration is better than a simple photopic response, but independent proof is lacking.

Still, I know that some of you are terribly worried that your meters may be giving erroneous readings under brightly colored conditions. That could happen when you're photographing brightly colored subjects or using a very strong filter, such as a No. 25 red. Either way, here's a home test that will either put your mind at ease or tell you exactly where your problems are. The test is not incredibly precise, but it's easy to do. In other words, it's "good enough for shutterbugs' work."

To run the test, you'll need a camera with a close-up lens, a meter, and a Macbeth ColorChecker chart. The close-up lens doesn't have to be a very good one; if you don't own a macro lens or a set of extension tubes, a screw-on close-up lens will do. Macbeth charts are explained in the next section.

Set up the Macbeth chart and move in close enough to it so that a single square fills the frame of your camera. Use your light meter to take a reading of each square in the chart, and use that

Figure 3–1 When the subject is the source of illumination in the scene, precision metering methods go out the window. High-speed film (Kodak TMAX P3200) allowed me to capture the sinuous curls of flame coming from this campfire with both a high shutter speed and small aperture. For this subject, opening up about 3 stops from what the meter told me gave the best results, but it was all guesswork and bracketing. On the other hand, the negative almost printed itself; no manipulations were needed.

reading to photograph that square. Don't make any compensation for light or dark squares or for the color of the square. When you've finished, pick one square on the chart, such as the middle gray square, take a reading, and use the reading as the basis for a series of bracketed exposures of that square. You won't need many exposures. A series of half-stop increments from + 2 to -2 stops around the meter reading will do.

Develop the film and look at it on a light table. All the exposures of the neutral squares at the bottom of the chart running from black to white should come out the same in your negatives. That is, they should all have the same density. If they don't, it means that there's an error in either your camera's exposure or in your meter's accuracy as a function of brightness. Let's assume that your meter and camera check out fine.

Now compare all the individual photos of the squares to one another. If your meter shows no color bias with respect to the B&W film you're using (which is not very likely), then all the negatives will have the same density regardless of the color of the square that was photographed. If any of them are significantly brighter or darker than the average, you have a deviation from that ideal. You can estimate the difference in the meter's vs. the film's sensitivity by comparing the density of those squares to the series of bracketed exposures you made. For instance, if you bracketed in half stops and your square is a good match for the bracket negative that is two increments lighter than the average negative, the square was metered with a one-stop error.

Assuming you've found some discrepancies, there's not necessarily any reason to panic. Load up another roll of film and repeat the procedure of making close-up readings and exposures at those readings, but pick your subjects from the real world. Try to pick the kinds of subjects you normally photograph. Most real-world objects are nowhere as saturated in color as the squares of a Macbeth chart; you may very well find that the huge deviation you saw when metering the Macbeth chart squares simply doesn't appear with any subject you're likely to photograph. However, if it does, you now know the exposure corrections needed for that meter with that film.

The Macbeth Chart

How do you know for sure that you're getting accurate color? You must have a reference to check your photos against. There are two major schools of thought on this. One school advocates photographing real subjects of the type you usually work with. Nothing looks or photographs quite the same (or as trickily) as real skin tones, chlorophyll-laden foliage, blue skies and flowers, and the like. If you're trying to ferret out the idiosyncrasies in your films and prints, tough, realistic tests are better. The other school pushes lab standards. Pick a reproducible and unchangeable subject and use that as your reference. Skin tones may be a tough test, but your model won't have precisely the same skin color when you get the film back as when you exposed it. Plants wilt, leaves fall. Skies are notoriously unreliable, as is your memory.

Both arguments have substantial merit. I think there is a good compromise, called the Macbeth ColorChecker Color Rendition Chart (Plate 6). The Macbeth chart has 24 differently colored squares in four rows. One row is a gray scale. Another has the three additive and three subtractive primaries. The remaining two rows contain colors that have a special real-world significance. There are squares for dark skin and light skin, foliage, blue sky, blue flowers, and for colors such as bluish-purple and yellow-green (which frequently give fits to film and paper).

The chart uses specially mixed pigments that have bumpy spectral characteristics very similar to their real-life counterparts. It is not a simple four-color print job like most color patch charts. Because of this, the squares look "lifelike" under almost any kind of illumination and to any film. I checked the light-skin square using a part of my skin that matched it under 2900 K incandescent lighting. They still matched within a few CC under both 20,000 K twilight and cool-white fluorescent lamps. There was almost no photometamerism because the patch and my skin had very similar spectra. A four-color, press-printed, "flesh tone" target matched my skin under 2900 K light but was far off under the twilight and fluorescent light.

Four-color printed charts tell only how your system responds to cyan, yellow, and magenta inks, no matter what colors they show. They are useful for tracking overall color balance, nothing else. The Macbeth chart, in my opinion, offers the advantages of a stable lab standard (that I can take anywhere) with both realistic and difficult spectral characteristics. I say it's the best test of accurate color reproduction.

CHAPTER 4

How Print Materials See

Sharpness

Some print materials *are* inherently sharper than others. The typical color-negative paper can record about 65 line pairs per millimeter (lp/mm), but a black and white (B&W) paper can reach 125 lp/mm. Ilfochrome and R-3 papers fall midway between at 80 to 100 lp/mm, depending on the product and surface finish. Even including an ample safety margin to allow for the numerous sources of unsharpness in a print all these materials will look perfectly sharp, because a perfectly sharp print need convey no more than 30 lp/mm (see Chapter 1).

Less common materials are less likely to offer perfect sharpness. Dye transfer prints can display only about 15 lp/mm, Ektaflex only 20 lp/mm. Ektaflex and dye transfer are "adequately" but not "perfectly" sharp, as I've defined these terms. Sharpness, though, is not the only criterion for judging a print. I'd hardly ever recommend an Ektacolor print over a dye transfer on the basis of image quality, even though the Ektacolor print could resolve more detail.

I honestly think that sharpness is overemphasized by many photographers. Sharpness is easy to measure, making it a ready target. It certainly is important, but other factors are equally, if not more so, in making a fine print. If that weren't true, we'd all use Tech Pan film and print it on Kodabrome II RC paper (the sharpest paper I've tested), and be done with it. Still, knowing that your print materials are sharp helps when you're trying to track down some other source of unsharpness in your prints. When researching the blurring of variable-contrast prints (see

Chapter 11) I could be sure that it wasn't a problem inherent in the paper, because earlier tests showed the paper was extremely sharp.

It's very easy to test your print material's sharpness if you possess some kind of resolution target. All you need to do is contact-print the target onto a piece of photographic paper and examine the resulting print with a good magnifier. That will give you the answer you need under the best possible conditions, since there are no optics in the way to degrade the image. When you're doing this kind of resolution test, take care to properly expose the print. The light and dark bars should be of equal width for the finest patterns in the target. If the black bars are bleeding out into the white area or if they're so thin as to be fading out entirely, correct your exposure.

You can save yourself some time if you'll simply take my word for it that no modern print material on the market has any real sharpness problems. If one's getting prints that are visibly unsharp, it's usually due to flaws of technique. Some VC papers have an inherent sharpness problem (see Chapter 11). Aerial-image grain focusers may also lead to large systematic focusing errors with any B&W papers, as Patrick Gainer has discovered (see Chapter 6).

The Exposure Range of Print Materials

Anyone who has made more than a few prints knows that the print material doesn't reproduce everything that's in the slide or negative; that is why we learn about paper grades. Many printers stop there. They accept that the print papers won't reproduce every tone the way they'd like, but they do not determine how big a problem it is for them nor learn how to circumvent it.

This blocks the way to fine prints. Paper contrast and exposure range are not immovable objects. Zone System practitioners and their successors have known this for years, but the information doesn't seem to have gone further, perhaps because the System and its variants have built up a mystique and methodology that puts off some printers. Perhaps they think that if they're not using some precise system, they shouldn't pay any attention to quantifying or manipulating these characteristics.

Whatever, I want to dispel that notion right now! This chapter is not a substitute for a decent course in sensitometry or densitometry or the Zone System—it's just a bunch of ways to better understand the medium we're working with. Remember, that's our goal: to understand our tools so we know how to manipulate them better.

If you print solely B&W and you're already using the Zone System or an equivalent, you can skip the rest of this chapter. I don't discuss anything you don't already know, although my approach may be different. If you're printing color or haven't systematically applied some system to your printing, stay and listen a while. I promise you'll get something of value, even if you were put off by Zone-type methods in the past.

We can measure the exposure range of a print material directly. This gives us an objective reference point in the chain that starts with the subject and ends with the displayed print. This is valuable information. Unfortunately, it's relatively useless alone. Suppose I tell you that a particular paper has an exposure range of 1.4 log units (l.u.). You know that means that the paper can handle an exposure of a little under 5 stops, but you have no idea how that relates to the original subject, to the negative or slide you're printing, or to the way the final print looks.

There are several steps between a subject and a print, so there are several pieces of information we need to know to be able to convert subject tonality into print tonality.

First is how the subject tones are rendered as densities in the film—what luminance value in the subject corresponds to each density value in the negative? The characteristic curves I talked about in Chapter 2 are graphs that describe this relationship—each point on the curve matches a subject luminance to a film density. The precise form of the curve depends on both innate characteristics of the film and how it's developed.

Next we need to know how much light the print paper receives through those film densities when it's exposed during printing. The type of enlarger light source and the enlarger lens affect this, as do flare and light leaks.

Figure 4–1 This subject pushed the exposure range of both the film and the paper. The luminance range of the original scene was nearly 12 stops. Even with careful exposure and processing, the highlight detail wound up on the shoulder of the film curve. The most careful printing placed it far enough off the toe of the paper curve to retain some tonal separation. Consequently, the rocket and gantry appear bathed in low-contrast light to the point where they look almost luminescent themselves.

Finally we need to find out what densities the print paper produces for various amounts of exposure as well as what its total exposure range is. Only by knowing this can we understand how we got from the subject in front of the camera to the audience in front of the print.

We start with the paper's exposure range because it's very easy to test and understand. It'll be our mental anchor as we move to considering both the original film and the final rendition.

Determining the Exposure Range and Tonal Qualities of Print Materials

You need only one tool to measure the exposure range of print materials: the ubiquitous step tablet. Stouffer (see Chapter 10) offers a variety of step tablets at prices well below Kodak's. A typical step tablet has density range into steps of 0.15 or 0.1 d.u. (one-half or one-third stops). For our purposes, 0.15 d.u. steps in a tablet with a total range of 3.0 will do. Don't spend the money for a calibrated step wedge—an uncalibrated one will suffice. Should you ever find yourself needing more than a 3.0 log exposure range, get two 3.0 d.u. step tablets and sandwich them together. You'll have a density range of 6.0, which is far greater than the range of any print material.

To measure the exposure range of your paper, contact-print the tablet onto the paper and process the print. Make sure that the exposure you give the paper is great enough so that there

Table 4–1 Exposure Ranges of Print Materials

Print Material	Range in Log Units (l.u.)
Agfa Multicontrast B&W grade 2 paper	1.7
Ilford Multigrade IV B&W grade 2 paper	1.8
Kodak Portra III color-negative paper	1.7
Kodak Ultra II color-negative paper	1.4
Ilfochrome CPS.1K color-reversal material	2.4

are truly black steps in the processed print. It's rare that there won't be any white steps. I try to make the darkest distinguishable step the third or fourth step from the end of the scale. That way I know I'm getting a true black.

Count the number of distinct steps in the visible print and multiply that by the density interval between the steps. For example, if your step tablet has 0.15 d.u. steps and you can see 9 steps, then your exposure range is 1.35 l.u. (log units). To convert that to stops, multiply by 3.3; for example, 1.35 l.u. = 4.5 stops.

This is a very easy test to run, and you should run it on every print paper and grade you normally use. Table 4–1 lists my test results for several different papers. Since we can readily produce negatives with a density range of 2.0 or greater and slides with a density range of 3.0 to 4.0, we know how much information we have to throw away when we make an unmanipulated print. Now we need to find out how the discarded information relates to our original subject matter.

Converting Print Exposure Range to Subject Exposure Range

Our goal is to find out how the exposure range of the print material you use relates to the exposure range of your original film and the density range that the print portrays. I refer mostly to B&W materials for the remainder of this chapter, because the differences between B&W films and papers are more striking; I can create clearer illustrations for you to see in this book. The tests are the same for B&W or color, transparencies or negatives. They are just as important for color.

Start by getting out your camera and a normal or moderate telephoto lens. Load the camera with a roll of your most commonly used film. Set up the camera on a tripod facing a sheet of blank white or gray board and make certain the board is evenly illuminated and fills the frame. Stop the lens down 2 or 3 stops from wide open and throw it well out of focus to produce a uniform image free from distracting fine detail.

Take an exposure reading off the board and set your camera to give 6 stops less exposure than your meter indicates, which should ensure getting a blank frame. Make a series of exposures starting at the -6 stop level and increase the exposure by a half stop with each frame until your exposure is 6 stops greater than the meter read.

Process the roll and make a contact print of it on your chosen print material. If you're doing your own film processing, cut the film into strips short enough to fit on the print paper, whether they're negatives or slides. If a lab processes your film, tell them to return it to you uncut and unprinted (and unmounted, if it's slide film).

Choose a print exposure that renders at least one frame of the film pure white and one pure black. Unless you're using a very-low-contrast film and a very-low-contrast paper, this shouldn't present any problem. If by some chance a 12-stop film exposure range wasn't enough to fully exploit the print material's exposure range, rerun your test with film exposed from -6 stops to +10 stops exposure in one-stop increments. That will overwhelm any print material!

Inspect the contact print as you did the one made from a step tablet. The frames that render as just barely pure white or black bound the exposure range of your print material in terms of the

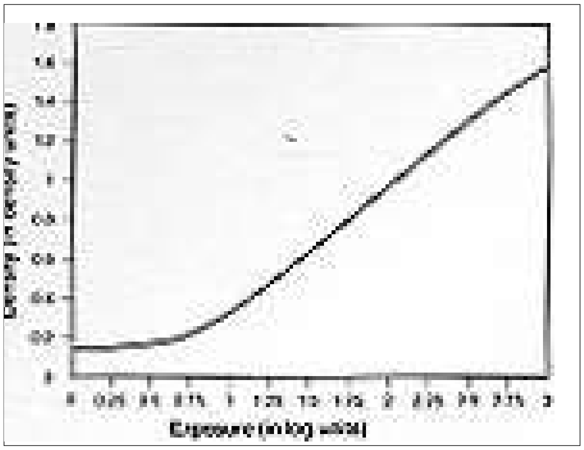


Figure 4–2 A characteristic curve typical of Kodak TMAX 100 film processed in Kodak TMAX developer. The midrange gamma of the film is fine, but the total density range is very high because there is little rolloff in the highlights.

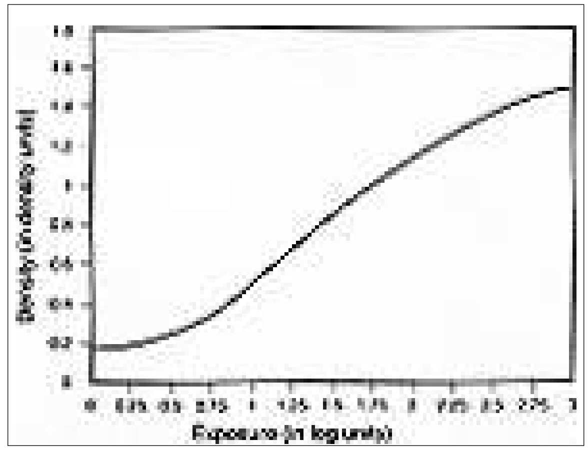


Figure 4–3 A characteristic curve typical of Ilford Delta 100 developed in Kodak Xtol developer. The midrange gamma is comparable to TMAX 100 in Figure 4–2, but the curve is more S-shaped, so the highlights have lower contrast and more of an exposure range, relative to the midtones.

exposure range the film was given. At one end of the series, you will find quite a few frames of film that have distinct densities when you look at them on a light table but that don't print as anything but black or white unless you sacrifice exposures at the other end of the scale. The task of a fine printmaker is to decide what to sacrifice and when, and what to do to minimize the sacrifice to reproduce more of the exposure range.

If you're a B&W printer, you'll want to run this test on all your favorite films. There are considerable differences between B&W films' characteristic curve shapes, and these differences greatly affect the subject luminance range that prints into a particular print paper, even when the films have the same midrange contrast.

For instance (Fig. 4–2), a film with a very straight characteristic curve retains relatively high contrast in the highlights and shadows. That means that a given density range in the film covers fewer stops of exposure than the same density range in a film that has a strongly S-shaped curve (Fig. 4–3). The highlights and shadows in that curve are much lower in contrast than the midtones, so a much longer subject luminance range can fit into the same negative density range, and from there into the print paper's exposure range.

Even if you're the kind of B&W photographer who uses only one type of film and learns to use it well, you probably use more than one grade of paper. It's worthwhile to contact-print the step tablet and the exposure film series on all grades. You can learn an amazing amount just by looking at the contact prints, far more than you can learn by reading characteristic curves. Even with a physics degree, I find it easier to interpret a paper's behavior from the step-tablet prints. I've found it very helpful to mount a set of step-tablet prints for different grades of the same paper side by side on a small card (Figure 4–4). At a glance, I can see the effect of changing paper grades on both the overall contrast range and on the placement of tones.

Manufacturers design today's VC papers to print using the same exposure over a wide range of paper grades, but the exposure is pegged to a certain gray level in the print. That may not be the gray level you care the most about. By looking at the comparison contact prints of step tablets (or of your film series), you can see what happens to each gray level when you change grades. For example, in Figure 4–4, moving from grade 2.5 to grade 3.5 would require me to increase the exposure by three-fourths of a stop if I wanted the highlights to stay the same, but decrease it by one-fourth stop if I wanted the same shadows. On the other hand, if I wanted a constant dark gray level, I'd need to make no exposure change.

It's amazing how much this simple visual aid helps my printing and reduces wasted test prints. I know it's hard to get up much excitement about making step-tablet contact prints. I put off doing it whenever I start using a new paper because it's a lot more fun to print real photographs! Eventually, I force myself to make and mount step-tablet prints. My printing immediately becomes much easier, and I kick myself again for procrastinating. (I should take my own advice more often.)

If you work in color, you'll probably have less testing to do than B&W printers will. There are fewer color papers on the market, and the differences among them in terms of exposure vs. density range are smaller. Furthermore, most color-negative films produce roughly the same gamma. There are some notable exceptions, such as Fuji Reala, but, on the whole, the differences in contrast of color-negative films are small.

There are greater differences in the sensitometry characteristics of slide films. In terms of overall exposure range, there is less difference between slide films than many people presume, but there are considerable differences in curve shape—that is, how the film apportions its density scale among shadows, midtones, and highlights. On the other hand, there are fewer reversal papers on the market than color-negative papers, so there is less testing to do in that area.

For any tests that require a step tablet, you can use the exposure sequence you made in your camera in lieu of a step tablet. Keep in mind that the results will apply only to that one film and its development. If you want an independent calibration of exposure vs. print density, you have to use a step tablet. If all you need is relative information about how different papers print different exposures, a film sequence will suffice.

It's prudent to make new step-tablet prints whenever a paper manufacturer comes out with an "improved" version of a print paper. Sometimes the changes are modest. For example, when Agfa changed from the original Multicontrast paper to Multicontrast Premium, the curve shapes remained very similar and the contrast grades changed only modestly. The new paper was obviously only an evolutionary improvement on the old. On the other hand, Kodak Polymax II paper looked nothing like Polymax paper did. The Polymax contrast grades shifted by as much as two whole units, and the apportionment of tones among shadows, midtones, and highlights was very different. If I hadn't run tests on the paper when it came out, I would have wasted a great deal of time trying to match older prints.

Paper Differences as Seen in Pictures

Over the years, I've trained myself to be able to see the paper differences readily in a step-tablet print. This gives me a standardized reference. But many people find it easier to see the changes in tone rendition by looking at a print of a negative rather than that of a step tablet. In fact, you can gain just as much information about your print paper from a print of a negative as you can from a step tablet.

If you've done much printing at all, you already know that there is almost no agreement among paper manufacturers or paper brands as to what a given grade of paper really means. Most photographers just wing it, remembering that some papers are more contrasty than others, but they don't really have the differences pinned down. Step-tablet prints let me pin differences down exactly. It's very easy to compare strips for different papers and find out precisely which grade of paper A matches a certain grade of paper B. This is something that is harder to determine from test prints of real negatives.

On the other hand, there is no question that real prints make subtle (and not-so-subtle) tonal differences more obvious. I always back up step-tablet tests with prints made from standard negatives I have made. There's nothing special about these negs, except that they have a good mix of tones (and colors, if applicable) for showing off a paper's characteristics. When testing out a new B&W paper, I try to print from three negatives—one requiring maximum paper contrast, one that prints well on grade 2 or grade 3 paper, and one that is so contrasty that it needs grade 0 paper (Fig. 4–5). For color work, I have negatives

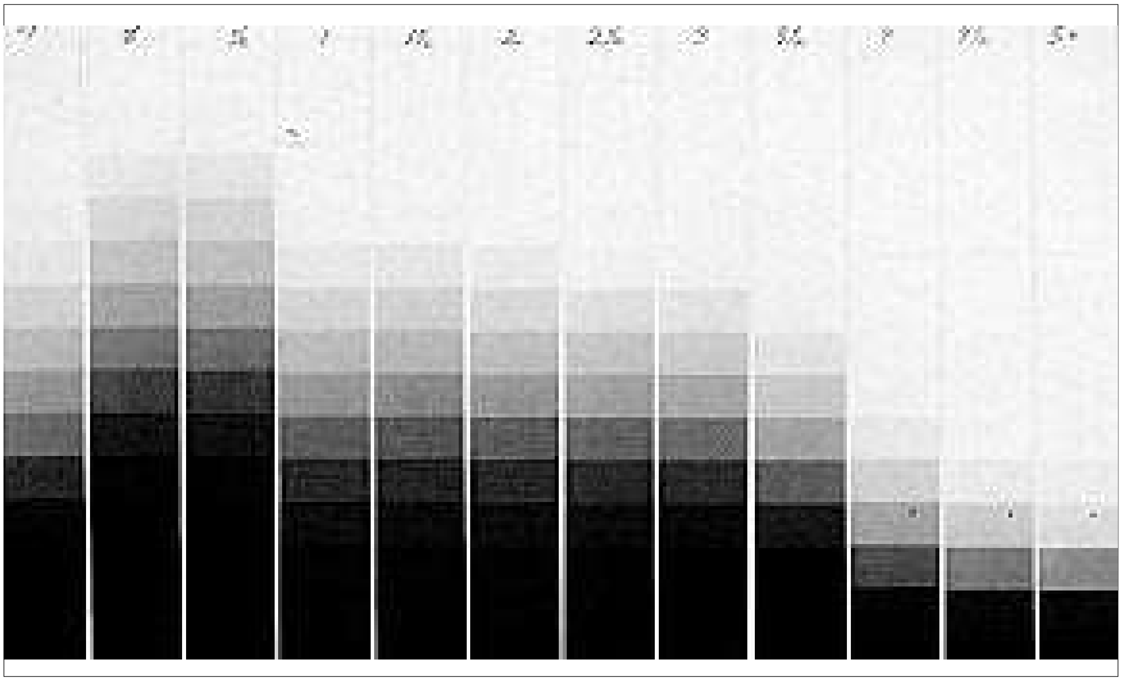


Figure 4–4 This is a set of step-tablet prints for Kodak Polymax II paper, made using the Kodak Polycontrast filter set. I kept the exposure the same for all the prints except for those below grade 1, which received twice as much exposure. A set of prints like this makes it easy to predict the effects on tonal placement of moving from one paper grade to another.

and slides of Macbeth charts, a self-portrait, and a very subtle still-life scene (Plate 7).

I've found that breaking the tonality down into highlight, midtone, and shadow-range qualities is a very handy way to describe the paper's characteristics. Prints on different papers can have exactly the same overall contrast and density range but apportion up their density ranges very differently among the three ranges. It's a lot easier for me to recollect highlight, midtone, and shadow range qualities than to remember entire characteristic curves.

By printing just a few negatives, I can usually tell how a new paper differs from previously tested ones. I compare the new paper's prints from the test negatives with prints from the same negatives on other papers. Differences in contrast and tonal rendition stand out. If there are major differences in contrast (there often are), I change contrast until I get a new print whose overall contrast matches the reference print. That tells me how much difference in the paper grades there is and lets me compare tonal rendition without being confounded by differences in the overall exposure range of the print material.

For example, let's compare how Kodak Polymax, Kodak Polymax II, and Ilford Multigrade IV Deluxe papers print a normal negative. Figures 4–6 and 4–7 show the changes in contrast and tonal rendition between the old Kodak Polymax paper and Polymax II paper. The two prints match in overall exposure range; I placed the lightest highlights exactly the same so that they print just barely below pure white. I selected the contrast grade for each paper to just separate the true blacks from the near blacks. The Polymax print was made with a grade 3 filter, and the Polymax II print was made with a grade 2 filter.

The results look rather different! In the center of the Polymax II print (Fig. 4–7) you can see that the tones in the patio are rendered with more separation and contrast. The average brightness level in this part of the image is the same in both prints, but a much larger portion of the density scale is assigned to this area in the Polymax II print than in the Polymax print (Fig. 4–6). This

Figure 4–5 This is a print from one of my earliest TMAX 100 medium-format negatives, before I realized how careful one had to be about controlling the density range in this film. There's plenty of detail and excellent tonal separation, but I had to print on grade 0 Agfa Multicontrast Premium paper to hold it all.

expanded density range produces a more brilliant-looking print. The overall effect is to give the impression that the Polymax print is lower in contrast than the Polymax II print, although the placement of the true blacks and true highlights is exactly the same in both prints.

The expanded midtone density range in the Polymax II print has to come from somewhere. On this paper, it comes from the shadows. In reproduction, the shadows will probably look darker in the Polymax II print than in the Polymax print. In the original prints, you can see that the near-blacks have been pushed farther down the density scale so that they are much closer to being black, although the true black point hasn't changed. Hence, the shadows have less density range available to distinguish tones, and the Polymax II print shows less tonal separation in the darker puddles and grass and foliage of the trees.

The Ilford Multigrade IV Deluxe print (Fig. 4–8) looks different from either of the Kodak prints, although it most closely resembles the Polymax print. The Multigrade print required a grade 3 filter to produce the same placement of the lightest highlights and the true blacks. Overall, the Multigrade print looks even lighter than the Polymax print because there is less density range apportioned to the highlights. The darker tones in the print can expand more into the lighter densities that would otherwise have been given over to highlights. Consequently,

Figure 4–6 I printed this 35mm Tech Pan negative of a patio at the National Center for Atmospheric Research on Kodak Polymax RC paper with a grade 3 filter.

the Ilford print shows even more tonal separation in the shadows than the Polymax print does, although the midtones seem to have about the same degree of tonal separation.

In comparing the Polymax II print with the Polymax print, I'd say it leaves highlight range unchanged, greatly expands the midtone range, and greatly compresses the shadow range.The Kodak Polymax II paper emphasizes the midtones (illustrated graphically in Figure 4–9). Both Polymax paper and Ilford Multigrade IV paper sacrifice midtone separation for better shadow separation. Comparing the Multigrade print to the Polymax print, the Ilford paper compresses the highlight range, holds the midtone range approximately the same, and slightly expands the shadow range.

This illustrates that even when you match paper grades to ensure that the overall contrast range is the same, you can get very different looking prints. Print papers have a limited density range they can portray, and each brand divides that range differently among shadow, midtone, and highlight tones. Don't ask which paper is best. The questions to be concerned with are which paper produces the tonal distribution you want with the kinds of negatives or slides you produce, and how you think your way through this problem to make such judgments for yourself.

How Important Is Print Density Range?

I've been talking as if all three papers have the same total density range. In fact they don't, but the differences are more readily measured by a densitometer than by sight. Be less concerned with a paper's total density range than with how it apportions that range. There is not a big difference between the ranges of conventional papers. The B&W papers I've tested vary from 2.0 to 2.2, with most closer to 2.2. An average color paper, whether for slide or negative printing, has a density range of about 2.2. Differences of 0.1 or 0.15,

Figure 4–7 The same negative, printed on Kodak Polymax II, required a grade 2 filter. This is a very close match in overall contrast, but individual tones fall at different places on the density scale.

Figure 4–8 This print was made on Ilford Multigrade IV RC with a grade 3 filter. Again, it has the same overall contrast as Figure 4–6, but the placement of tones is very different, as the text describes.

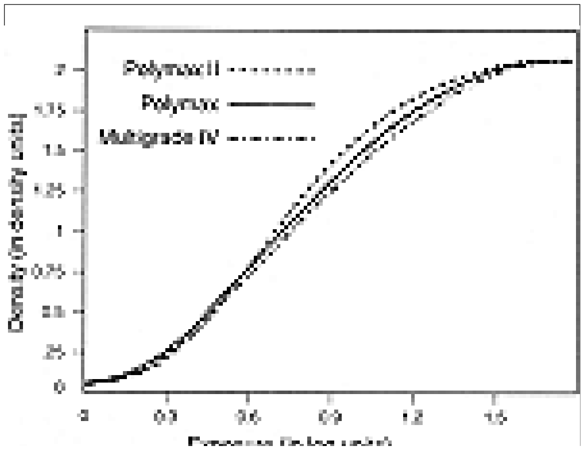


Figure 4–9 These curves graphically illustrate the important ways in which the tonal rendition of medium-contrast Polymax RC paper differs from that of Polymax II and Ilford Multigrade IV RC papers. These are not actual characteristic curves for the products.

typical of competing conventional products, are not very significant and make only a modest difference in the number of tonal steps we can see. Those differences have an equally modest effect on our impression of print brilliance.

I develop B&W prints to completion, as cutting development time to reduce contrast is one of the worst things you can do to a print's blacks. I lightly selenium-tone the prints to eke out a bit more range; heavy selenium toning decreases the maximum density, but very light toning increases it. One reason that my dye transfer prints look much better than my chromogenic prints is that dye transfer prints have a much greater density range than any other print medium. Depending on the print contrast, dye transfers have a D-max from 2.6 d.u. to nearly 3.0 d.u. The difference of 0.5 d.u. or more between a dye transfer print and the other processes makes a huge improvement in tonality.

But that's far greater than the density differences between conventional prints. The different ways in which conventional papers divide their total density range among highlights, midtones, and shadows overwhelm the slight differences in their density ranges. Tonal distribution is by far the most distinguishing quality of competing brands. The paper with the greatest density range *would* give the best tonal separation in a print, *if* all other qualities were equal. They're not.

Paper Differences as Seen in Step Tablets

Step tablets are a much more versatile tool for understanding paper characteristics, although they take more experience to read well. Step tablets also provide a much handier reference. On an 8 x 10 card, you can mount prints of step tablets, which will tell you as much about a paper as a whole stack of individual prints, and you'll be able to get the information at one glance. Figure 4–4 shows such a card for the different grades of Kodak Polymax II paper. If you're not used to looking at step tablets, I suspect you aren't getting much from the picture, but after you read this section, you'll have learned a lot about Polymax II paper from this one illustration.

Let's look at some individual step-tablet contact prints to get an idea of how to analyze what we see. For the first example (Fig. 4–10), I've chosen step-tablet prints in the middle of the contrast range for four papers and tried to pick the prints that most closely matched in contrast grade. In other words, the contact prints are roughly analogous to the comparison photos (Figures 4–6 through 4–8) of the patio that we already analyzed. To get approximately the same total exposure range from both Polymax paper and Polymax II paper, I had to use filters that differed by nearly 1.5 paper grades. Polymax II with a grade 1.5 filter is only slightly less contrasty than original Polymax with a grade 3 filter. A grade of 2.75 would have been even closer. The exposure sensitivities of the two papers are nearly the same. The Polymax II print is very slightly darker, perhaps a half-step difference. To match prints, I'd first try about 15% less exposure than I would have with Polymax paper.

Would this actually give me a matching print? No, because the two papers apportion the density scale differently. Look at steps 11, 12, and 13 in both prints, corresponding to middle to light gray. Although they cover about the same density range in both prints, notice how much bigger the density jump is from 11 to 12 in Polymax II. Thus, there will be more contrast and tone separation in the middle to light tones. On the other hand, Polymax makes a very sharp transition from dark gray to nearly black in steps 9 and 8. There's not nearly as great a jump in the darker steps in the Polymax II print. There, those steps are much more evenly spaced, which means that if you need a print with good separation in the shadows as opposed to the midtones, Polymax II will not serve you as well as Polymax.

Next, let's compare Ilford Multigrade IV and Agfa Multicontrast Premium papers. These two prints are close in overall contrast; the Agfa print is perhaps one-fourth grade harder than the Ilford print. On the basis of the middle gray tones, the two papers also have almost the same sensitivity. If you needed to make comparable grade 2 prints on both papers, you could use just about the same filter and exposure.

However, these papers differ in how they divide up the tone scale. The Agfa paper shows a lot of separation in the midtones and shadows; there are big density differences among the steps from middle gray to black. In comparison, the Ilford paper shows much more modest jumps over that range. The Agfa paper renders dark grays with more tonal separation but blocks up in the shadows a bit faster than the Ilford paper. Compared to the Ilford paper, the Agfa has a tendency to push the darkest grays toward black.

Similarly, the midtone steps in the Agfa print encompass a greater density range than do the same steps in the Ilford print. The steps from 10 to 14 show much greater jumps in density from step to step in the Agfa print than they do in the Ilford. The Agfa print will look a lot snappier in the midtones.

For the Agfa paper to have greater density differences in the steps in the shadows and the midtones, it must be pulling range from the highlights. The lightest steps in the Agfa print are much closer together in density than are the equivalent steps in the Ilford print. The Agfa paper has a "long toe"—large differences in exposure produce small differences in density. The Ilford paper will give much snappier highlights at the sacrifice of some snap in the midtones.

One paper is not better than another. I like the Agfa paper, but I also like films with relatively high contrast in the highlight portions of their curves, such as Kodak TMAX 100. I'm printing a film with contrasty highlights on a paper that tends to have a low-contrast toe. That makes sense of a sort. Were my preference in films different, I might find that the Agfa print didn't produce enough brilliance in the highlights. If I print subject matter with specular highlights such as water or snow, the Agfa print will display them more flatly; it might look more lively in the midtones, but the Ilford print would look more brilliant and less grayed-out.

I'll let you compare Polymax and Polymax II to Multigrade IV and Multicontrast papers. You should be able to see that Polymax paper resembles the Ilford paper in the way it divides up the gray scale, and that Polymax II paper looks a lot more like Agfa in its tonal rendition.

As a final example, look at the grade 5+ step-tablet prints for these papers (Fig. 4–11). What a huge difference in print contrast! Polymax paper is by far the least contrasty, and Polymax II the most. In between, are Agfa Multicontrast Premium and Ilford Multigrade IV papers, with very similar overall contrast. At first glance, it looks like there isn't much difference between Agfa and Ilford because they both show about the same number of steps from pure black to pure white (six in the original prints, although they may not all be visible in reproduction). But when you look at each step, you see real differences between the papers. In the highlight-to-midtone region, step 10 to step 9, we see a much bigger jump in print density in the Ilford print. This says the Ilford paper apportions more of its total density range to the highlights than the Agfa paper. Consequently, the Ilford paper produces a print with slightly more apparent contrast with subjects in which highlights are prominent.

There is also a bigger jump in print density between steps 8 and 7 (from darker middle gray to dark gray); thus, the Ilford paper will also produce more apparent contrast in the transition from middle grays to very dark grays. As I've pointed out, this expanded density range comes at the expense of other portions of the tonal curve. We see that the visible difference between steps 8 and 9, the dark middle grays to light mid-

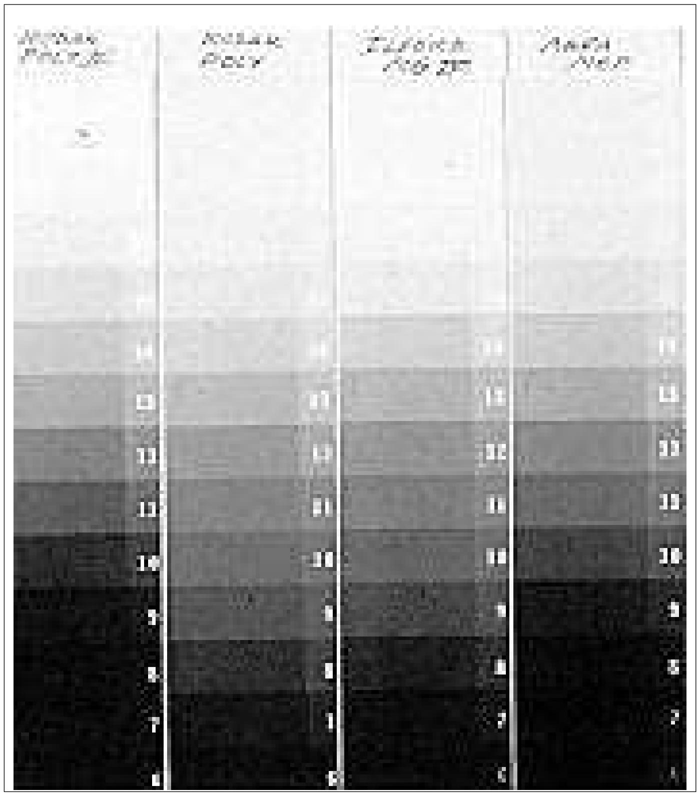


Figure 4–10 These are grade 2 step-tablet prints for four different variable-contrast B&W RC papers—Kodak Polymax, Kodak Polymax II, Ilford Multigrade IV Deluxe, and Agfa Multicontrast Premium. The text describes how to use step-tablet prints like these to analyze the tonal and exposure characteristics of different print papers.

dle grays, is smaller (of lower contrast) in the Ilford paper than in the Agfa paper. If you're printing a subject that depends primarily on middle tones, the Agfa paper will give a snappier-looking print. The Agfa paper also shows a bigger density jump between steps 7 and 6 (the transition from dark gray to nearly black), which tells us that the just-visible shadow details will separate better on the Agfa paper than the Ilford.

You can see all this tonal information in real comparison prints. That's the ultimate purpose—to understand how a real print will look. I'm showing how to read the same information from a simple contact print of a step tablet.

The information we can easily read from step tablets but not from a stack of prints is the relative sensitivity of the paper. I made all the contact strips with the same exposure. Knowing that there are half-stop differences between the steps in the step tablet, we can use the step tablets to choose the exposure we need when printing on a different paper. This is not a constant factor; it depends entirely on which gray level we wish to preserve from print to print. For instance, all four step-tablet prints have very similar transitions from true black to near-black between steps 5 and 6, which tells us that if we're trying to make a print that just manages to pick up the finest shadow detail (e.g., printing an "available darkness" negative and trying to hold a good black), we should start out using approximately the same exposure for all four papers.

On the other hand, if our goal is a similar rendition of a middle gray, there's more than a half-stop difference between the papers; Polymax

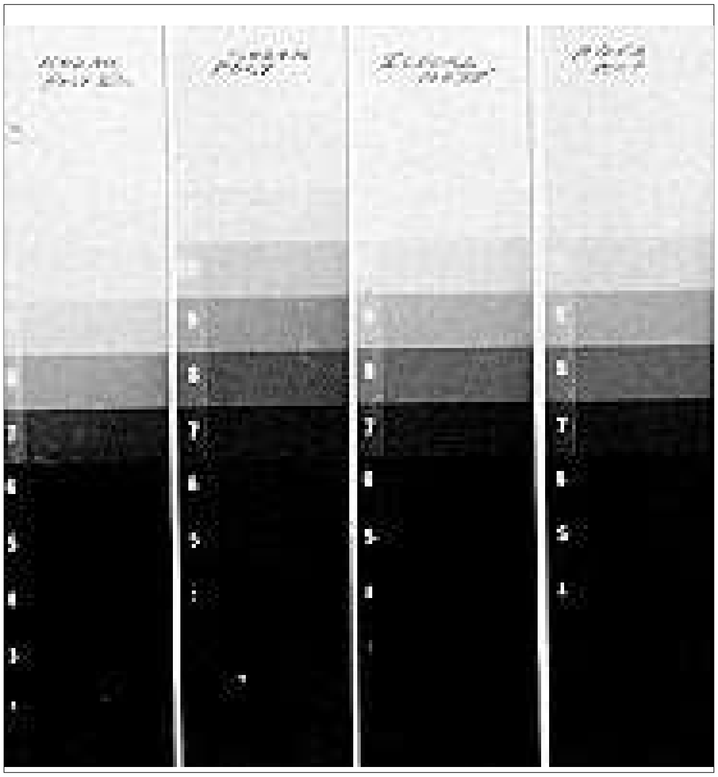


Figure 4–11 These are high-contrast step-tablet prints for four different variable contrast B&W RC papers—Kodak Polymax, Kodak Polymax II, Ilford Multigrade IV Deluxe, and Agfa Multicontrast Premium. They were all printed with a grade 5+ filter, but they look very different both in overall contrast and in tonal placement. The text describes these differences in detail.

II paper is the least sensitive of the four. This illustrates a very important point: There is no constant exposure correction factor when you change papers or paper grades. Whether we're talking about VC papers or graded papers, the exposure correction factor always depends on the precise gray level that you are trying to preserve in the new print. A set of step-tablet prints makes it extremely easy to estimate what that factor will be; I can reliably go from one paper to another and get a first test print that comes close to preserving just the gray level I want. You can't possibly do that with a constant correction factor. This is part of the way I conserve both print paper and my printing time.

At this point, you should be able to make much more sense out of the set of step-tablet prints. Note how you can trace across the step tablet to see how exposures need to be changed from grade to grade to preserve a specific gray level. It's less easy to see in Figure 4–4 how the distribution changes with paper grade and where the white and blacks fall. Nevertheless, you can still get a sense of the relative renditions of grades at a glance. (If you can get information like that from an illustration in a book, think how much more you can from original step-tablet prints.)

Even if you're happy using the standard exposure recommendations of the paper manufacturer, you'll find a chart like this indispensable when you use a color-head enlarger to create different paper grades (Fig. 4–12). That doesn't yield the maximum grade 5+ contrast that VC filters provide: 200 CC of dialed-in magenta filtration is equivalent to about grade 4.5.

Allowing for that one limitation, a color head is my preferred light source for doing VC printing for two reasons. First, I can obtain pre-

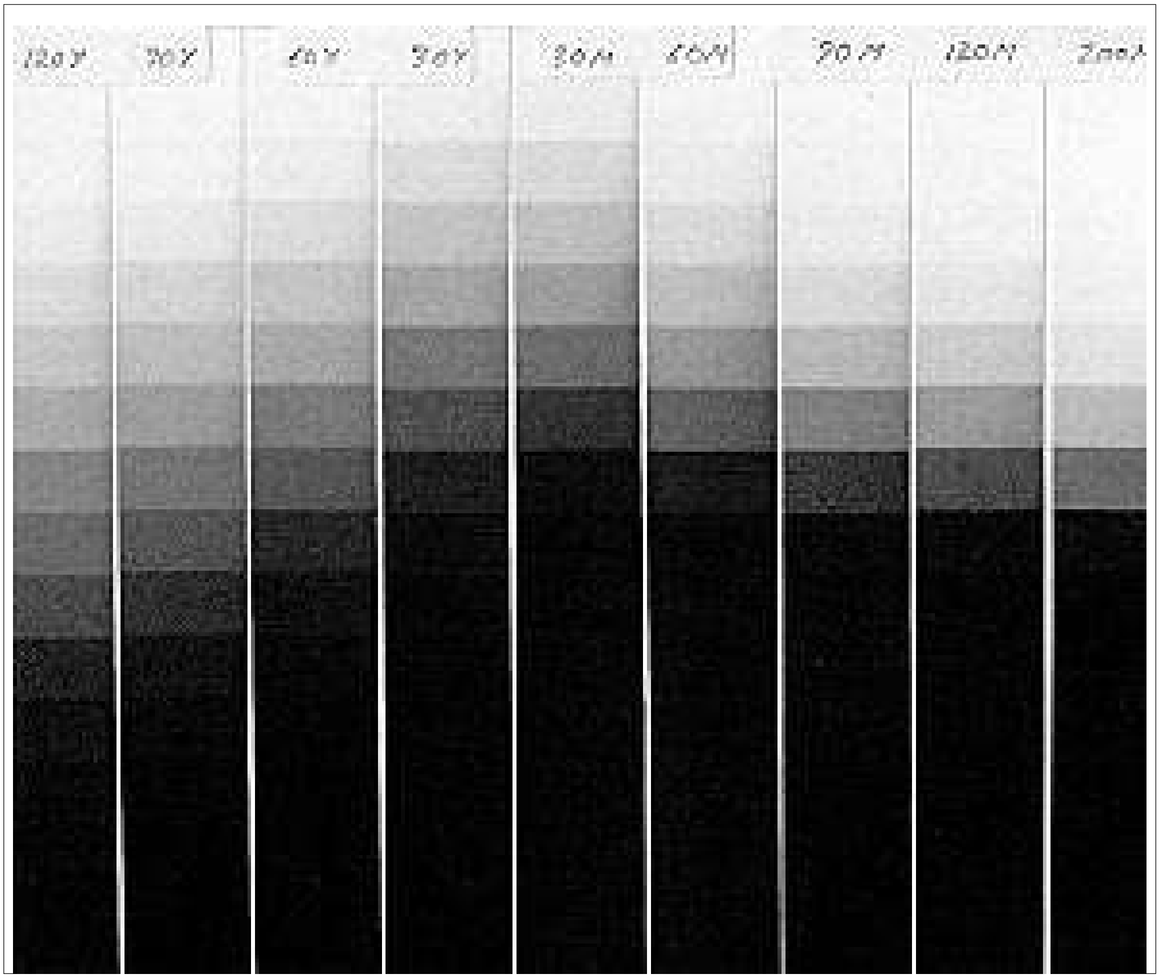


Figure 4–12 This is a set of step-tablet prints for Kodak Polymax II paper, made using the dial-in filtration in a Beseler 45S color head. Filtration ranged from 120 CC yellow (far left) to 200 CC magenta (far right). Compare the prints in this illustration to those in Figure 4–4, made using a VC filter set. I used the same exposure for all the prints in this figure. A set of prints like these are invaluable for determining the correct exposure and filtration when using the dial-in method of making VC prints.

cisely the paper grade I need, not just the half-grade increments produced by VC filters. If I want to print on grade 3.2 paper, I can create 3.2 paper. It's just a matter of tweaking up the magenta filtration another 5 CC or so. Not every image needs this kind of fine-tuning, but sometimes the ability to produce fractional grades of contrast in a paper can make or break a fine print.

Second, it reduces the exposure times for my prints. VC filters that produce supposedly equal exposures achieve this by adding density to the filters in the middle grades so that the exposure times go up to the times needed for the most extreme grades. All I use is yellow or magenta filtration, in varying degrees, to produce different contrasts. There's no unnecessary additional filter density introduced to equalize all the exposures. But this makes things inconvenient without some sort of table of relative exposure times. Since the manufacture of the paper doesn't provide me with exposure times when I'm using dial-in filtration, especially for intermediate grades, my set of step-tablet contact prints provides a reliable and easy reference guide.

CHAPTER 5

MATCHING THE CHARACTERISTICS OF THE FILM AND THE PRINT MATERIAL

As I pointed out in Chapter 4, it's not enough to know the tonal characteristics of your print materials. Those qualities take on meaning only when one combines them with the characteristics of the film and of the original scene. There is no ideal paper curve; there is only the curve that works well with the image. In this chapter, I use black and white (B&W) materials to illustrate most of my points, but what I say also applies to color printing.

The Zone System and its successors, created by such fine artisans as Ansel Adams, Minor White, Howard Bond, and Phil Hyde, are invaluable tools. These systems let you turn subject luminances into precisely the print densities that you want. I have no intention of reinventing this wheel—it's round enough and it rolls along just fine. What I discuss here is deciding what densities you want to represent your original subject.

Here's a quick recap of the guiding principles. The print material has a particular density range, and all the tones in the print come from that range. Because of the inherent limitations of our eyes, a particular density range produces only a certain number of distinguishable tonal steps. Think of the density range of the print as being divided among three categories—the highlight tones, the midtones, and the shadow tones. We can divide those steps as we wish among the three categories, but divide them we must—we cannot magically add more tonal steps to the print.

Suppose that you value tonal separation in the highlights above the shadows. To get that, you must devote more of the density range of the paper to the subject highlights, as illustrated by the dotted curve in Figure 5–1.

That is the only way to get more tonal steps in the highlights and to produce a greater density difference in the print between adjacent tones in the subject. The additional density you devote to highlight tones comes from the density range available for midtones and shadows. One or both sets of tones must be compressed to expand the range of the highlights.

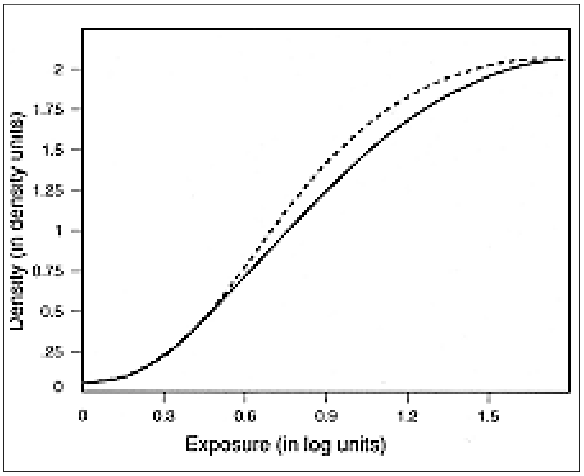


Figure 5–1 These two curves graphically illustrate the difference between a paper with a lot of highlight and midtone tonal separation (dashed line) and one with very little separation (solid line). Since the total density range available to the two papers is the same, the extra range in the highlights and midtones comes at the expense of tonal separation in the shadows. Note that the exposure range for both paper curves is the same.

Although I describe this process as if it were a case of making choices about a paper's tonal placement, it's not really up to you. The paper manufacturer decides what the characteristic curve of the print material will look like. You have some control over this with processing, but not much. You'll never make Ilford Gallerie look like Agfa Portriga Rapid no matter how much you mess with development and other darkroom tricks. The relative amounts of highlight, midtone, and shadow-density range are pretty well locked into the paper when you get it.

What you do have control over is which paper you print on. Fortunately, there are plenty of papers on the market, and no two of them handle tonal placement the same. Since the paper ultimately reflects some real-world subject, there is no single ideal paper even if you hew to one ideal tonal scheme. Different films also have different tonal distributions, and the final distribution of subject tones in the print is a combination of the paper and the film's characteristics. Many fine printers keep a variety of papers on hand and choose the one that best suits the subject they are printing. You must decide what tonal placement scheme is most important to you and select the papers that come the closest to fulfilling that scheme. Below I describe some of the approaches I've taken toward selecting good film and paper combinations.

I pointed out in Chapter 1 that the human eye normally sees finer tonal differences in the highlights than in the shadows of a print. I like a paper that compensates for this by providing better-than-average separation in the shadows. I have only so much density range in the print to work with, and I'd rather grab the extra range from the highlights than from the midtones. The midtones define print brilliance; reducing their range makes the print look dull and lifeless no matter how great the shadow detail is. Consequently, I favor papers with great shadow separation and a long, low-contrast highlight range. Agfa Multicontrast is a good example of a paper that divides the density range to give more to the shadows while shortchanging the highlight range rather than the midtone range.

These aren't absolute criteria. The goal is to get a print that looks good, not one that meets an abstract ideal. For instance, I described in Chapter 4 why I preferred the tonal rendition of Kodak's Polymax II paper to that of Polymax. The newer paper has poorer shadow separation, which detracts from its appearance, but it has much better midtone brilliance. On the whole, I think it has a much better balance of characteristics than the old paper. Highlight tones contribute range, and shadow separation contributes depth, but midtone separation contributes brilliance to a print.

A gutsy negative makes the obvious complement to such a paper. Indeed, I tend to favor richly exposed negatives with a fairly straight and

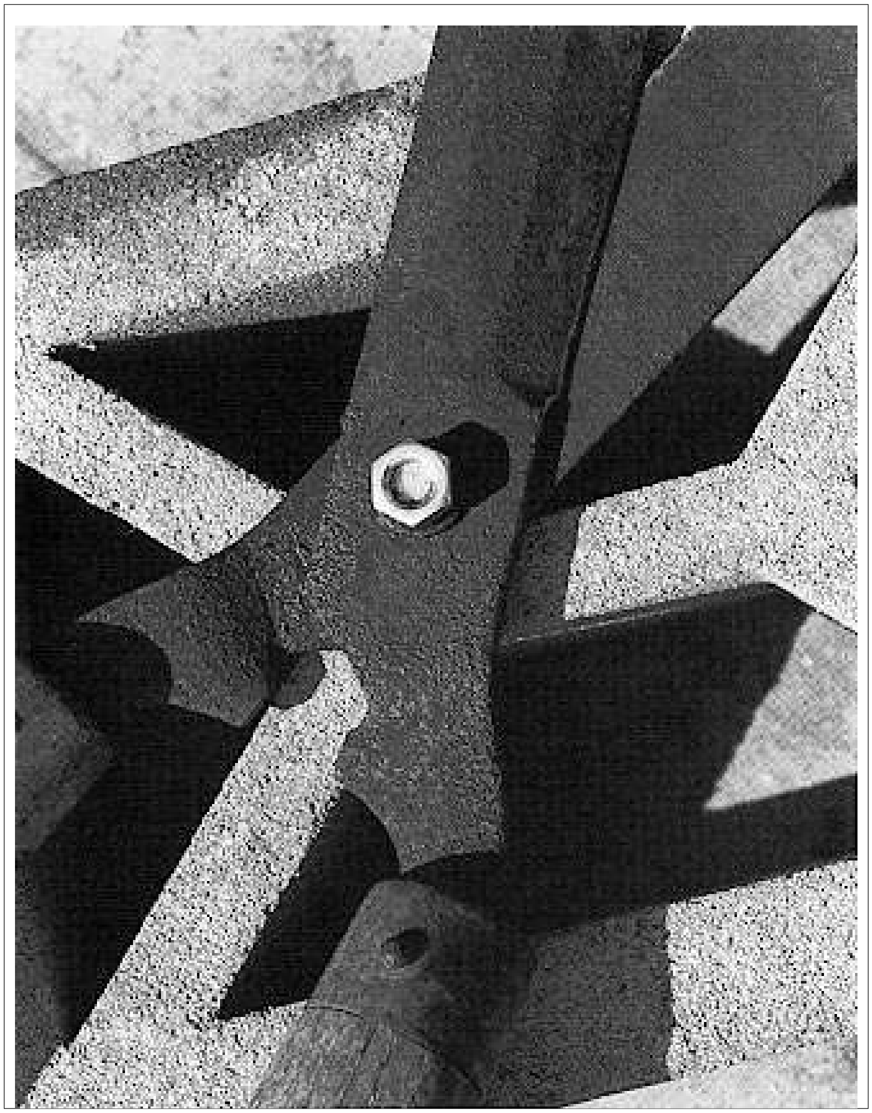


Figure 5–2 This photograph of corroded garden shears, printed on grade 2.5 Agfa Multicontrast Premium RC paper from a medium-format TMAX 100 negative, shows the excellent quality such a paper lends to films like TMAX 100, which have contrasty highlights. The long shoulder of the paper minimizes tonal separation in the highlights but maximizes the exposure range the paper can accommodate. This paper improves the midtone brilliance, bringing out the relief in the shears and the concrete.

long characteristic curve that offers good shadow detail with plenty of highlight separation. I think TMAX 100 is ideal, especially if I rate it at EI 50 and pull the development time by about 20%. Such negatives are definitely not everyone's delight, but they are mine. They print extremely well on a paper like the one I've described, but on the wrong paper they'd be just about unprintable.

In other cases, my taste in films drives my choice of paper. I am particularly partial to Ilford XP-2's fine-grain structure and smooth tones. I especially like its characteristic curve's pronounced and exceptionally long shoulder. If the word for TMAX 100's look is "robust," the word for XP-2's is "long." Highlights go on forever, albeit at ever-decreasing contrast. It never blocks

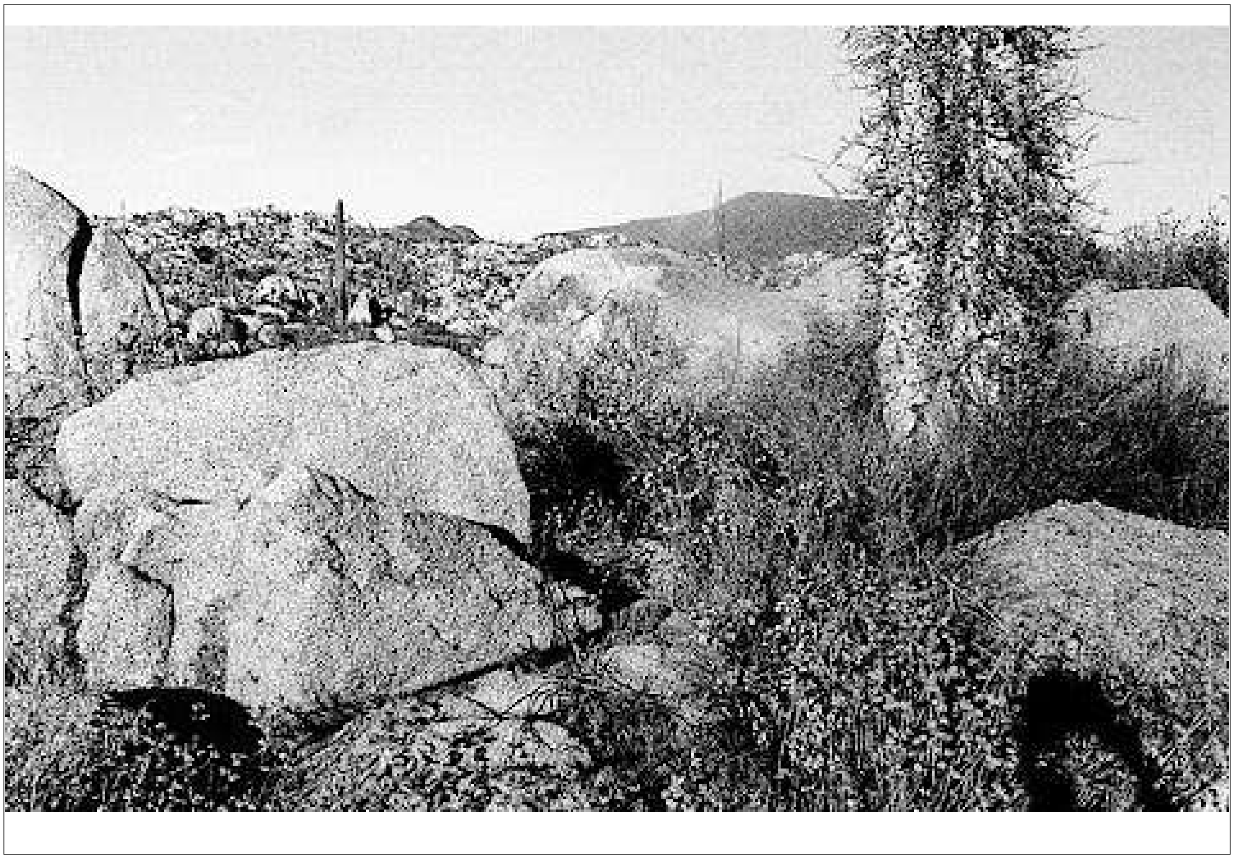


Figure 5–3 This is a grade 4 Kodak Polymax II print, from a medium-format XP-2 negative made in the Baja desert. XP-2's very low highlight contrast works better with a paper that has good highlight separation, especially for a subject such as this one, which depends upon distinct highlight tones.

up, no matter how extreme the luminance range. It's a film made to record exceptionally long ranges, which is a type of subject I photograph a lot. I give the film ample exposure to make sure I get the shadow detail I want because I know the film will handle the highlights.

However, doing this is deadly in combination with a paper such as Agfa Multicontrast. The film and paper both favor shadow contrast over highlights. Together they yield great shadow detail, but the highlights are so flat and lifeless that the print often looks awful. For long-luminance XP-2 images, I need a paper with much more highlight contrast, even if it means sacrificing some shadow separation to get it. Otherwise, the aesthetic point of photographing such subjects disappears.

If the subject's luminance range is more moderate, XP-2 prints very nicely on my usual papers. It's not just the film's characteristics that dictate the choice of paper; it's also the subject photographed. To make the best possible prints, one must not only keep different papers for different films, but also for different subject characteristics. This is certainly not as convenient or inexpensive as stocking one type of paper and learning to work within its limitations. This book isn't about making the least expensive print; we're after the best print.

Still, I do most of my B&W printing on one kind of paper; 99% is done on no more than two. That's normal. The difference between an ordinary printer and a truly fine one is that when the fine printer hits an image that just doesn't "sing" on the usual paper of choice, she figures out why the print is lacking and looks for a material that will fulfill her vision.

Fiber vs. Resin-Coated Black and White Papers

I refuse to get into the great debate over the relative beauty of fiber and resin-coated (RC) papers. Some people love one and hate the other. If you like RC paper, ignore the folks trying to tell you it's ugly. How do they know what's ugly to you? If you hate the look of RC papers, I'm not going to tell you anything that will change your mind either. If you're looking for a settlement to this argument, you won't find it here. Nevertheless, I can make some general and reasonably objective observations that apply to almost all fiber and RC papers.

Veiling

I don't know why it should be, but veiling is one of the more contentious issues associated with glossy RC prints. I observed it the very first time I used a black and white RC paper (Polycontrast, in 1972), and I have since seen it in almost all glossy RC papers. Yet some printers claim that there is no such problem, and paper manufacturers say little about it.

What is veiling? It goes by many names. Some printers call it a "fog"—they don't mean unwanted density in the whites but an effect like looking at the print through light fog. Others call it "surface haze," or "oily sheen." The solid blacks in a veiled print don't look really black; they look grayish due to back-scattered light from the surface of the print. In extreme cases, they are even a little shiny—if you hold a veiled print so that light bounces directly off the print toward you, the blacks actually look lighter than the darkest grays.

I don't know what causes veiling. I've examined veiled prints under the microscope, and I can see pitting in the surface of the print in D-max areas that I don't see in lighter areas. Obviously, that is part of it, because the pits scatter ambient light toward the viewer. I don't think it's the entire story.

Not every paper suffers from veiling. In the late 1970s and early 1980s I was using Unicolor RC B&W paper, which produced a beautiful glossy surface without the least hint of veil. Blacks were rich and deep. That proves that such RC papers are possible. I don't know of any current RC glossy papers that show similar beauty.

Processing can make veiling worse or better. My tests indicate that using a nonhardening fixer with some RC papers increases veiling. High-temperature drying entirely eliminates veiling. In particular, the radiant heat (IR) dryers produce a beautiful glossy surface in any RC paper, no matter how ugly it may look when air dried. My guess is that paper makers rarely test papers with tray-processing techniques. Those of us who can't justify the high cost of an IR dryer and dry prints at room temperature are out of luck. Fortunately, I really like pearl surface in RC papers or I'd probably give up on them entirely.

Tonal Range

Almost without exception, RC papers have a whiter base than fiber papers. If your prints need an extra touch of brilliance that only an ultrawhite base can provide, you must consider RC papers. I have negatives that simply do not print well without those bright highlights, and for that reason they look bad on a fiber paper.

On the other hand, I find that many RC papers don't have as good tonal separation in the deepest shadows as fiber papers do. Even when the two prints have comparable D-max densities, many fiber papers looker somehow "richer." This is not a universal trait, but it's certainly a common one. I cannot explain it, but I do wonder if it is in some way associated with the veiling problem in terms of how silver is laid down in extremely dark areas. If you're having trouble getting tonal separation in the shadows, you should investigate some of the fiber papers on the market.

Beyond these two common qualities, there are no universals that distinguish RC from fiber. Contrary to some reports, RC papers can tone just as well as fiber papers. Gold or selenium toning improves many RC papers' tonal separation and D-max as effectively as it does for fiber papers. You can effectively use soft or contrasty developers, and warm- or cold-tone developers.

Every paper is unique. No two fiber papers render tone or color the same way. Neither do any two RC papers. It is quite possible you will find a specific fiber or RC paper that you like better than any other paper on the market. It is impossible to say which kind of paper that will be.

Permanence

Now we are into the realm of unavoidable controversy. There is substantial evidence that untoned RC prints are more at risk of deterioration than are fiber-base prints. In Chapter 12, I present good evidence that RC papers today have inherent problems that make them less durable, particularly framed prints on display.

RC prints need protection to bring them to the level of permanence that fiber prints have. There is controversy over how much protection is needed. Some people think that the standard mild "archival" toning with selenium or gold that is typical of fiber printmaking is sufficient. Other experts, such as Jim Reilly of the Image Permanence Institute in Rochester, New York, argue that all silver prints are susceptible to damage unless toning converts a large fraction of the silver image. In all honesty, even with extensive postprocessing treatment, I am unsure of the lifetime of my RC prints, although I believe it is adequate. In contrast, there is ample evidence that properly treated fiber-base prints meet archival standards.

Permanence is not the only criterion for choosing a print material. If it were, we'd make only carbon or platinum prints in B&W and tricolor pigment prints in color. We choose our print materials on the basis of overall appearance, cost, and convenience, as well as permanence. Too often, we completely ignore permanence in favor of these other criteria, and we place far too much trust in the paper manufacturers to provide us with durable materials. Caveat emptor!

CHAPTER 6

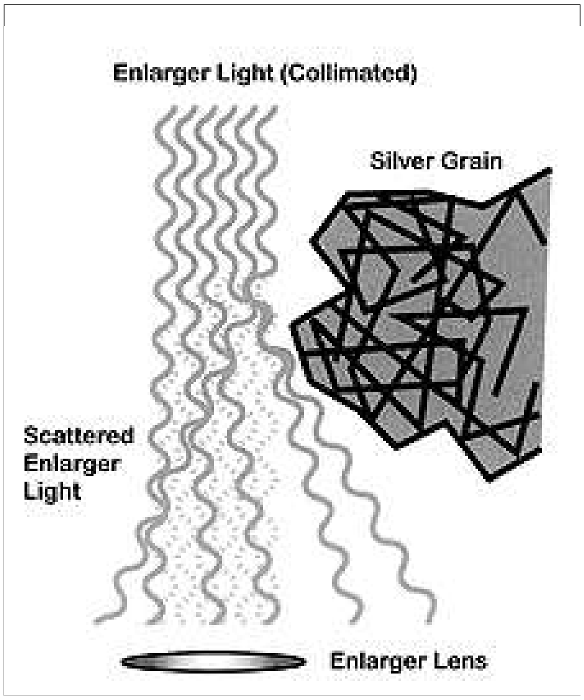
ENLARGING ISSUES

CONDENSER VS. DIFFUSION LIGHT SOURCES

One of the more enduring (not to mention contentious) of darkroom questions is: What effect does the enlarger light source have on print quality? Almost all printers use either a condenser, cold-light, or diffusion head, and almost all have strong opinions about which is the best. I decided to investigate these opinions with my Beseler 45 VX-L enlarger. Beseler makes condenser, diffusion, and cold-light heads for this chassis, so I could compare the characteristics of these heads without the confounding effects of different enlarger designs.

I tested the Beseler 45 Condenser Lightsource, the Dichro 45S color head and the 810 cold-light head for both black and white (B&W) and color printing. Why color? Because, while most of the arguments revolve around B&W printing, according to some folk wisdom there are differences in color print characteristics caused by different heads.

The Condenser Lightsource uses an incandescent #212 bulb rated at 150 watts with a color temperature of about 3000 Kelvins. The condenser arrangement is fixed relative to the lamp; raising and lowering the entire lamp assembly and condenser assembly changes the field of coverage in the film plane up to 4" x 5" format. The Dichro 45S color head provides diffuse illumination covering up to 4 x 5. Interchangeable mixing chambers control the coverage. The light source is a tungsten-halogen 250-watt lamp running at about 3300 Kelvins. The 810 cold-light head covers up to 8" x 10" format and uses special broad-spectrum fluorescent tubes roughly equivalent to a color temperature of 3500 Kelvins.



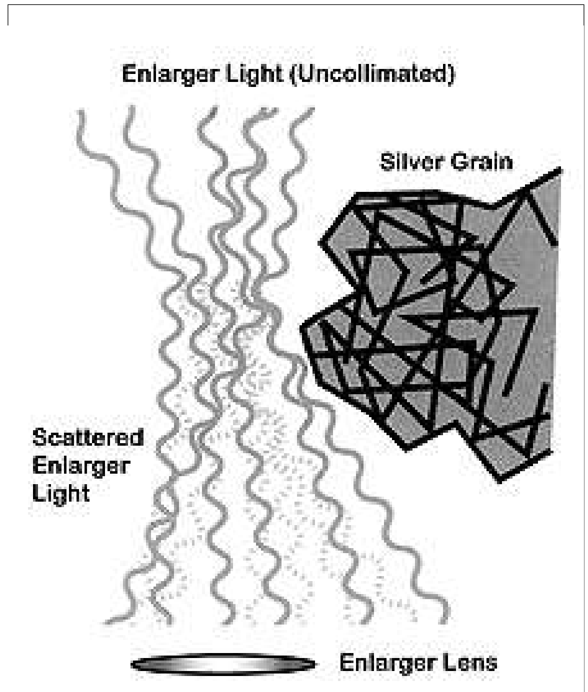


Figure 6–1 These two figures illustrate schematically what happens to enlarger light rays that pass close to a silver grain. Scattering redirects each of the rays (the wavy gray lines). In Figure 6–1, the light is highly collimated; most of the rays would hit the enlarger lens if not blocked or deflected (dotted gray wavy lines). Scattering is much more likely to bend a ray so that it doesn't enter the lens. (Note: the light waves and silver grain have been enlarged greatly to illustrate this. On the same scale, the lens would be a kilometer away and tens of meters across!)

Figure 6–2 This light is uncollimated: it comes in from all different directions. The original ray paths are shown with light dotted waves, the redirected paths with solid gray wavy lines. Although diffuse rays are scattered just as much by the silver grains as collimated light is, the scattering is just as likely to redirect a ray toward the lens that would originally have missed it as to direct a ray away from the lens. Consequently, scattering of condenser (collimated) light reduces the intensity of the light much more than scattering of diffuse (uncollimated) light.

I made prints with lenses from 28 mm to 240 mm from a variety of film formats. I printed Kodak Technical Pan, Kodak TMAX 100, Ilford Delta 400, Ilford XP-2 chromogenic, and Kodak TMAX P3200 B&W films. I made color prints from Konica Impresa 50 negative and Kodachrome 25 and Fujichrome Provia 100 slide films. I mostly used variable contrast paper to get the fine contrast control I needed to match B&W print contrasts between the different heads. I ran a few tests with graded paper to see if the variable contrast paper introduced odd results of its own (sometimes it did).

The primary difference between different kinds of enlarger light sources is how highly collimated the beam of light illuminating the film is. Diffuse light hits the film from all directions. Diffusion and cold-light heads come close to this condition. Collimated light brings all rays of light in perpendicular to the film plane (a point-light source meets this condition, but for a variety of reasons it's a poor choice for pictorial photography). A condenser lamphouse produces semi-collimated light.

Figure 6–1 illustrates how collimated light is affected by a lone silver grain. Light passing very near the edges of the grain scatters in a complex combination of diffraction, refraction, and quantum-mechanical interactions. Collimated light scattering from the edges of the grain is more likely to be directed away from the lens than toward it. Figure 6–2 shows what happens with a diffuse light system—rays come in from all directions and are scattered in all directions. There's no more chance of a ray being scattered away from the lens than toward it.

Consequently, silver grains will scatter more collimated light than diffuse light out of the optical path; this much is easy. Accurately computing the amount of light scattered and absorbed by a silver grain, though, is a state-of-the-art physics problem. Determining the precise effect of myriad overlapping grains would make a tough Ph.D. thesis. We have to rely on experimentation to find out what really happens.

Didn't Callier settle this matter a century ago? The contrast difference seen between prints made with condenser and diffusion enlargers is frequently referred to as the *Callier effect*. Unfortunately, as Al Blaker discovered, this is an error; he found that Callier was studying materials very different from modern photographic emulsions, with scattering physics different from that which we see in today's films. Callier worked with materials whose scattering components were smaller than a wavelength of light; this has quite different properties from our typical films, which have grains larger than a wavelength. Callier's work predicts effects quite different from what printers report (e.g., film with larger grain should show a greater Callier effect). Also, Callier did not specifically study printing contrast—how light transmission changes with the density of light-obscuring grains.

The Big Questions

I investigated the following questions, listed in ascending order of controversy (and difficulty):

- Do different kinds of heads introduce different amounts of flare and light scattering?
- Do inexpensive condenser heads provide less uniform illumination? Is a cold-light head best?
- Do condenser light sources produce sharper color prints or differences in color rendition or contrast, as some have asserted?
- B&W prints made with condenser lamp houses appear grainier, but are they sharper? Do cold-light heads produce especially "soft" prints?
- What changes in B&W print contrast and tonal distribution are due to the light source? Everyone agrees that different light sources produce different B&W print contrasts from the same negative. What's really going on, and can one compensate for this by changing paper grade or film development?

Some of my results (e.g., uniformity of illumination) will surely vary with the enlarger head being tested, and you readers should keep your minds open to possibilities I miss. This research cannot be the last word on this subject.

Flare

Flare is non-image-forming light that comes through the enlarger lens and degrades the contrast and the tone separation in the print. Flare doesn't refer to light leaks around the negative carrier or the lamp housing or any other source of light that is not in the optical path.

An old shutterbugs' tale about enlarger light flare asserts that condenser enlarger heads produce much less flare than diffusion or cold-light enlarger heads. I looked into this matter years ago with a random selection of about a dozen different enlargers of all different types and prices. Some were hobbyist-level items, but all were suitable for serious amateur printing; there were no $49 wonders. There were differences in the amount of flare between enlargers, but even the worst didn't produce enough flare to degrade the tones in any print made using conventional materials. There was no correlation between the amount of flare and the type of light source. Flare had more to do with the internal geometry of the lamp housing, the bellows, and the negative carrier assembly than with the collimation of the light. Light bouncing off the sides of the bellows chamber in the enlarger and reflecting from the surfaces of glass below negatives in glass carriers was more likely to produce problems than the kind of light source above the film.

Flare occurs between the film stage and the lens stage, so the amount of flare light is roughly proportional to the average amount of light transmitted through the film. Here's an effective test for flare. Take an empty negative carrier and stretch a thin strip of black tape across the middle of the carrier. I found it doesn't matter if the tape is shiny or matte, so I used a half-cm wide strip of black electricians tape across a 4 x 5 carrier.

Put the carrier in your enlarger and print the image of the tape strip on a sheet of normal-grade paper. Before making the print exposure, lay a step tablet on the print paper next to where the image of the tape strip will be. Use an exposure about 15 times greater than you'd normally used for printing.

Figure 6–3 illustrates the results for the 810 cold light head (I masked the light-emitting area of the 810 head down to a 4" x 5" area to match the other two heads). I made this print with a 240mm Beseler APO-HD lens (the most flare-free lens I own) on Agfa Multicontrast Premium with no filtration. The minuscule amount of light that is scattered into the projected shadow of the tape produces a measurable density in the print because of the extreme exposure. The step tablet print tells me the difference in intensity between the flare light and the unobstructed light. Each step in the step tablet is a half-stop increase in density. The density in the image of the tape falls between steps 15 and 16 on the tablet, indicating the flare is about 7.8 stops less than the background exposure. The same test with a Dichro 45S diffusion head showed a flare level 8 stops below the mean light level, while the 45 Condenser Lightsource flare was 8.2 stops below the mean light level. The condenser head was best, but all the flare levels are too low to produce any fogging in the print.

Are these differences of importance in printing? No, and here's why. The 7.8-stop flare level of the 810 head is over 2.3 log units below the average background light level. A negative with an average density of 0.7 would show flare equivalent to a film density of 0.7 + 2.3 = 3.0 d.u. No printing paper made can handle that long a luminance range, so this level of flare would have no effect on print quality.

In all my tests, no enlarger has ever produced worse than -2.0 d.u. of flare; even that worst enlarger would have a flare level with an average negative of 2.8 d.u. below white light. I've never had occasion to print a negative with a total density range that came anywhere close to 2.8! The flare level is well below the light level transmitted through the densest part of my negatives; hence, it can't degrade the highlights in my prints.

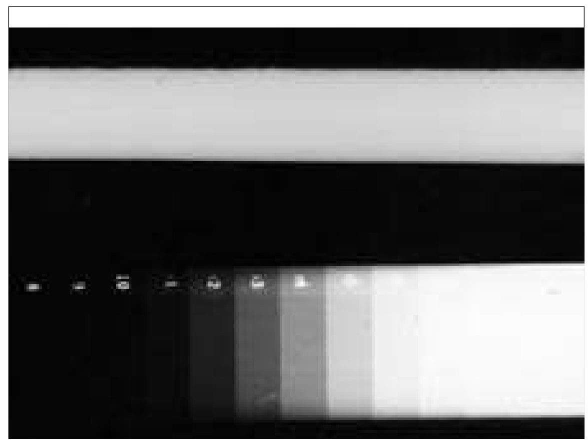


Figure 6–3 This test print shows how much flare is produced by the Beseler 810 cold-light head. The light-gray bar is the projected image of a strip of black tape stretched across the negative carrier. Next to it is a contact print of a Kodak step tablet. I gave the print enough exposure to produce some density in the image of the tape (which would have printed as white if there were no flare). The density is only slightly greater than step 16 in the tablet, which is 8 stops below background level.

For slides, the worst-case flare would be somewhere between an equivalent density of 3.4 and 4.4. Under extreme conditions and with very substantial masking, you might barely get to a 3.4 level when printing, but there's not much detail beyond that in any slide. Remember, this example is for the worst enlarger I tested; most enlargers did much better. My conclusion is that flare isn't a problem with enlargers. You should give more concern to light leaks in the enlarger head that get reflected from the walls of the darkroom or even illuminate the print easel directly.

Be more worried about light scatter from an old enlarging lens; scratched or hazy lens surfaces produce a measurably higher level of flare than pristine lenses and will degrade prints.

Enlarger lenses tend to acquire deposits from the air in the darkroom. Unless you're very careful about having clean air flowing into your darkroom and to carry off the chemical fumes (most of us aren't as good about this as we should be) some of the grime will be chemicals from your solutions. Because these chemicals are mildly corrosive, they attack the glass and antireflection coatings on the lens over time. They create microscopic pits in the surface of the lens or a slight obscuring veil that won't come off. Either way, they make the lens look hazy, which creates far more flare than you'll ever see from a new enlarger and lens. It's a good idea to run a flare test occasionally. It's a very good idea to keep your enlarger lens capped whenever you're not printing.

Uniformity

Testing the uniformity of an enlarger is easy only if you have a lens that you know doesn't produce much light falloff. You may not be able to determine if nonuniformities are due to your enlarger or your lenses; it's something of a catch-22. I discuss this in the section "How to Test Lenses" later in this chapter. For this test I used my Rodagon 135mm lens, which I knew produced less than 1/8 stop of light falloff at f/11 for small magnifications.

I set up my enlarger with an empty negative carrier in the negative stage and made a print on the most contrasty paper I had, exposing for a middle gray in the print. I used Kodak Polymax paper with a grade 5+ filter, which has less than a 2.6-stop exposure range.

The processed print from this kind of test will never be perfectly uniform gray, although it may get quite close. Figure 6–4 shows my results for the diffusion head. To quantitatively measure the light falloff, I contact-printed a Kodak step tablet onto another sheet of the same paper (Chapter 4, Figure 4–10). I compared the steps in that print to the darkness of the uniformity-test print to determine the difference. The Dichro head showed essentially no falloff toward the corners, but there was a gradual falloff from right to left and a little mottling. This isn't unusual with color-head enlargers using mixing boxes. The difference in exposure from one side of the print to the other was between 1/6 and 1/8 of a stop—extremely good performance. The 810 cold-light head did slightly better; there was no left-to-right nonuniformity.

Figure 6–4 These prints, on Kodak Polymax grade 5+ paper, were made to test the uniformity of the Dichro 45S and condenser lamphouses. They were printed using an enlarger lens that has been shown to have a negligible degree of light falloff. The Dichro 45S print, above, is extremely uniform, although there is a slight darkening to one side of the field.

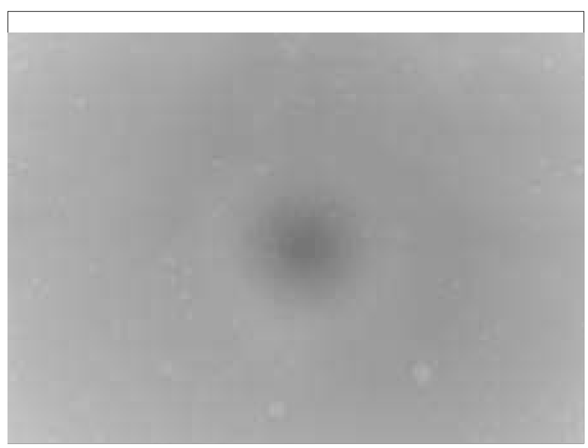


Figure 6–5 The condenser enlarger print shows a strong dark "hot spot" in the middle and small whiter circles scattered throughout the field. The hot spot is experimental error, caused by running this test with no film in the negative carrier; it disappears with film in place. The pale spots came from dirt on the condenser surfaces.

Figure 6-5 shows my first test for the condenser head; it looks pretty awful. There's a big hot spot in the center, corresponding to almost a half-stop difference in exposure. Pale circles are scattered throughout the field; they came from bits of dirt on the surfaces of the condenser. They went away after I took apart the condenser assembly and carefully cleaned the elements.

The hot spot turned out to be an experimental error! The shiny flat bottom of the lower condenser acted as a mirror, reflecting the illuminated upper surface of the enlarging lens. The hot spot is really a very out-of-focus image of the lens. Putting film in the negative carrier eliminated that mirror image. When I reran this test with a sheet of film in place and clean condensers, the uniformity of illumination was superior to the diffusion head. That really surprised me, as this is not an ultra-expensive head with specially ground and aligned condenser elements. Obviously, these results will depend very much on the specific make of heads, but this proves that you can get uniform elimination from a condenser head without spending a fortune.

Why didn't I use a photometer to directly measure the light reaching the print easel? Because it's extremely difficult to align one to eliminate the errors introduced by off-axis measurements. Since we only care about the effect of light variations on prints, the direct approach eliminates such problems.

Color Printing

Color film images consist of clouds of dye, not opaque silver grains. There shouldn't be much scattering from a transparent dye cloud, so you'd not expect there to be any difference in print quality between condenser and diffusion light sources.

Nonetheless, some excellent printers have asserted that using a condenser enlarger does produce crisper, contrastier prints than a diffusion enlarger. A few enlarger manufacturers have even made condenser heads specifically for color printing. My fellow dye transfer printers use a point-light source and a liquid gate film carrier to make separations from slides, hoping to extract the maximum possible image detail.

How could this possibly matter? First, the dye clouds displace the emulsion (Fig. 6–6). If you look at light reflecting off the emulsion side of a slide, you can see a relief in the surface of the emulsion corresponding to the image. Portions of the emulsion with lots of dye in them are thicker than portions with none. This surface variation will bend light like a lens. If you hold a slide up to a near-point light (e.g., a bare lightbulb across the room), you can easily see extra-bright rims alongside sharp dark edges caused by the refracted light. The same can be true for color negatives, although the effect is much smaller. Also, dye clouds don't have precisely the same refractive index as blank gelatin, so there could possibly be some scattering effects from dye clouds (I don't actually know if there is enough to matter).

I knew from previous tests that there would be no difference in print quality between the cold-light head and a standard diffusion color head, so I tested the diffusion head against the condenser head. I made all color prints using the tricolor filter method: three sequential exposures made through red, green, and blue filters, with the exposure times adjusted to produce the correct density and color balance in the print. I did this so that I could produce matching prints on both heads without introducing extra filters into the light path. I printed a 35mm Konica Impresa 50 negative on Kodak Ultra II paper and Kodachrome 25 and Fuji Provia 100 slides on Kodak Radiance paper. The reason I printed both Kodachrome and Provia is that Kodachrome slides have a distinctly different grain structure than that of any E-6 film.

I made 10X enlargements using my Computar 55mm f/1.9 lens at f/4.8, to maximize both sharpness and contrast. This lens is capable of projecting an image far sharper than anything the unaided human eye can see. I sandwiched the film between optically flat glass (microscope slides) and carefully aligned my enlarger using a Zig-Align.

In overall appearance, the diffusion and condenser head prints were indistinguishable. There

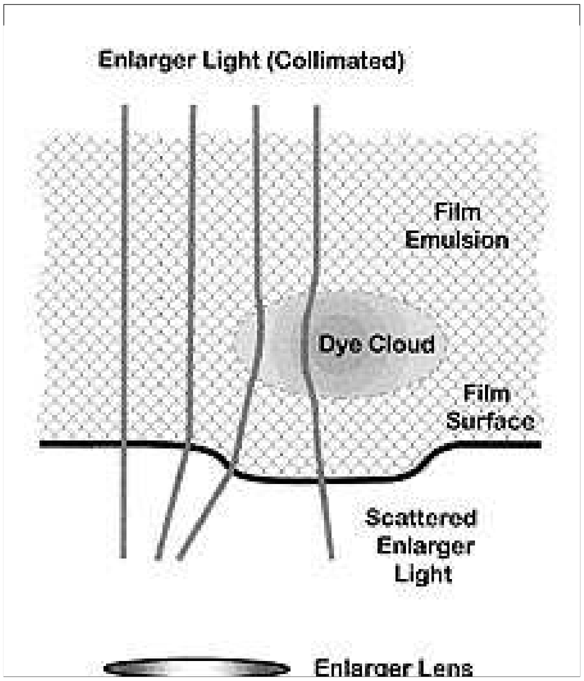


Figure 6–6 A schematic illustration of what happens to light rays passing through color film in a condenser enlarger, showing why color film might print differently with a condenser head than a diffusion head. The image-forming dye clouds within the emulsion push up the film surface, creating a relief that refracts light. This causes a slight edge enhancement effect, which is easily seen by holding a slide up to a near-point light source, like a distant lightbulb. Dye clouds themselves may have an effect on the light path, as they don't have precisely the same refractive index as clear emulsion, but this hasn't been demonstrated.

was no difference in color rendition or saturation, overall print contrast, or placement of tones within the paper's range. This was the easy part.

The hard part was comparing grain and sharpness. I found that there was no end to the amount of fine-tuning I could make on the sharpness of my prints. Each time I thought that one head definitely produced sharper prints than the other, I'd go back to the other head and try a little harder and discover that I could match or exceed the print I made on the first head. I found myself increasing the distance from the enlarger head to the print easel in 1mm steps in order to see super-subtle differences when viewing the prints through a 10X Hastings Triplet.

This task was not made any easier by longitudinal chromatic aberration in the enlarging lens and in the human eye (the focus-foiling effects Patrick Gainer and I have discovered: see "Grain-Focuser Gotchas"). These two effects exist independently in varying degrees for different enlarger heads, lenses, people, and papers. In almost no case did I find that the actual plane of best focus precisely corresponded to the apparent plane of best focus as seen through my Micromega focuser. Rarely was there a big enough difference to matter in regular printmaking, but for comparing the ultimate limits of quality of different heads it was confounding.

It took many days and dozens if not hundreds of prints for me to be confident that I had reproducible results. I learned not to jump to a conclusion the first time I saw a visible difference. I had to run the same tests three or four times before I was sure I had the experiment fully under control. If you wish to undertake such tests yourself, consider yourself warned.

Ultimately, I found no difference in image sharpness in the Impresa 50 color negative prints. The finest details in the print were considerably less than 10 microns wide in the negative. Even with the Hastings Triplet, I could not convince myself of any difference in resolution or sharpness.

Apparent grain, though, was another matter. The grain in the condenser print was ever so slightly more evident and irregular in appearance. Oddly, this grain looked the crispest at a focus that did not produce quite the sharpest rendition of the image detail. How can that be?

The more pronounced grain in the condenser print was not actually an image of the grain but a spurious effect from the surfaces of the film. It's due to refraction by the slightly irregular surface of the emulsion and by microspheres that are placed on the surface of the film during manufacture. These microspheres don't interfere with normal printing, but they are one of the reasons why printing color film with a point-light source without an oil-immersion carrier doesn't work. They bend the light very strongly out of the normal path. In short, surface irregularities can masquerade as film grain.

This effect is even more pronounced in Kodachrome and E-6 film prints, as the surface relief is much greater than in a color negative. My diffusion head 10X enlargements from Kodachrome 25 and Provia 100 had significantly smoother but less-sharp-looking grain than the prints made with the condenser head. The condenser prints actually exhibited about 10% better resolution, down around 80 lp/mm in the original film. This improvement in sharpness is only just barely visible under the best of viewing circumstances. Still, it shows that in the most extreme case, there may be some merit to enlarging slides with a condenser head, as long as the slight increase in image sharpness is more important than (or desirable in combination with) the noticeable increase in apparent grain.

B&W Print Sharpness

I said that testing color prints for sharpness and graininess was tough. Well, the B&W tests made the color work seem like a picnic! On top of the problems I've already mentioned, including the fact that focus shifts of less than 1 mm change the image structure, I had to use variable contrast paper in order to match the contrast of prints across the heads. I chose Agfa Multicontrast Premium for this task because I knew from previous work that it showed the least focus shift due to longitudinal chromatic aberration. That's not quite the same as "none," and there was also the "Gainer Effect" to take into account. So I had contrast to match, focus shifts to correct for, and hundreds of prints to make. I got exactly the same results in terms of print graininess and sharpness with the cold-light head that I got with the diffusion head. Whatever I report regarding the diffusion head, you can assume it applies to both.

I made prints using Kodak Technical Pan, Ilford Delta 400, and Kodak TMAX P3200 film, which span the range of graininess and sharpness available in B&W films. I got the same results with all three and am confident that choice of film had no effect. Here's what I found with Tech Pan film:

Figure 6–7 A full-frame grade 2 condenser print from a 35mm Kodak Tech Pan negative. This is the primary negative I used to study print graininess and sharpness for B&W printing. The detail I paid most attention to is the small clump of bushes in the shadows against the wall in the center of the photograph.

My test photograph (Fig. 6–7) is a nearly-full-frame 8" x 10" print from a 35mm negative, printed on grade 2 Agfa Multicontrast Premium paper with the condenser head. As before, I aligned the enlarger and sandwiched the negative between microscope slides. I concentrated my attention on the central small clump of bushes at the wall. Figure 6–8 shows an enlargement (40X in the original 5" x 7" print) of that area. I examined the finest detail in the light branches and blades of grass near the wall.

Figure 6–8 This is an enlargement of Figure 6–7. In the original print, it's a 40X blowup. Here, it's about 20X. The tree trunk in the center of the photograph is further enlarged in Figures 6–9 through 6–12

Figure 6–9 (enlarged from Figure 6-7) and Figure 6–11 (enlarged from a corresponding diffusion head print) show the very finest detail; they would have 240X magnification in 5 x 7 prints! The smallest blades of grass and leaves are 5 microns. These two images represent the very sharpest prints I could make with both enlarger heads. There is no difference in the sharpness of image detail between the prints. This is most interesting, because the grain is obviously more defined in the condenser print. The difference in graininess of the two kinds of prints is visible even in the original 8X enlargements. Unlike my results for color prints, this really is film grain we're seeing.

Figures 6–10 and 6–12 are reversed versions of Figures 6–9 and 6–11. These positive images represent the way the projected grain in

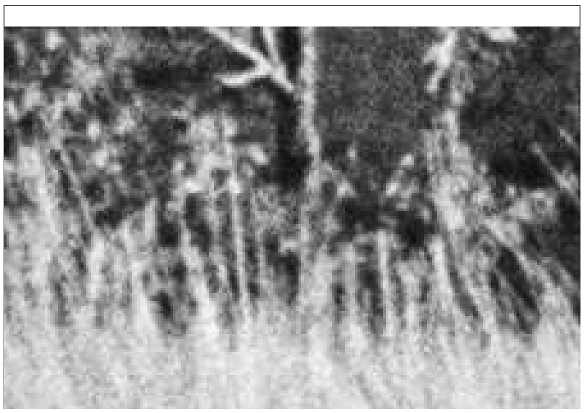


Figure 6–9 These four illustrations are enlarged over 100X from the original negative.They show the level of fine detail that could be seen in the original 7" x 10" prints that they were made from. This print was made with the condenser head.

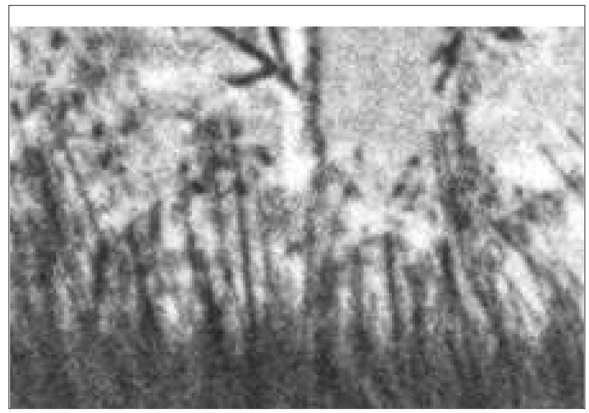


Figure 6–10 This negative print of Figure 6–9 illustrates what the light hitting the print paper actually looks like. In this print, dark spots are silver grains, whereas in the normal print to the left, the dark spots are the spaces between the grains.

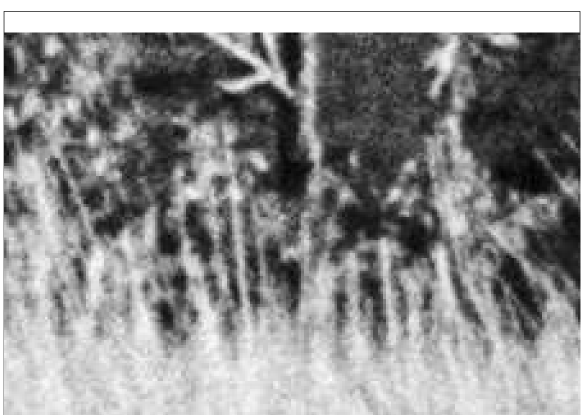


Figure 6–11 This print was made with the diffusion head. While the grain is more distinct in the condenser-head print, there's no difference in the sharpness of the actual subject detail. The finest image detail in this negative is five microns in size.

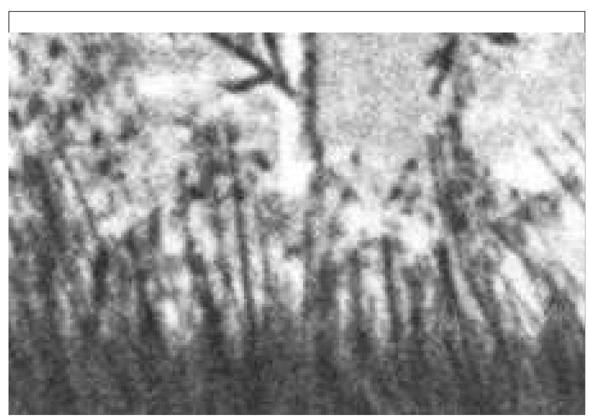


Figure 6–12 The negative print of Figure 6–11. The sparsely scattered grains in the thin areas of the negative are clearer in the condenser print. Where grains pile on top of each other to make image details (the darker parts of the negative prints), the condenser print doesn't resolve separate grains any better than the diffusion print does.

the negative looks to the print paper. Each little dark spot in these prints is silver grain (the dark spots in Figures 6–9 and 6–10 are the spaces between grains). In the lighter portions of the positive images, the grain looks slightly crisper in the condenser-head print. Yet, the larger dark image features in those prints have no more real detail in their edges. They have more fine irregularities to them, because each grain is more evident, but the aggregate effect is not an actual increase in image detail, merely visual noise. I duplicated these results with a Delta 400 negative; it's not an artifact of Tech Pan.

How can the grain look sharper but not the image? No enlarger lens is good enough to show the actual structure of the grains themselves; we're looking at images of blurred and scattered light as I described previously. Since the individual grains in collimated illumination scatter more light out of the optical path than those printed with a diffuse light, there is a greater difference in light intensity between the image cast by the grain and the surrounding clear film. That produces a more distinct spot in the print paper, regardless of what is (not) being resolved. A print will register the image of single grains (or spaces between grains) even if they're well beyond the resolving power of the lens.

As an analogy, consider that you can photograph stars at night, even though each star is far too small to resolve. The star's image is blurred out to the resolution of your system, but as long as there's enough brightness difference between the blurred star image and the surrounding sky, you get the image of a star. But there's a big difference between recording a single star and trying to photograph two stars that are so close together their images blur into each other.

Similarly, the light passing between grains and the shadows cast by grains produces a printable image even when the actual structures themselves are smaller than the resolution of our enlarging system. Image detail is composed of organized aggregates of grains (more correctly, the spaces between them). It's detection vs. resolution; our prints detect grains, just as our astrophotograph detected stars, but we don't resolve their structure. If we had cameras and enlarging systems so good that we could actually reproduce image detail down to the very finest of grain structures, we might see a difference in image sharpness. But the limitations of physical optics guarantee that we never will. The grain features that scatter the light are truly submicroscopic.

I thought I might see some difference between the heads with a poorer lens; that Computar 55mm lens is capable of imaging over 350 lp/mm. So, I tried an old triplet of mediocre resolution that didn't produce decent performance except at f/11. The triplet prints weren't as crisp as the ones made with my Computar, but there was still no difference between the condenser- and diffusion-made prints.

I'm now convinced that condenser light doesn't produce genuinely sharper B&W prints. If highly defined grain lends an impression of greater sharpness to your work, then you should use a condenser head. If the impression of sharpness in your prints depends only on the image detail, then the head won't matter.

I would not expect this result to change with different designs of enlarger head, but you never know. If someone has test results out there that contradict mine, please drop me a note.

Contrast and Tonal Placement

The most profound difference between diffuse and condenser-head printing, as every printer has observed, is that prints made with diffuse light are less contrasty. Some folks say the difference is much greater with fine-grained films; some argue that one can match the condenser print when making a diffusion-head print by a simple contrast adjustment. Most everyone attributes these effects to the work of a fellow named Callier in the last century.

Unfortunately, Callier was not studying the same kind of scattering phenomena as occur when we enlarge film. The kind of scattering Callier studied is related to the kind that makes the sky blue. The kind we're concerned with is related to what makes water clouds white and dust clouds gray. As I said earlier, Callier's work makes predictions about contrast changes that

Table 6–1 **Exposure Corrections Required to Produce Matching Prints**

Film	Ratio of actual exposure to predicted exposure (beyond 2.6X correction, +/- 0.05)	Additional filtration needed to match contrast (beyond 35 CC Yellow, +/- 3CC)
Tech Pan	1.13	70 CC Magenta
TMX 100	1.12	70 CC Magenta
Delta 400	1.0	60 CC Magenta
TMAX P3200	1.0	65 CC Magenta

don't agree with what we see in the darkroom. So, if you must refer to the "Callier effect," remember that it's no more than a convenient name. Sadly, Callier has little or nothing to tell us about photographic printing.

I did almost all my tests on Agfa Multicontrast Premium paper. In the few cases where I used another paper, I'll say so.

My first step was to calibrate the diffusion and cold-light heads against the condenser head to provide a comparable exposure. I contact-printed a Kodak step tablet using all three heads and adjusted the exposure time and the filtration for the cold light and diffusion heads to give me a print that exactly matched the condenser-head print in contrast and density.

The diffusion-head print required 2.6 times as long an exposure as the condenser-head print did, even though the lamp in the diffusion head puts out much more light. That condenser head uses light much more efficiently. Adding 35 CC yellow filtration to the diffusion head produced a step-tablet contact print with the same contrast as the no-filter condenser print. That makes sense; the color temperature of the quartz-halogen lamp in the diffusion head is a few hundred Kelvins higher than the condenser bulb, so the ratio of blue to green light in the diffusion light is higher.

The higher percentage of blue light from the cold-light head resulted in unfiltered cold-light contact prints equivalent to grade 3-1/2 prints made with the condenser head. Adding a grade 0 filter plus 40 CC yellow to the light path matched contrasts. Once I'd done that, I found no difference in the contact prints between all three heads, which comes as no surprise.

Next, I printed an Ilford XP-1 negative as a control. XP-1 is a chromogenic film—it produces a monochrome image by using dye clouds. It ought to print much the same as a color negative; if scattering from the film grains is really responsible for the contrast and tonal differences, there ought to be no difference between printing XP-1 on a diffusion head and on a condenser head. After I printed the XP-1 with the condenser head, I applied the 2.6X exposure factor and 35 Y filtration pack to make a print with the diffusion head. That exposure factor was within 3% of what was needed to produce an identical print. This proved that the contact-print correction factors gave the right results for enlargements when silver grain effects didn't enter in.

I then made condenser-head enlargements on the equivalent of grade 2 paper from four different B&W films. They were (in order of film graininess) Kodak Tech Pan, Kodak TMAX 100, Ilford Delta 400, and Kodak TMAX P3200. Finally I made diffusion-head enlargements to match the condenser enlargements.

All the diffusion-head prints required additional filtration and/or exposure beyond the base correction factors. These additional corrections are presented in Table 6–1. This confirmed that the diffuse light did alter the printing characteristics of a silver-grain negative. But the differences did not follow the expected pattern.

Figure 6–13 shows a set of step-tablet contact prints of the different grades of Agfa Multicontrast Premium. 70 CC of additional magenta filtration is a substantial contrast change—equivalent to grade 3-1/4 paper. But the contrast difference between 60 CC and 70 CC is not great (only about 1/6 grade) and the correction didn't steadily decrease from Tech Pan to TMAX P3200, as conventional wisdom predicted. This suggests that the fine microstructure of the film grain has as big an impact on the scattering characteristics as the overall grain size. It's well beyond my capabilities to test and analyze such differences. Electron microscopes, anyone?

The changes in contrast correlate poorly with changes in exposure. I'd expected that any change in contrast caused by increased scattering would have to be accompanied by a corresponding change in exposure. Yet, for both Delta 400 and TMAX P3200, I needed almost no exposure correction despite a great contrast change. So perhaps scattering isn't the whole answer? I can't explain it, only report it.

Contrast-matched prints made with the two heads don't look the same, as Figures 6–14 (condenser) and 6–15 (diffusion) illustrate. I made this photograph of my dear, since-departed cat, Pentax, on 35mm Ilford Delta 400 film. The negative's density range portrayed in both prints is identical, yet tonal placement is clearly different: the light midtone-to-highlight areas in the condenser print have more contrast. At the other end of the scale (less visible in reproduction) the shadows are a bit more open in the diffusion print. The diffusion print compresses the paper density range used to render the highlights in the negative and expands the paper density range used to render the shadows. Put another way, the condenser head is more likely to block up extreme highlights when moderate highlights are printed the same. The cold-light head does not produce a print that is visibly different in any way from a print made with the diffusion head.

Is this a genuine difference in the way the condenser and diffusion heads transmit light through the negative or merely an idiosyncrasy of

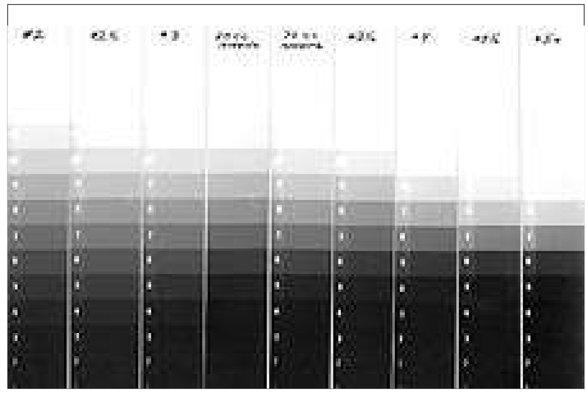


Figure 6–13 A set of contact prints of a Kodak step tablet made on Agfa Multicontrast Premium paper. The #2 filter corresponds to the contrast of paper used to make all the condenser-head prints. The 60 CC and 70 CC magenta strips illustrate the range of contrast changes needed to match diffusion head prints to the grade 2 condenser head prints; both fall between grade 3 and grade 3-1/2 filtration. The very large jump in contrast from grade 4-1/2 to grade 5+ equals the difference in contrast between printing a very flat negative on diffusion and condenser heads.

Agfa Multicontrast Premium? To test that, I made prints from several negatives on two other variable contrast papers: Ilford Multigrade IV Deluxe and Kodak Polymax II. The precise placement of tones varied with paper, as none of them have the same characteristic curve, but this effect of diffusion light compressing the highlights and expanding the shadows appeared in all cases.

This looks like a genuine effect of the light source to me, unless all three major variable contrast papers share this same characteristic. The kind of illumination affects the characteristic curve shape (Fig. 6–16). I could not check this for graded papers, unfortunately, because none of the papers I tried produced exactly the contrast spacing between grades that I needed to match prints. In general, this will be true—it will only be by lucky coincidence that a combination of film, enlarger heads, and brand of graded paper will let one produce matching prints on both condenser and diffusion-head enlargers.

Might one match tonal characteristics on both kinds of heads by altering film development time to compensate for the difference in print

Figure 6–14 These two photographs of my cat Pentax were made from the same 35mm Ilford Delta 400 negative. Figure 6–14 was printed with a condenser head, Figure 6–15 with a diffusion head.

Figure 6–15 Although the prints match exactly in the overall negative density range portrayed, they differ significantly in the placement of tones within that range. The diffusion head print has flatter, lower-contrast highlights and more open shadows.

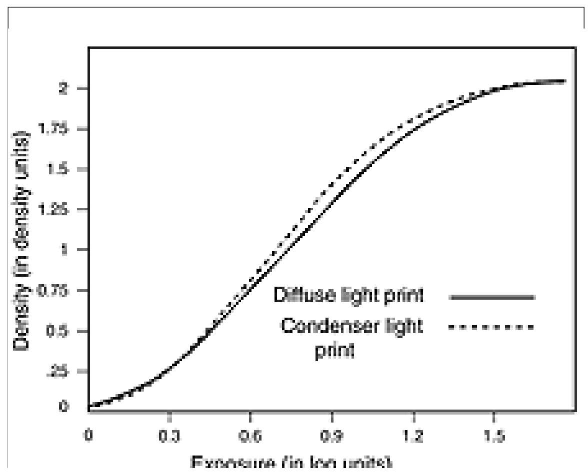


Figure 6–16 Idealized characteristic curves illustrate the differences between diffuse light and condenser light for prints of the same overall contrast. Diffuse light produces prints with higher shadow contrast but lower highlight contrast. Since the shadows lift up from D-max more quickly in the diffusion print, diffusion-light prints portraying the same density range from the original negative will have slightly lighter midtones and highlights than corresponding condenser prints. Extreme condenser-print highlights, though, are more likely to block up.

contrast? In order for altered film development to match tonal placement as well as overall contrast, the change in development would also have to warp the film curve in just the right way to counteract the changes introduced by the enlarger head. There's probably some combination of film and developer out there for which this happy accident will occur, but there is no general rule about what happens to the shape of the film's characteristic curve (as opposed to its overall slope) when one varies development time. It depends upon both the film and the developer.

In the same way, reducing film development time to produce negatives of a contrast more suitable for condenser printing may both reduce film grain and increase sharpness. The reduction in film grain may partially offset the enhanced appearance of grain in condenser prints. Some films show a large reduction in graininess, while others show very little. The effect such a change would have on your printing depends entirely upon your choice of films.

The changes in development time to effect the desired contrast change also vary considerably with film. In most cases, the improvement in inherent film sharpness will be small. Personal testing is the only way you'll find out if it's enough to matter; no blanket generalizations are possible. One *might* produce sharper negatives that *might* produce sharper prints than one would get by giving that same negative a bit more development and printing it on a diffusion head. I emphasize *might*; we've seen many of the suppositions that have been made about printing fail to hold up under scrutiny.

In my final tests, I examined how the enlarging heads handled very low contrast negatives. I diffusion-printed a Tech Pan negative that was properly exposed (but very flat) on Agfa Multicontrast Premium with a number 5+ filter. I could make a matching print using the condenser head with only a grade 4-1/2 filter. Numerically, that doesn't sound like much, but as the step tablets in Figure 6–13 indicate, there is a great difference in contrast between those two grades.

Next, I printed an underexposed TMAX P3200 negative. Again, I attempted to match a grade 5+ diffusion-head print with the condenser head. In this case, the grade 5+ print made with the condenser head was only slightly more contrasty than the diffusion-head print! A condenser print made with the grade 4-1/2 filter was much flatter. The condenser head improves contrast with properly exposed but extremely flat negatives, but this advantage almost disappears when printing seriously underexposed negatives.

To summarize my results:

- In order of increasing amount of flare, we have condenser, diffusion, and cold-light heads. No head produces enough flare to register in a print. Other than flare, diffusion and cold-light heads produce indistinguishable results.
- All heads can produce illumination uniform enough for a demanding printer.
- The uniformity and flare results will depend upon the specific make of head. The following conclusions should hold for any make of head:
- A condenser head produces a grainier color negative print than a diffusion head, but this "grain" is actually an artifact generated by irregularities in the surface of the film; the prints are no sharper. Prints from color slides are both grainier and slightly sharper. The choice of head has no effect on color or tonal rendition.
- Chromogenic B&W negatives print the same with all heads, indicating that any differences in the printing qualities of the heads are a result of the silver grain image, not an inherent property of the light source.
- The condenser head produces grainier-looking B&W prints than the diffusion head, but it does not produce sharper image detail. Any apparent sharpness increase is an illusion created by the more crisply rendered grain.

None of the following involves a "Callier effect;" Callier's work doesn't apply to photographic printing:

- The condenser head produces more contrasty prints from silver B&W negatives than the diffusion head, and the difference in contrast is almost independent of the B&W film used. Changes in overall print exposure between the heads doesn't correlate with changes in contrast.
- Relative to a diffusion head, a condenser head prints the negative highlights with more contrast and the shadows with less, in prints that match in overall contrast. Hence, it is not generally possible to exactly match a condenser print with a diffusion print either by changing paper grade or by changing film processing, although one may get lucky.
- Condenser heads produce much more contrasty prints of normally-exposed, very flat negatives but offer very little contrast increase in prints from extremely underexposed negatives.

How Sharp Does a Lens Have to Be?

The single most important piece of photographic equipment you'll ever own is your enlarging lens. It doesn't matter how good the camera body or lens is or how expensive the enlarger chassis is. A mediocre enlarging lens will make every print mediocre.

Enlarging-lens makers produce remarkably good optics, given the price, but our standards are so high that even these unusually fine lenses can prove inadequate. As I said in Chapter 1, our eyes are exceptionally sensitive to edge sharpness or acutance. Consequently, although we only need about 5 line pairs per millimeter (lp/mm) for an 8 x 10 print to look adequately sharp, we need about 30 lp/mm for it to look perfectly sharp. This represents about a 7X enlargement from 35mm format, half that much from medium format, and about 2X from 4 x 5 format. For resolution of merely adequate sharpness, the 35mm image has to have about 35 lp/mm on the film, the $2^1/_4$ image needs about 20 lp/mm, and the 4 x 5 image needs a bit more than 10 lp/mm.

You may recognize those resolution figures. They're close to the values camera makers use for depth-of-field marks on lens barrels. For adequate sharpness, even mediocre cameras and lenses have little trouble making the grade, and all formats are adequately sharp. Similarly, just about any enlarging lens, even a very inexpensive triplet, meets the adequate sharpness criterion, although such a lens has other serious problems, such as color fringing and very bad light falloff at the edges.

Fine printers don't put up with merely adequate quality. We strive to achieve images as close to perfection as we can. If perfection demands 30 lp/mm in an 8 x 10 print, then we need a whopping 200+ lp/mm in the negative. You cannot get that much subject detail in 35mm format; you'll do well to get half that. Consequently, you cannot make a 35mm image that has more detail than you can use in an 8 x 10 print. It's barely possible in 120 format. You'll have to go to 4 x 5 format before you can afford to throw away image sharpness. At that format, you'll need 60 lp/mm, which is doable, albeit difficult.

The scary truth is that if you truly seek perfect sharpness, then you have to work in 4 x 5 or preferably 8 x 10 format. I make most of my photographs in medium format. I can live with less than perfection in exchange for a more portable and versatile setup. But I've never deluded myself into believing that bigger wouldn't be observably better.

A 35mm format enlarging lens must be capable of imaging well over 200 lp/mm to produce a perfectly sharp, full-frame print; if you're enlarging only a portion of the original, the requirements are even tougher. It's better to print from medium format, but it's still very demanding of your enlarging setup and alignment and of your enlarging lens. Again, you really need 4 x 5 or larger formats.

You may be thinking: Why does it matter that enlarging lenses be able to reproduce such fine detail when we can barely photograph 100 lp/mm of image detail onto our 35mm film? Why do we care about 35mm enlarging lenses projecting in excess of 200 lp/mm? The answer is that we must reproduce more than the original subject detail. Sharpness depends on both image detail and image *structure*. An important part of perceived sharpness is crisply rendered grain. Blurry grain makes us feel that an image is fuzzy. Development edge effects that improve acutance have a structure much finer than the image detail, and rendering this well is critical to a perceived sense of sharpness.

Less obviously, but more important, sharpness affects the tonality of the print. Photographic prints are made up of millions of minuscule images of the grains (or dye clouds) in the original film. The collective impression we get from the little pointillistic elements is one of continuous tone. If we do not sharply reproduce the grain of the original film in the print, our subjective perception of the tones changes. Worse, the tones recorded by the print paper are physically degraded, especially in the extreme highlights and shadows, because the tones at extreme ends of the tonal scale are made up of sparsely spaced and very small images of grains (or the spaces between grains). These details are so small and so faint that they lie right at the edge of the print paper's ability to reproduce them. If they are blurred just a little bit, they become so faint that the print paper doesn't register them. Thus, what should be a very dark gray, for example, can print as pure black.

There is an old photojournalists' printing trick for saving marginal negatives. You can squeeze a bit more contrast from a print by making it slightly out of focus. Some of the delicate highlight detail and deepest shadow detail will be truncated and lost entirely, and the print will be more contrasty than a sharply focused print. However, fine printmakers usually don't want to sacrifice tones. We fight to get good tonal separation in the midtones without losing the highlight

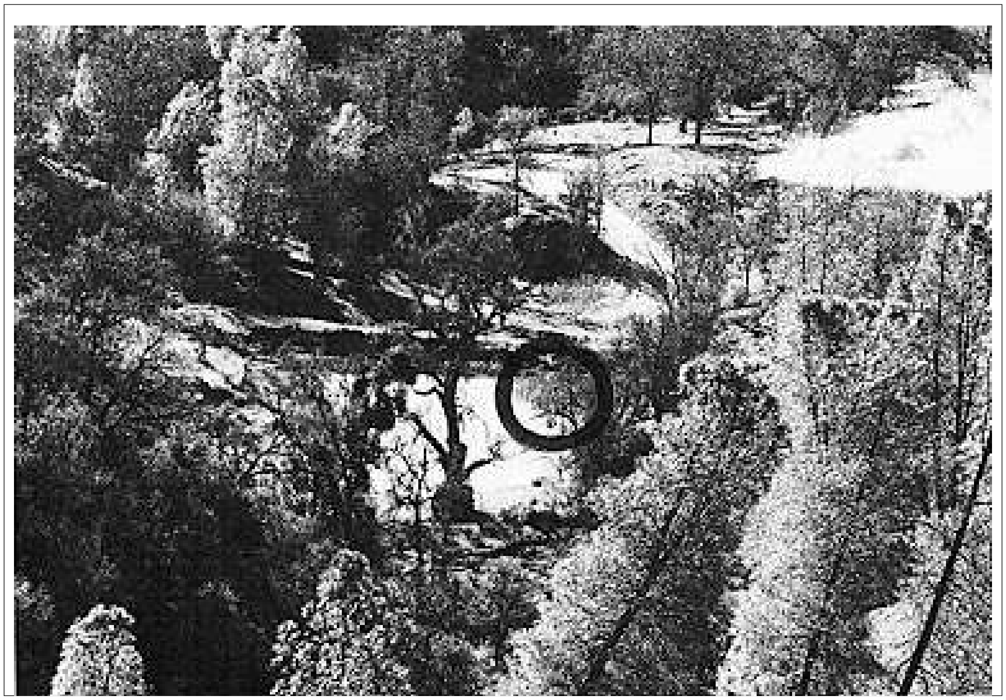


Figure 6–17 This is a Polymax print made with the Computar 55mm f/1.9 lens at f/4, using 150 CC of magenta filtration. The original negative area is about half a 35mm frame of TMAX 3200 film exposed at EI 1000. The small circled area in the center of the picture indicates the portion of the photograph that is shown enlarged in Figures 6–18 and 6–19.

or shadow detail because of the limited exposure and density range of most printing materials. A less than perfectly sharp print makes that even more difficult.

You can see this for yourself in Figures 6–18 and 6–19, which show highly enlarged sections from an extremely sharp print vs. an adequately sharp print of the photograph shown in Figure 6–17. At normal viewing distances, both prints look sharp and the grain is visible, but because the grain is mushed out in the less-than-perfect print, we've dropped out some tones in both the highlights and the shadows. You may not notice any difference in fine detail from a lens that resolves 150 lp/mm vs. one that resolves 300 lp/mm, but you'll certainly see a difference in the tonal quality.

Remember, this is under ideal circumstances! Sources of image degradation build on each other. If your lens is just barely able to meet your criteria, your enlarger alignment is just barely up to snuff, your focus and your print material sharpness are borderline, and—well, when you compound all the sources of blur—I guarantee you that you will be well below the requirements for perfect sharpness.

Every step in the photographic chain takes its toll. The enlarging lens resolution, the enlarging focus error, and the print paper resolution all add their own blurs to the total blur in the image. A top-notch 35mm format enlarging lens can resolve 300 lp/mm at f/4-f/5.6. That's 43 lp/mm in a 7X print. If your focus error is also equivalent to 43 lp/mm in the print (a focusing distance of about 1 mm at the easel at f/4.8 and 7X, but only about 1/60 mm in the negative plane), your combined resolution can be no better than 30 lp/mm in the print. That doesn't take into account the resolution limits of the paper, the quality of your original negative, or any alignment errors in your enlarger. If you haven't checked your enlarger's alignment (see Chapter 14), it's not likely to be anywhere near perfect.

Disheartening, right? This is a reason people move to larger formats. Unfortunately, that is not

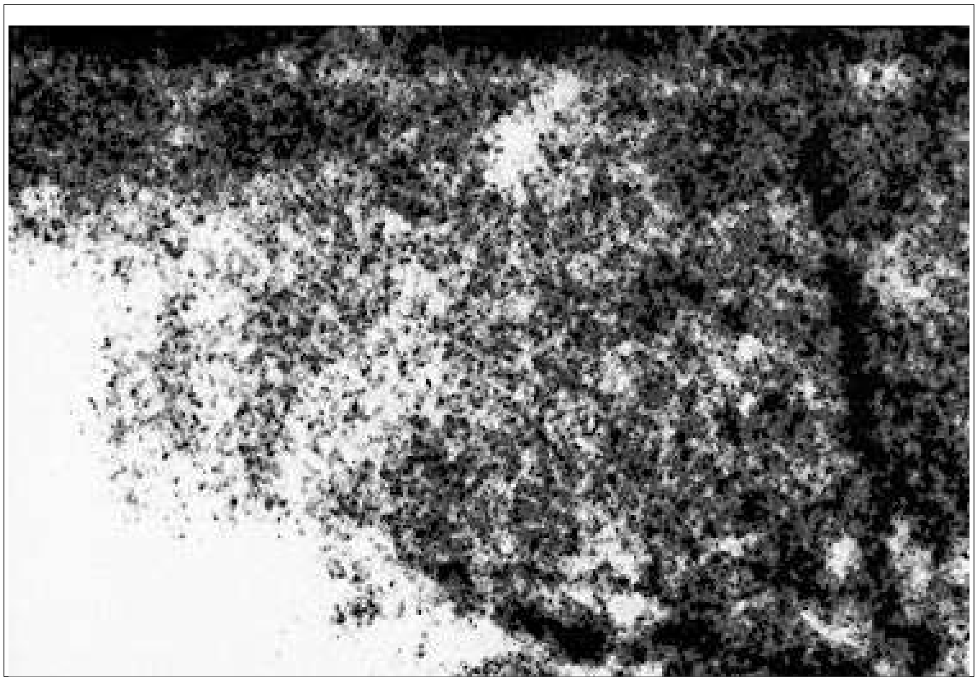


Figure 6–18 This is a highly magnified section of the print shown in Figure 6–17, with the focus adjusted to produce the sharpest print. The Computar lens is capable of resolving 300 lp/mm.

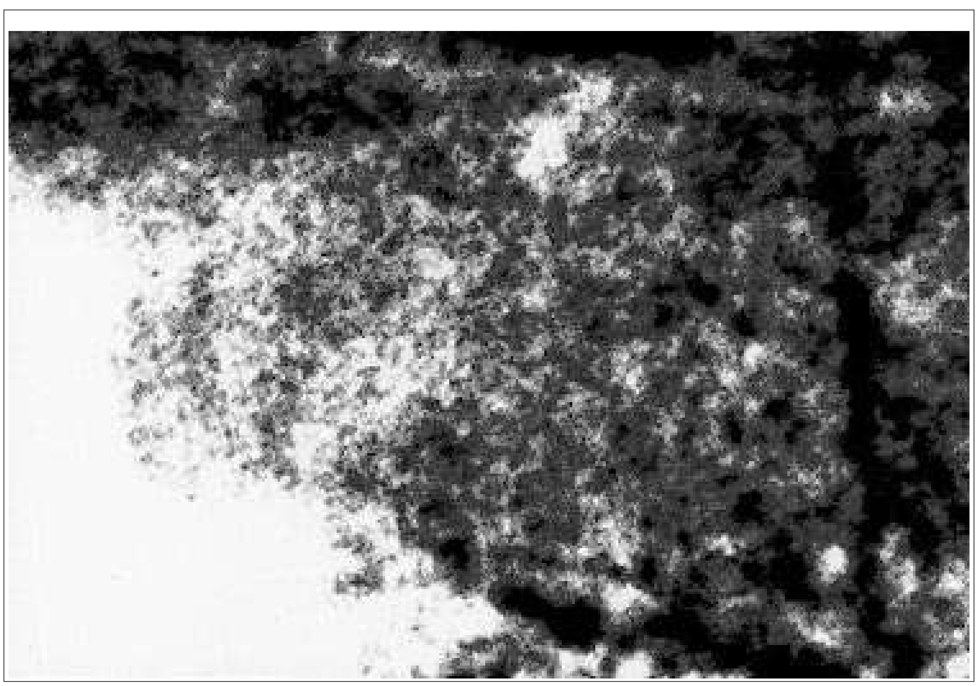


Figure 6–19 This print has a slight focusing error, equivalent to using an enlarging lens resolving less than 150 lp/mm. The grain of TMAX 3200 is blurred, not only reducing sharpness but causing shadows to block up and highlights to lose tonal information.

always a workable solution. Bigger tools are less convenient, a lot more expensive, and frequently less versatile. I avail myself of many tricks to make my images crisper, but I'm not monomaniacal. My advice is to do what you can to improve your image sharpness, but don't compromise the rest of your photography along the way.

It's Not All Resolution Figures

When I was a photographic neophyte, I believed that the further I stopped down my lenses, the sharper my photographs and prints would be. I also thought that as optical design (not to mention my fortunes) improved I would be able to purchase ever-sharper optics, ad infinitum. Those dream bubbles burst when I learned of diffraction and how it combines with other fuzzmakers in the photographic pipeline that runs from subject to print. When light rays are limited to passing through a finite aperture, they bend slightly from their ideal straight-line paths. The slight bending blurs an otherwise perfectly sharp image. That's diffraction, sans the physics. Unfortunately, there is no way to undo the blurring or to prevent it.

You *can* calculate diffraction. You don't need equations to follow my explanation, but they're given on the facing page should you want to have them. These three equations will let you estimate the impact of diffraction effects on your pictures. The diffraction-limited resolution of a lens depends on the working aperture of the lens and the wavelength of light.

The first equation gives the diffraction limit of resolution. It tells us that diffraction reduces resolution when the *f*/number or the wavelength of the light increases. For green light at a wavelength of 550nm, a good average choice, the equation simplifies to:

$$Resolution = 1500/Aperture$$

Aperture in this equation is the marked aperture multiplied by (1 + image magnification). In other words, if you are using an enlarging lens set to f/5.6 to make a print at 8X magnification, the aperture is f/50 in the plane of the paper easel (it's about f/6.3 from the point of view of the film). How serious is this? It limits print resolution to about 30 lp/mm in green light, which corresponds to a blur circle of about 0.03 mm, as per equation 2. Stopping the lens down further will reduce sharpness proportionately. Imaging in deep blue light will sharpen things up by a quarter; working in the deep red will reduce resolution by a quarter.

As another example, if you are doing slide or negative duping with a macro lens set to f/16 at 1:1 magnification, its real aperture is 16 x (1 + 1) = 32. The diffraction-limited resolution will then be about 50 lp/mm for green light in the film plane.

In addition, contrast drops with increasing resolution. The finer the detail you're imaging, the lower the contrast of the projected image. At the diffraction limit contrast will be very low.

Is this really a problem? Yes! My macro example yields a diffraction-limited resolution that is only moderately better than that needed for adequate sharpness in a 35mm negative (0.02 vs. 0.03mm blur circle). Similarly, my enlarging example results in diffraction-limited resolution that just meets the criteria for perfect sharpness in a print (30 lp/mm).

These are the ideal limits for a perfect lens projecting an image in perfect focus onto an emulsion of infinite resolving power. Real-world results are much worse. If you know the magnitude of the different sources of blur in your image, you can estimate the total blur by using the third equation. The equation for figuring the combined blur caused by two individual blurs looks just like the Pythagorean theorem for right triangles:

$$Total\ Blur^2 = Blur_1^2 + Blur_2^2$$

For resolution, that would be:

$$Total\ Resolution^2 = 1/(1/Resolution_1^2 + 1/Resolution_2^2)$$

Although the biggest source of blur predominates, lesser ones take their toll. For example, if you have a print paper that resolves 65 lp/mm (a 0.016mm blur circle) and diffraction blur in your projected image limits you to

$$\text{Diffraction-limited Resolution (in lp/mm)} = \frac{820,000}{\text{aperture x wavelength (in nm)}} \tag{1}$$

$$\text{Blur (in mm)} = \frac{1}{\text{Resolution (in lp/mm)}} \tag{2}$$

$$\text{Total Blur} = \sqrt{\text{Blur}_1^{\,2} + \text{Blur}_2^{\,2} + \text{Blur}_3^{\,2} + \ldots} \tag{3}$$

45 lp/mm in the paper plane (a 0.02mm blur circle), the print resolution can't be much better than 35 lp/mm (a 0.03mm blur circle). If you've also made a focusing error that would add another 0.02 mm of blur (equal to 50 lp/mm), print resolution drops below 30 lp/mm. Although each component easily exceeds the criterion for perfect sharpness, the combination of all of them is marginal.

In the darkroom, diffraction matters at relatively large apertures. Figure 6–20 shows actual resolution measurements I made of my 55 mm f/1.9 Computar compared to the theoretically-perfect, diffraction-limited resolution. You can see that at apertures below f/4, the lens truly is diffraction-limited. Stopping the lens down further only reduces sharpness. No matter the lens design, it cannot produce noticeably better resolution at f/4 and smaller apertures than this lens can. Stopping down below f/7 reduces theoretical sharpness below 200 lp/mm, the minimum that one needs to achieve perfect sharpness in 8 x 10 prints from a 35mm negative.

Because blurs compound, diffraction affects depth of field (or of focus). Standard depth-of-field equations do not take diffraction (or any other sources of blur) into account. If you want to incorporate diffraction or other sources of blur into those estimates, you have to take the allowable blur circle and reduce it by the amount of blur contributed by the other effects before calculating the depth of field. For instance, if the total allowable blur is 0.03 mm and your lens projects 45 lp/mm onto the print, the optical blur is about 0.022 mm and the allowable blur (other than optical) is about 0.02 mm. So, you would need to use a blur circle of 0.02 mm in the depth-of-field equation if you wanted the total

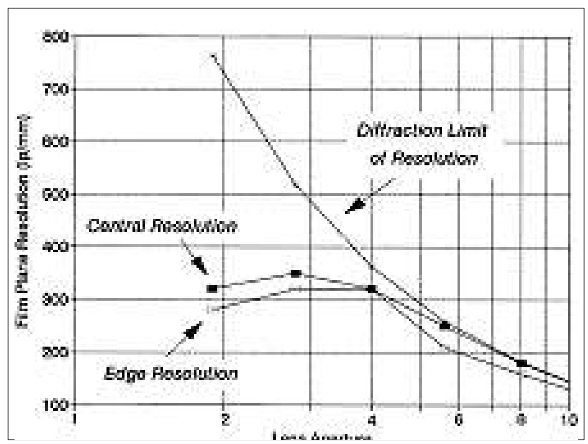


Figure 6–20 This graph compares the actual measured resolution of a 55mm f/1.9 Computar enlarging lens with the theoretical diffraction-limited resolution. The lens is fully diffraction-limited by f/4. Smaller lens openings may improve contrast and other image characteristics, but they will not improve sharpness. A better lens design could not produce significantly better resolution at apertures of f/4 or smaller.

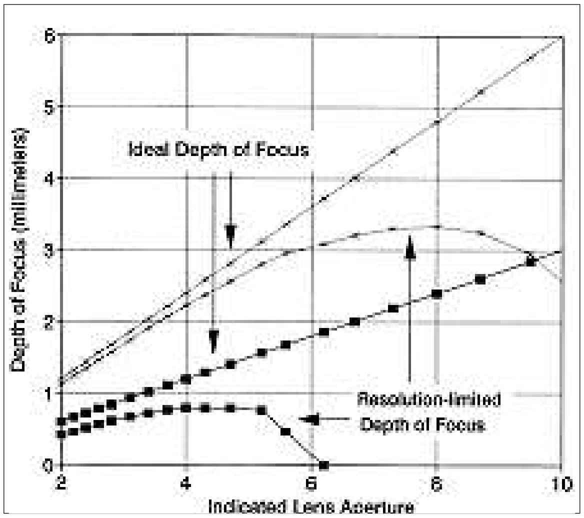


Figure 6–21 This graph shows the calculated depth of focus on either side of the paper plane for the 55mm Computar lens at 8X magnification. The curves were computed for two print resolutions, 30 lp/mm (filled squares) and 15 lp/mm (stars). For the resolution-limited curves, I reduced the allowable blur for depth of focus by the lens's measured resolution (plotted in Figure 6–20) using equation 3. See the text for details on computing the blur circle. Note that when real resolutions are used, the usable depth of field reaches a maximum value and then decreases for smaller lens openings.

blur to stay at 0.03 mm. Figure 6–21 shows the real depth of focus for my Computar lens when making an 8X enlargement, based on the data in Figure 6–20.

It's important to understand diffraction, but not to become obsessed with it. There's a lot more to a good enlarging lens than sharpness. Overall, most small-format lenses show better optical correction as you stop them down, and very few lenses are optimally corrected wide open. Flare, contrast, and light falloff are all worse at large apertures. As a rule, you have to close your 35mm format enlarging lens down a few stops before it becomes well-corrected enough for diffraction to be the biggest problem. For instance, my 55mm Computar shows so little contrast at f/1.9 that it is unusable at that aperture. Its sharpest aperture is f/2.8, but f/4 is the optimum aperture when one takes into account contrast and light falloff. A notable exception to this is Nikon's now-discontinued Apo El-Nikkor enlarging lens, whose optimum aperture is wide open at f/5.6.

Some large-format enlarging lenses are sharpest wide open. Beseler's wide-angle 240mm HD-Apo lens for their 810 cold-light head performs almost to the diffraction limit at all apertures, starting wide open at f/9. As with its smaller brethren, flare and contrast are worse wide open, so its optimum aperture is f/11 to f/13. Sharpness is a little worse, but the overall image quality is much better.

Grain-Focuser "Gotchas"

If you're only printing color, you can skip this section because the problem I describe here won't affect you. If you do any kind of B&W printing, you better read on.

A new source of print unsharpness was reported by Patrick Gainer in the Jan/Feb 1997 issue of *PHOTO Techniques* magazine (back issues are available from Preston Publications, 6600 W. Touhy, Niles, IL 60714). Patrick discovered that one can get a significant error in focus by using aerial-image grain focusers but not ground-glass-image grain focusers.

These two types of focusing aids differ in how they present the enlarged image. Ground-glass focusers project the magnified image onto a screen made of frosted glass. You look at the projection through a magnifying eyepiece. Aerial-image focusers create a real magnified image suspended in space; there is no screen between the viewer and the image. As a rule, aerial image focusers are considered to be better and more accurate, because the grain pattern of frosted glass doesn't obscure the finest details of the image.

Gainer's focusing problem is independent of the one I discovered with VC B&W papers (see Chapter 10), although it can be just as large. This problem can occur with any B&W paper if you're using an aerial-image focuser.

Patrick determined that there is enough longitudinal chromatic aberration (LCA) in the human eye to cause a big focus error if one focuses with deep-blue light. You may have noticed this effect for yourself if you try to look at something through a deep-blue color separation filter. Generally, you have to strain to get your eyes to focus correctly; the focus position has shifted so much that it's uncomfortable for the eyes' muscles to accommodate.

There is no problem with a ground-glass focuser because one is looking at an image projected on a screen. You may have to strain to see the screen sharply, but when you bring the screen into focus, you're looking in the correct plane for accurately adjusting your print focus. With an aerial-image focuser, one is comparing a "floating" image with the apparent position of a set of crosshairs that you prefocus. If the images shift in distance from what they should be, you get an erroneous indication of the correct focus distance.

For years, we've been exhorted to focus our B&W prints by using a blue filter to ensure that we are focusing with the same color light that the paper is sensitive to. The reason for doing this was to make sure that there was no focus shift due to LCA in the enlarger lens. This concern has generally been irrelevant for any modern enlarging lens used with graded papers; they are well-enough corrected over the visible spectrum so that this technique is not necessary. However, the technique still helps with some older lenses, and we thought using it never hurt. Well, it can!

Patrick discovered a focus shift of 10 mm or more, between blue-light focusing and white-light or green-light focusing, in the focus position indicated with one aerial-image focuser. The blue-light focus was wrong! This is a very serious focus shift, and it will produce visibly unsharp prints. It's comparable to the size of the focus errors I found with some VC papers, but it's an entirely independent effect. In my setup, I don't see focus shifts due to my eyes' aberrations of more than a few millimeters. Conversely, Patrick's setup produces a huge aerial-focuser focus shift but no detectable VC-paper shift. Regardless, I agree with Patrick's conclusion that there is no value to focusing with blue light these days, and it may cause real sharpness problems. I now focus with white light and seem to get fine results. In addition, I'm not straining my eyes by looking at a horribly dark, weirdly colored image.

Again, this warning applies only if you're using an aerial-image focuser, not if you're using a ground-glass focuser. On the other hand, the VC paper problem can show up regardless of the kind of focuser you're using. You may suffer from one problem but not the other. (Some days, I marvel that we ever manage to produce anything resembling a sharp print!)

The Best Enlarging Lenses in the World

Enlarging lenses must be much better than on-camera lenses. An enlarging lens has to sharply project the grain structure of the film or the print looks mushy and tonal quality suffers. Do you ever wonder just how good your enlarging lenses really are or how good they really should be? Have you suspected that there might be a super-lens that would work miracles on your prints? I've heard many old shutterbugs' tales (yes, I collect them):

Buy Brand X—they make contrasty lenses.

Get an apochromatic lens for really good color prints.

Use an 80mm or longer enlarging lens for 35mm format to get the best sharpness and evenness of illumination.

Like so many other photographers, Ken Werner (one of the first editors of the late, lamented *Camera and Darkroom*) and I wondered what the truth was from the very first day we set foot in a darkroom. Back in the 1980s, we did something about it. Since Ken has a degree in physics from Columbia University and I have one from Caltech, we knew our share of optics. First, we worked out a comprehensive testing program for enlarging lenses. Then we contacted every maker of top-notch enlarging lenses and requested samples. I spent 6 months testing 90 lenses with 70 different designs in search of the answer to the main question: What are the absolute best enlarging lenses for 35mm, 120, and 4 x 5 formats?

As far as I know, our tests are still the most comprehensive set of enlarger lens tests ever done. Remarkably, very little of what we learned is outdated. I've examined some (but not all) new lenses as manufacturers have introduced them; there have been relatively few changes in the lens designs or additions to the lines. If you own a top-notch enlarging lens made within the last 15 years, it's probably as good as anything sold today.

Third, I ignored availability. A number of lenses in my list, such as Computars and Eurygons, aren't made any more. Why are they included? Because they turn up "used" or "remaindered" from time to time, and there's no reason not to buy a used enlarging lens in good condition.

Our answer to the main question is the table on page 88. I have a *lot* to say about enlarging lenses, and I'm sure some of you won't want to wade through all of it. So, before I inundate you with standards and other technical data, here's the condensed, tech-free version.

The Tech-Free Version

Buy a six-element lens if you can possibly afford it. Four-element lenses are only modest performers. They may be acceptable for moderate enlargements from large formats, but they are unacceptable for 35mm work. Regardless of format, if you put a print made with a four-element lens next to a print made with a six, you will see the superiority of the print made with the better lens. *Never* buy triplets; don't even take one for free.

Print paper is no longer cheap and neither is your time. With print paper at more than $50 a box, it doesn't make much sense to save $100 by getting a mediocre lens. Why make inferior prints, which you'll only have to remake when you buy a better lens and develop more discerning tastes? Don't buy a lesser lens even for someone who's just beginning. Introducing a beginner to printing with a lousy lens is like introducing someone to the pleasures of playing music by giving them a pennywhistle.

Make sure your lens has good coverage with little light falloff. Even a novice printer can see when the supposedly uniform sky fades out at the edges of the print! An ideal lens will cover your format with no more than one-fourth stop of light falloff at optimum aperture. An enlarging lens that meets this standard will almost always perform well in other optical respects.

A good enlarging lens will typically give you maximum sharpness at the widest aperture that produces good image contrast. For 35mm format lenses, that is usually 1 to 2 stops down (f/4 to f/5.6). For medium-format lenses, it is more likely 1 stop down, and for large-format lenses, it may be wide open. Diffraction takes a toll on sharpness as you stop down. A lens that performs optimally at f/5.6 always beats out one that is optimum at f/11. Generally, a faster lens is likely to be better at its optimum aperture than a slower one is.

Because of light falloff, reject wide-angle enlarging lenses. Unless you absolutely must have the extra magnification of a shorter lens, stay with 50 mm or longer for 35mm work. Use 80 mm to 100 mm for medium formats, and go to at least 135 mm for 4 x 5 work. These are minimum standards—not all 50mm lenses have acceptably low levels of light falloff for 35mm work, and not all 80mm lenses cover a $2^1/_4$ square (although all cover 645 format). Stay within 30% of these guidelines (e.g., 50 mm to 65 mm for 35mm format). If you go to a much longer focal length, the overall lens performance goes down, not up.

With a few exceptions, no lens performs superbly with more than one format. For best results, you need a separate lens for each format you print. Although some lenses on my list qualify for more than one format, they are frequently more expensive than two separate lenses would be.

If your lens dates back to the 1970s, it has almost certainly been superseded by a visibly superior design. Think about retiring that 25-year-old optic. Also, as I said earlier, chemical fumes in the darkroom can damage enlarging lenses. You may find that your 10-year-old lens has irremovable haze or pitting on one or more of the surfaces. A little won't matter, but a lot significantly increases flare. Keep lenses properly capped when you're not printing.

When you're ready to buy a lens, don't search the ads for the rock-bottom lowest price unless you like gambling. Buy your lens from a reputable dealer who has a no-questions-asked exchange policy. You'll pay a bit more, but the insurance is worth it for two reasons. First, the only way you can be sure that a lens will perform for your needs is to make test prints with it. No lens is perfect; they all have design trade-offs. You need to be sure that the lens provides acceptable light uniformity and image clarity. Second, about one-third of the lenses I've tested have been so badly decentered that I could readily see fuzziness or smearing of the image along parts of the edges of the frame—10% were so bad that I wouldn't take one for free. The proof is in the printing; if your test prints look good to you, then the lens is good enough.

The High-Tech Version

Ken and I decided that we'd call a lens genuinely excellent if it produced prints that appeared perfectly sharp, with no significant flare or distortion and no visible falloff in illumination from the center to the corner of the frame under the most demanding printing situations. These are strict standards designed to differentiate the merely "fine" from the truly superior. If a lens doesn't appear in the table on page 88, that doesn't mean the lens is bad; it means that it didn't reach our lofty standards. In practical use, a "fine" lens that didn't quite meet our standards would still deliver extremely good prints in most applications.

Sharpness

Perfect sharpness implies that any greater degree of sharpness is beyond the ability of the eye to see. We can perceive variations in print detail down to 30 lp/mm at a normal viewing distance for an 8 x 10 print. Even though one cannot see detail that fine, a print that resolves less than that appears fuzzier than one that reaches 30 lp/mm. A 35mm negative needs to be enlarged roughly seven times to make an 8 x 10 print, so 30 lp/mm in a print corresponds to 200 lp/mm in the original film. Accordingly, 200 lp/mm became our minimum for enlarging lenses intended for 35mm film. Larger formats need less enlargement so the enlarger lenses don't have to work as hard. Since photographers demand even higher quality from these formats, we set our minimum resolution standard at 150 lp/mm for 120 film and 100 lp/mm for 4 x 5.

Contrast is the difference in brightness between "black" and "white" detail in the image. A lens can have high resolution along with low contrast, and vice versa. The lower the contrast, the more washed-out fine detail looks. If fine details have low contrast, the print paper won't reproduce them well and the eye will have trouble seeing them. High resolution isn't enough—high contrast is just as important. In fact, for 4 x 5 lenses, contrast turns out to be more important than resolution.

You need to use a glass carrier for your negatives if you want to see the sharpness and contrast in your prints that a first-rate lens is capable of. Glassless carriers, convenient as they are, do not hold the negative flat enough. Even the best enlarging lens in the world can't deliver a high degree of sharpness from center to edge if the film isn't flat.

Consider, though, that a glass carrier will introduce a certain amount of flare, and keeping them clean can be very time-consuming. There are always trade-offs.

Illumination

The greater the angle of coverage of a lens, the dimmer the corners of the projected image compared to the center. Lens designers compensate by designing lenses that divert extra light to the edge of the field; if they didn't, no enlarging lens would be able to produce even illumination. For those of you who are technically inclined, enlarging lenses perform better than the $\cos^4$ law.

I determined that a print on grade 5 paper appears uniform if the light level falls by no more than one-fourth stop from center to corner. We used that as our falloff standard for all formats, testing a lens at the minimum aperture at which it passed the sharpness test. More lenses failed to pass the light falloff test than any other test. If I had this to do all over again, I'd start with the light falloff test. All the lenses that passed both resolution and falloff tests showed low flare and low distortion values. The table on page 88 contains comparative measurements for these qualities for each lens, in case you have special needs that demand exceptional correction. But even the "worst" winning lens would not show print degradation due to flare or distortion in normal use.

Is It Flat?

An ideal enlarging lens takes a flat original film and projects a flat image of it onto the emulsion of the print paper. In the real world, the focal "plane" is a slightly wavy surface. How closely that surface comes to being a true plane determines just how sharp a print can be. For example, to meet our sharpness criterion, a lens used at f/4 to make an 8 x 10 print from a 35mm negative has a depth of focus of only 2 mm. Stopping down doesn't increase the depth of focus much, as diffraction quickly takes its toll. I dropped several lenses from the list when they passed all the initial tests but didn't produce flat enough images.

One rule of thumb says that you get the best overall focus if you focus about one-third of the way out from the center. In general, this rule does not work. A compound lens will normally have some slightly-decentered lens elements. They distort the surface of best focus produced by the lens. What ideally is a smooth curve becomes bumpy, with slight hills and valleys in different parts of the field whose locations vary from lens to lens in unpredictable ways. For some lenses, the best average focal distance corresponds to the center of the field. For others, it may be at a point midway out from the center, or even at one particular corner, but not at the others. The only way to find a representative focusing spot for your lens is to carefully study your lens's focal surface. The most reliable way to focus is still to spot-check image quality all over the field.

There are two characteristics I did not consider. The first was price: I wanted to find the best lenses, not the best bargains. The second was the physical design of the lens. Some had metal mounts, some plastic. Some have half-click stops; others offer continuously adjustable apertures. These things affect your choice, but they don't affect image quality. I found about 20 lenses, ranging in price from under $200 to several thousand dollars, that were truly excellent.

Picking Out a Lens

What Focal Length Is Right?

How do you decide what the right focal length lens for a given film format should be? On the one hand, shorter lenses provide greater magnifications at the same distance from the negative to baseboard, and they are usually better corrected than longer lenses of the same covering angle. They may also be cheaper. On the other hand, a longer focal length lens does not have to cover as wide an angle to encompass the format, so one might expect better image quality to come from working with a narrower field. A longer focal length lens might also show less light falloff for a given format.

My tests show that longer lenses do minimize light falloff, but there are some normal focal-length lenses that do just as fine a job. Longer lenses usually have smaller maximum apertures and more aberration, so they do not perform quite as well as their shorter counterparts. Remember, diffraction takes its toll—a lens that is diffraction-limited at f/8 always loses to a lens that is diffraction-limited at f/5.6. Slightly long lenses (for example, 65 mm for 35mm format or 105 mm for 120 format) sometimes have a modest advantage in total image quality over normal lenses.

Some folks claim that printing with a much longer focal length, using only the center of the lens's field of view, produces superior results. Maybe it did with older lens designs, but that technique has been wrong for at least 20 years. My results prove that except for providing more uniform light output, longer focal lengths don't project a higher quality image.

Medium- and large-format enlarging lenses typically have a maximum aperture of f/5.6. Even if they perform best wide open, and most don't, they can't be sharper than a lens that is optimal at f/4.5. Most longer lenses have optimum apertures of f/8 to f/11. Optical theory says they'll only be about half as sharp as their short brethren, and my tests confirm that.

Consequently, although a little more focal length in the lens helps light uniformity, much more compromises sharpness. There is no point in buying a longer-than-normal lens when you can buy a normal one of equal or better quality. The extra focal length gains you an undetectable improvement in uniformity, but you'll almost always pay for it with a visible loss of sharpness. That longer lens costs a lot more, too!

The one exception is if you are doing very high-contrast work with products such as litho film. In that case, almost any nonuniformity of illumination is unacceptable, and you are justified in going to a longer focal-length lens. Otherwise, over a 35mm-sized field of view, a good 35mm format lens outperforms a good medium-format lens. Ditto for medium versus large format. Because larger formats are enlarged less, the lenses don't have to provide the same level of optical performance. The lens manufacturers don't design in quality you don't need.

On the short side, I found no wide-angle lenses that met our standards. Some had acceptable image quality in the corners, but none could pass the light falloff test. Thus, for optimum optical performance, I do not recommend any lenses shorter than 50 mm for 35mm work. 80 mm is the minimum for 120; 90mm to 100mm focal lengths are preferable. For 4 x 5 work, use a focal length of 135 mm or more.

Lens manufacturers include the working magnification range of a lens in their data sheets. Pick a lens that matches the range you normally work within. A lens that performs superbly at 10X will probably look very bad at 3X or 40X.

As an example, my 55mm f/1.9 Computar is unsurpassed in sharpness when used within its wide magnification range of 4X to 20X. It has an adjustable front element for optimizing its performance at each magnification. Outside that range, performance drops off rapidly.

The extreme-enlargement illustrations in most of my articles are made with an ancient 28mm f/4 Componon. That lens was designed for subminiature format and much greater magnifications. It can't hold a candle to the Computar over the Computar's working range, but at 40X it's markedly sharper.

At the low magnifications, the Computar's color correction deteriorates. I can make great separations with it from 35mm on 8" x 10" film, but it's useless for making seps on 4" x 5" film: the resolution is fine, but the color fringing is horrible.

Apo Is as Apo Does

An apochromat is a lens design that is supposed to correct lateral and longitudinal chromatic aberration for three different wavelengths of light. Should you go whole-hog and spring for an "apo" lens? My tests showed that those lenses usually have a slight edge in crispness over their non-apo siblings, but they aren't truly apochromatic lenses!

Lateral chromatic aberration is an off-axis aberration in which the magnification of the image at the print easel depends on the color of the image (Plate 29). This produces color fringes at the edges of the field even in focused images. It's not reduced by stopping down.

Longitudinal chromatic aberration is the biggest residual color aberration in most enlarging lenses. The lens focuses different colors of light at slightly different distances from the lens. Serious longitudinal chromatic aberration degrades both contrast and sharpness and can cause focusing problems when one prints with some papers (see the next section). Although almost no top-notch enlarger lenses showed significant lateral color when used within its normal magnification range, almost all showed longitudinal color. In fact, apo lenses suffered as badly from longitudinal color as non-apo ones.

The sole exception is the now-discontinued Apo El-Nikkor, which is a true apochromat. If you need the ultimate in color correction, this lens provides it, but it costs thousands of dollars, assuming you can find one! I don't own one and you probably don't need one, but I thought you should know, just in case.

So, just what makes these other "apo" lenses apo? I don't have the foggiest idea! And, by the way, I do excellent color separation work with fine non-apo lenses.

An Unfortunate Omission

Several years ago, I discovered that there can be as much as 15mm difference between the plane of best focus seen by our eyes and the proper focal plane for VC paper (for a full explanation, see Chapter 10). The culprit is longitudinal chromatic aberration (LCA) combined with newer VC papers that respond into the near ultraviolet, which is outside the spectral range for which the lens is well corrected. The human eye sees almost nothing there; when we focus our enlargers, we're using a different part of the spectrum than what the print paper sees and which the lens may bring to a different focus.

Not all enlargers put out enough violet-ultraviolet (V-UV) light to cause problems. Not all VC papers have such extreme sensitization. The quality of LCA correction for V-UV light varies greatly with the lens design. Consequently, you may not have any problem (most printers don't), but I suggest you run a careful focus check on any lens you're considering buying to use with VC papers. I'd look especially carefully at lenses that I report as having larger-than-average amounts of LCA in the visible spectrum.

Misalignment Blues

Now for some really bad news. It is *very* difficult to manufacture a perfect lens, with all elements precisely positioned and centered (i.e., so that the center of curvature of each lens element lies on a common line). Almost every lens I have examined has slightly tilted or decentered element(s). A perfectly aligned lens produces a symmetric image—the corners may look worse than the center, but all four corners look alike. When a lens has an element out of alignment, some corners of the image will look worse than others.

A little misalignment is normal and won't seriously degrade performance. We decided that a premium-grade lens should show less than 50% variation around its perimeter (for example, resolution varying from 120 lp/mm to 180 lp/mm). Lenses with more than 50% variation were "significantly" misaligned by our standards. We awarded lenses with 75% or more variation the appellation "dogs." Even among my top-rated lenses, there is about a one-in-three chance of getting a lens that is significantly misaligned and a one-in-ten chance of getting a real dog. Frankly, we were astonished at finding so many misaligned lenses.

As far as I can tell, all lens makers have this problem, and the performance of one well-made sample has nothing to do with the chance of buying a poorly made one of the same kind. I can't recommend any particular lens maker or design as particularly reliable. You are gambling no matter who you buy lenses from. As a result, I recommend that you purchase an enlarging lens only from a store that will let you exchange it if you are unhappy with it. That probably means paying a higher price, but think of the extra dollars as insurance against being stuck with a lemon. Nevertheless, the price can still be reasonable. Is a $30 lens as good as a $900 one? No, but I have tested $200 vs. $700 35mm format lenses that were both so good that you'd have no reason to choose one over the other. To coin a phrase, "You get what you pay for … except when you don't. Sometimes, you get a lot more. Or a lot less."

Before you run off to exchange a lens, please make sure your complaint is legitimate. Remember, less than 50% edge variation is acceptable and is very difficult to see in a print. Furthermore, two "identical" lenses can vary in quality by 25% due to normal manufacturing tolerances. Please double-check your test conditions before harassing an underpaid sales clerk. *If you don't do your tests perfectly, your results don't mean ANYTHING.*

How to Test Lenses

Light Falloff

How do you determine whether light falloff is due to your lens or your enlarger? If you're testing a small-format lens on a large-format enlarger, you can assume that most falloff you see is due to the lens. Conversely, you can check the uniformity of your enlarger light for small formats by projecting the light with a large-format lens. In that case, little of the falloff is due to the lens. For example, test 35mm mixing chambers with a 100mm to 150mm lens. That still leaves situations (e.g., a large format lens with a large format enlarger) in which you can't say for certain what the source of the problem is, but at least you can tell whether you have a problem.

If you're using a condenser-head enlarger, changing the focal length of the condenser array to change the field of coverage can also mess up the uniformity of the illumination. Usually, condenser enlargers produce the best results when the condensers are matched to the focal length of the enlarging lenses. All you can do is test the combined light falloff of the condenser assembly and the enlarger lens. That will let you compare the relative merits of enlarging lenses. If you find that the combined falloff is greater than what is acceptable, well, that is still something you want to know!

I used a Chromega Super Dichroic D diffusion enlarger that I knew produced very uniform illumination. How did I know that my Chromega was so good? I got lucky—I found a lens and enlarger combination with less than 0.1 stop of light falloff, so small that it didn't matter how much was due to the lens and how much to the enlarger.

To test for light falloff, make prints with the bare enlarger light (no negative in the carrier) on grade 5 B&W paper. I taped a couple of crosshairs into the negative carrier to make it easier to locate the center of the field. Be sure that the entire projected image area of the carrier fits on the sheet of paper. Make prints at apertures from wide open to 3 stops down. Stopping down reduces light falloff, but there will be little change after 2 or 3 stops. Select exposure times that produce medium-gray prints.

Next, contact-print a step tablet onto a sheet of the same paper. The step tablet I used has steps at half-stop intervals. I made two contact prints, with exposure times that differed by 19% (for example, 21 and 25 seconds), a one-fourth stop difference. That let me measure exposure variations of less than one-fourth stop.

Compare the density at the center of one of your light falloff prints to the step-tablet prints, and write down the number of the step that most closely matches the gray tone in the print. Then check the corner of your print and note the difference in exposure steps.

Suppose your step tablet has density intervals of a half-stop between each step, and you followed my suggestion of making two step-tablet prints that were one-fourth stop different in exposure. You find that the center of your test grade matches step 4 on the darker step-tablet print, and the corner of your test print matches step 7 on the lighter step-tablet print. That means there's a difference of 3.5 steps between the center and corner exposures on your test print. 3.5 x 0.5 = 1.75 stops difference in illumination over your field of view.

I found that I could measure exposure differences as small as one-eighth stop (0.04 l.u.) between different parts of the image field this way. You should measure the light falloff at all four quarters of the field. If your light source is out of alignment, you can get very different amounts of falloff in different corners.

An enlarger's uniformity of illumination can change with time. I didn't know this for many years, and it caught me. After using my Chromega enlarger for over 15 years, I started to notice light falloff at one edge of my pictures. I assumed that I had knocked something out of alignment or that it was a fault in my technique. I spent several months and many prints trying to figure out what I was doing wrong. By accident, I discovered that my enlarger had changed. I happened to rerun my uniformity tests for an article. I was most surprised to find nearly a full stop of light falloff along the right side of my image area. A careful inspection of the light integrating box for that format showed that there was slight discoloration of the diffusion plate on the bottom and that there was a very slight change in the whiteness of the plastic walls that lined the integrating box. Of course, cold-light heads are subject to such changes because tubes age and the inner walls of the head become dirty or discolored. It doesn't take much to mess up the light. Condenser enlargers do not suffer this kind of deterioration, but they *can* be knocked out of alignment.

Consequently, I strongly recommend that you check your enlarger's uniformity every few years. It took nearly 20 years for my enlarger to deteriorate that much, so this isn't a problem that appears overnight. Yet, by the time I caught it, I had to remake quite a few prints, and I kicked myself for not having caught it earlier.

Distortion

Distortion is a lens aberration in which the images of tangential lines (the lines perpendicular to the radii) are slightly curved. If they bow toward the optical axis, it's called pincushion distortion. If they bow away, it's called barrel distortion. Stopping down doesn't affect distortion. In the table on page 88 I give the amount of bending as a percentage of the total length of the side. In no case did I find distortion that was serious enough to matter for normal printing purposes.

To measure distortion, stretch a hair across a negative carrier near one border of the film frame. Line up a straightedge with the projected image of the hair on the baseboard and use a ruler to measure how much the image bends away from the straightedge at the middle. Divide the distance separating the straightedge and the projected image of the hair in the middle of the frame by the projected length of the frame. That's the amount of distortion. You only need to make this measurement along one edge.

Flare

Use the flare test that I described at the beginning of this chapter. I ran all my flare tests on the Super Chromega to eliminate the enlarger as a source of variation in the results. Take such results as a good *relative* predictor. In reality, flare depends on the distribution of light (not just the total amount) and on your enlarger, too. A test like mine made on a single enlarger does not tell how much of your flare is due to the enlarger and how much is due to the lens. What it does tell is whether a new lens is significantly better or worse than your old lens and whether you have a total flare problem.

Advanced Tests

The following tests require some kind of resolution test target that will provide ultrafine detail. You will also need a focusing magnifier that gives a clear, high-powered image and that lets you examine image quality at both the center and the corners of the field. I believe the Peak Critical Focuser Model 1 (the one with the rotatable eyepiece assembly) is the only precision-focusing scope currently available that allows one to observe the far corners of the image. It is certainly the very best.

There are many high-resolution test plates made, but they can be expensive tools. Conventional photographic negatives and low-cost "enlarger test" slides won't help. At best, you might get a fuzzy 100 lp/mm from such items, which is not good enough. You need at least 200 lp/mm, and the target must be sharp and grainless (the replica target I made goes to 500 lp/mm). Edmund Scientific[1] sells a variety of USAF test-pattern resolution targets in the $100 range.

To make a low-cost target that produces only qualitative information but that costs only a few dollars, go to your local art supply store and

1. Edmund Scientific, 101 E. Gloucester Pike, Barrington, NJ 08007. For orders, a catalog, or product information, call 1-856-573-6250 or go to http://www.edmundscientific.com.

buy a sheet of the sticky-backed halftone material used to make "grays" in graphic artwork. A well-known brand is Zip-A-Tone. Look for 100 line or better, 50% gray. Burnish a piece of the halftone onto a sheet of plate glass. You now have a flat test target for enlarger alignment and lens testing. Each dot on the screen has plenty of fine, contrasty detail. You will easily be able to see aberrations such as lateral and longitudinal color and astigmatism, which causes lines radial to the optical axis to be focused at a different distance than lines that are tangential. Astigmatism produces smeared images because off-axis horizontal and vertical details can't be focused at the same time. To do the tests described below, you can substitute the halftone plate target for every place where I use a resolution test plate. The tests will run the same.

Resolution and Contrast

This test is a measure of the ideal on- and off-axis image quality of the lens. It doesn't take into account how well the lens focuses an image onto the plane of the paper.

Set up the resolution target and lens so that the target is in the center of the field of view of the lens. Focus the image of the lens wide open and make note of the resolution, contrast, and any visible aberrations. You won't be able to measure contrast objectively, but after looking at a few lenses you will develop a very good sense of how much relative contrast there is in an image. You will certainly be able to see the differences in image contrast as you stop the lens down. As for the aberrations, don't worry about a technical description; you're concerned only with what they do to the image quality. You're looking for visible signs of image deterioration. Are you seeing smearing of the fine detail? Are there color fringes on the edges of the bars? Does the fine detail shift color as you focus through the point of best focus?

Stop the lens down, making the same observations for each f/ stop. To check for focus shift associated with stopping down, refocus the image with the lens closed down two stops below wide open, then recheck the image quality wide open. This is a more sensitive test for focus shift than by focusing wide open and stopping down the lens because depth of focus at smaller apertures makes it harder to see focus errors. If the wide-open image looks fuzzier than before, you've got focus shift. None of the best lenses I tested exhibited serious amounts of focus shift; usually it was immeasurably small.

Next, set up the target and lens so that the target is 80% of the way to the corner of the field in one of the sharper octants (see the centering test). Misalignment of a lens element only degrades performance and never improves it; I found that the best sector of a modestly misaligned lens was comparable in image quality to the overall performance of a well-centered lens. Repeat the observations and measurements you made in the center of the image field. The edge tests usually separate the really good lenses from the merely adequate ones. It's a lot easier to get high performance from a lens on-axis or over a very narrow field of view than it is to get uniformly good performance over the entire film format.

Lens Element Centering

A perfectly aligned lens produces a symmetric image—all four corners have comparable image quality, even if they look different from the central image. If one or more lens elements are slightly tilted or mounted off-center, the image will be degraded more at some corners than others. This test measures how much the optical performance varies around the edge of the field.

Put the target in the enlarger at a position about 80% of the way toward the corner of the format you are studying. Turn the bar target so that the lines in it run at a 45-degree angle to the radial line. Most lenses show some astigmatism, which produces different quality images and focal planes for radial lines and tangential lines. By placing the plate at this angle you get an average of the images for both kinds of lines.

Carefully focus the image with the lens wide open and note the finest bar pattern you can see, what aberrations are visible, and how contrasty the image is. Rotate the lens mount (or unscrew the lens) by one-eighth of a turn, refocus the image, and record the appearance. Repeat this process for the entire perimeter of the lens and compare the best and worst octants of the field.

You should expect to see some variation in both contrast and resolution. A 25% to 50% variation in resolution is acceptable and normal. You may also see a slight increase in astigmatism for some positions, but you should not see heavy smearing or distortion of lines (one symptom of a misaligned lens element). A sudden jump in image quality between two adjacent positions also indicates possible decentering. Usually, a decentered lens element not only produces lower resolution in parts of the field but also produces noticeably less contrast and more smearing.

Field Flatness

This is the most difficult test to perform without special equipment. Along with a test plate and a Peak (Micromega) Critical Focuser, you need an enlarger you can adjust to align the negative stage, the lens, and the baseboard, and a rotatable lens mount.

To successfully align your enlarger with the precision required for this test, you need an optical alignment tool such as the Zig-Align (see Chapter 14). A mechanical alignment tool, such as an adjustable bubble level, is not precise enough, although you can use it to get your negative, lens, and paper stages roughly positioned. Before the Zig-Align was invented, it could take me hours to bring my enlarger into good enough alignment by trial and error. The allowable error in the paper stage for this test is about 1 mm. (You may decide you want to skip the whole mess, and I can't say I'd blame you.)

Once you have an aligned enlarger, the test procedure is straightforward. Place your test plate on the piece of plate glass in the negative stage at the center of the field. Focus the lens with the f/stop set to the optimum aperture and note the image quality, just as if this were a regular resolution test. Move the test plate one-fourth of the way to the corner and repeat the measurements; do NOT refocus the lens. Repeat these observations at the half, three-fourths, and full corner positions. Then move the target back to the center of the field, rotate the lens by one-fourth turn, and repeat the series of observations. Do this for all four quadrants.

Don't expect to see image quality in this test as good as that in the "ideal" resolution tests, except at the center of the field where you are focusing. All lenses have a curved "plane" of focus; thus, at every point but the center you may be looking at a somewhat out-of-focus image. Sometimes the focal surface is wavy, wandering above and below the center point. At other times, the center is a low or high point in the surface so that every outer zone looks somewhat out of focus.

You may also see occasional points that are much better or worse than nearby points. Those are the places where the focal surface has a little bump in it. This is a normal, inevitable result of making a lens in the real world; slight imperfections cannot be avoided. Live with it, unless the bump is so huge the image quality looks quite awful.

Remember, this test does not measure the best overall focus—it measures only image quality when you focus at the center. Sometimes that will be the best choice, but not always. Once you have studied your lens in detail, you can decide what is a good average focusing point and rerun the test series using that point as the reference point, instead of the center. In this way, you should have a good idea of the best image you can expect your lens to project onto a flat sheet of paper.

Ratings of the Best Enlarging Lenses

All lenses provided full-stop aperture ring detents. If they provided half-stop detents, there's a single X in column 2. If they also provided continuous aperture settings, there's a second X in column 2. Column 3 is the aperture that I judged produced the best combination of sharpness and contrast. Column 4 is the smallest lens opening that met my test standards; at apertures below that, diffraction effects reduced image quality below the standards. Flare and falloff were measured at the optimum aperture.

Lens	Stops 1/2 - Cont.	Optimum f/ stop	Minimum f/ stop	Flare (in stops)	Falloff (in stops)	Distortion (%)	Comments
35mm Format		Standard test magnification for 35mm format was 8X.					
Beseler Color Pro 50mm f/2.8		4	7	-7	0.3	0.5	Slight smearing and low edge contrast at f/2.8 but good central contrast. Some longitudinal color. Falloff under 0.2 stops at f/7. Same image quality at 5X. Slightly poorer at 11X and 16X.
Schneider Componon-S 50mm f/2.8	X - X	4.8	8	-7	.3	0	Best central contrast among 50mm lenses. Slight haloing wide open. Slight lateral color, magenta-green longitudinal color. Exceptionally flat field.
Computar 50mm f/2.8	X	4	7	-7	0.35	0.5	Very similar in appearance to Color Pro. Also sold under the name Apo-Computar.
Nikon El-Nikkor 50mm f/2.8N		4	7	-7.5	0.3	0.5	Slight haloing wide open, but good contrast even at f/2.8. Slight lateral color, some longitudinal color. Slightly lower resolution at 5X. Slightly lower contrast at 11X and 16X.
Rodenstock Apo-Rodagon N 50mm f/2.8	X - X	4	7	-7	0.15	0.25	Good edge contrast at f/4, but low-fair at 2.8. Worse than average red-green longitudinal color. Poorer contrast and resolution at 11X and 16X.
Computar 55mm f/1.9	X	4	5.6	-6	0.12	0.3	Best edge contrast and light falloff among short focal lengths. Adjustable front element corrects spherical aberration at different magnifications. Needs accurate condenser alignment to prevent vignetting. Also sold as Apo-Computar.
Nikon El-Nikkor 63mm f/2.8N		4	7	-8	0.12	0	Slight haloing wide open. Good to very good contrast overall at f/4. Some lateral and longitudinal color. Better contrast at 5X, worse at 11X and 16X.
Computar 65mm f/3.5	X	4	7	-7	0.2	0	Slight smearing wide open, but overall image quality as good as Nikkor 63mm. Better corner contrast but a bit more lateral color. Good performance at all magnifications. Also sold as Apo-Computar.

Lens	Stops 1/2 - Cont.	Optimum f/ stop	Minimum f/ stop	Flare (in stops)	Falloff (in stops)	Distortion (%)	Comments
Schneider Componon-S 80mm f/4	X - X	4.8	8	-8	0.15	0	Slightly better central contrast than Eurygon, but slight lateral color. Low contrast at f/4 limited by red-green longitudinal color. Slightly poorer image at 11X. NOTE: Also qualifies in 120 format category.
Rodenstock Eurygon 80mm f/4	X - X	5.6	7	-8	0.1	0	Relatively low contrast at f/4. Lower edge sharpness than shorter focal length lenses. Slightly poorer image at 11X. NOTE: Also qualifies in 120 format category.
Nikon Apo El-Nikkor 105mm f/5.6N		5.6	8	n.a.	0.1	0	Most perfectly made lens and priced accordingly. No detectable aberrations of any type, no decentering. Good contrast at f/5.6. Sharpness not quite as high at optimum aperture as lenses with f/4 optimums because of diffraction. Same performance at 5X. The only true Apo lens. NOTE: Also qualifies in 120 format category.
120 Format		Standard test magnification was 4X. Standard format was 6 x 6 cm. Unless otherwise noted, lenses were suitable for 6 x 4.5 through 6 x 7 format, with only small changes in optimum aperture or light falloff.					
Schneider Componon-S 80mm f/4	X - X	5.6	8	-8	0.4	0	Not suitable for 6 x 7 format due to light falloff. At f/8, falloff improves to 0.2 stops. Otherwise, very similar in quality to Eurygon. NOTE: Also qualifies in 35mm category.
Rodenstock Eurygon 80mm f/4	X - X	5.6	8	-8	0.2	0	Medium contrast at f/4; best contrast at f/8. Slight longitudinal color. NOTE: Also qualifies in 35mm category.
Rodenstock Apo-Rodagon 80mm f/4	X - X	5.6 (6 x 6) 7 (6 x 7)	8	-7	0.25	0	Fair-to-good contrast wide open, very good at f/5.6. Large longitudinal color; other aberrations negligible. Sharper but lower contrast at 6X.
Schneider Componon-S 100mm f/5.6	X - X	7	8	-7	0.25	0	Very good contrast with some longitudinal color. Somewhat lower contrast at 8X. Central resolution not quite as high as other lenses, but image field extremely uniform.
Leitz Focotar II 100mm f/5.6		7	9.5	-6.5	0.15	0	Good overall performance, uniform field. Slight longitudinal color, but very good contrast. Performs well at higher magnifications.
Nikon Apo El-Nikkor 105mm f/5.6N		8	9.5	n.a.	n.a.	0	See rating in 35 mm section. Stopped down to f/8, this lens covers 6 x 7 format. NOTE: Also qualifies in 35mm category.

Lens	Stops 1/2 - Cont.	Optimum f/ stop	Minimum f/ stop	Flare (in stops)	Falloff (in stops)	Distortion (%)	Comments
Nikon El-Nikkor 105mm f/5.6N		7	8	-8	0.2	0	Light falloff drops almost to zero at f/8. Very good contrast at f/8, but some longitudinal color. Better resolution, less contrast at higher magnifications.
Rodenstock Rodagon 105mm f/5.6	X - X	7	8	-7	0.25	0	Falloff drops to 0.1 stops at 1 stop down. Very uniform field. Good contrast at f/5.6, very good at f/8. Some longitudinal color. Almost same quality at 6X and 8X.
Rodenstock Rodagon 135mm f/5.6	X - X	7	9.5	-8	0.12	0	Negligible light falloff at f/8. Medium contrast at f/5.6, very good at f/8. Slight longitudinal color. Quality holds up better at small apertures than 105 mm Rodagon. Uniform image over most of field. NOTE: Also qualifies in 4 x 5 format.
4 x 5 Format	Standard test magnification was 4X, except for light falloff test (done at 2.5X). All four lenses had very similar contrast and resolution.						
Nikon El-Nikkor 135mm f/5.6		8	11	-7.5	0.25	0	Low to medium contrast at f/5.6, good at f/8. Some longitudinal color.
Rodenstock Rodagon 135mm f/5.6	X - X	8	13.5	-7.5	0.25	0	Slight longitudinal color. Slightly higher resolution, but lower contrast than 135mm Nikkor. NOTE: Also qualifies in 120 format.
Rodenstock Rodagon 150mm f/5.6	X	8	11	-7.5	0.25	0	Almost as sharp as Rodagon 135mm. Good contrast at f/8. Some longitudinal color at f/5.6.
Schneider Componon-S 150mm f/5.6	X - X	8	13.5	-7.5	0.25	0	Best contrast of 4 x 5 lenses, but not quite as sharp as 135mm Rodagon. Slight longitudinal color.

CHAPTER 7

PRINTS FROM SLIDES VS. PRINTS FROM NEGATIVES

On average, for equal amounts of money and effort, a print made from a transparency does not look as good as one made from a color negative. That "equal" qualifier is most important because the point of this book is to teach techniques that let you make prints that rise above the mundane. You can overcome most deficiencies by appropriate application of technique. There is no fundamental reason that prints made from slides can't look as good (albeit different) as those from negatives. Before you can make them, though, you need to know what you're up against.

The underlying problem is that transparencies are made to be viewed, not printed (see Chapter 2). From the outset, color negatives are designed to be printed, and they use many tricks that slide technology can't. The most important is the orange mask built into negatives. The integral mask, as it's called, is not of uniform density. If you could remove the image from the film, you'd see that the mask is a faint reversal (a positive) of the negative's image. The mask corrects the color of the image-forming dyes in the film and improves the contrast characteristics of the film (Fig. 7–1).

The dyes used to make color films don't have perfect spectral characteristics. For instance, a real cyan dye might also contain a little magenta hue, thereby making it too blue (Fig. 7–2). If you were to print that dye image directly on color-negative paper, it would not print true red (the complement of cyan), but reddish-orange. Let's say that the cyan has a 10% magenta component. We can cancel that out by creating a reversed integral mask containing just enough magenta dye in the unexposed portions of the film to equal the undesirable

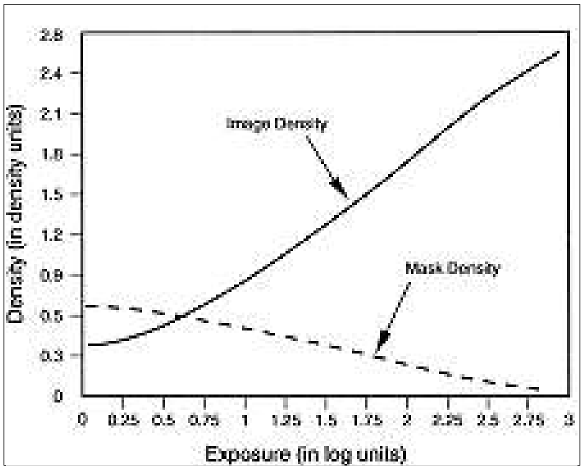


Figure 7–1 These characteristic curves illustrate how the density of the orange color-correcting mask in a color negative corresponds to the density of the image. The mask is a low-contrast positive image, which both moderates the contrast of the negative and corrects color errors.

magenta component (Fig. 7–3). When you combine this mask with the cyan-dye image, the negative takes on an overall 10% magenta cast that we can filter out during printing. That eliminates the unwanted color from the cyan dye.

The film manufacturer tailors the mask to cancel unwanted colors in the image-forming dyes. Of necessity, such a mask must be colored; thus no slide film can use this trick. The negative's mask also helps control film contrast and is part of the reason that color-negative films have long and straight characteristic curves, unlike slide films' pronounced S-shaped curves. The typical slide film has a total exposure range of 7 to 9 stops, including the extreme toe and shoulder of the characteristic curve. The relatively straight midrange of the curve covers about half that exposure range. In comparison, a color-negative film has an exposure range of 10 stops or more, with much less toe and shoulder.

As I discussed in Chapter 2, color-negative films use advanced color couplers to chemically control the development process and increase color saturation without increasing contrast. Slide films can make only limited use of these couplers because the coupler must not leave any visible trace in the processed film. To produce a good midrange saturation without couplers, the typical slide film must be relatively contrasty in the midtones.

All these factors work against the slide print. A color-negative print paper gets to deal with a film image that is low in contrast, has a linear exposure/density relationship, and is made up of spectrally pure colors (thanks to the mask). The slide paper has none of these assists. Considering this, it's surprising how good slide prints can be!

Differences in Tonal Rendition

An unmanipulated slide print is more contrasty than an unmanipulated print from a color negative. Slide-paper makers have improved their materials over the years, but the print from a slide still reproduces less of the original subject's luminance range. The slide print also has exaggerated midrange contrast at the expense of tonal separation in the highlights and shadows. If your objective is a good print, you can reduce the problem by choosing a slide film that has a relatively linear characteristic curve. One of the best in this respect is Kodak Ektachrome 100 Professional (EPN). Also avoid slide films that have a very high D-max. A slide film with a maximum density of 3.8 looks a lot better to the eye than one with a maximum density of 3.2, but it is much harder to print. When Fuji introduced Velvia, the first of the extra-high D-max films, printers went nuts trying to print everything the slide had captured.

Contrast-control masking (and to a lesser degree, fogging) tames the overall contrast of slide prints. You'll need to mask a much higher percentage of your slides for printing than you will for your negatives. Almost every slide I make on a sunny day needs to be masked before I can make a good print of it. Masking does not undo the S-shaped curve of the slide film. Even a masked slide print has expanded midrange contrast and suppressed highlight and shadow contrast compared to a color-negative print of comparable overall contrast.

You can also help control contrast by choosing a slide paper appropriate to your images. For

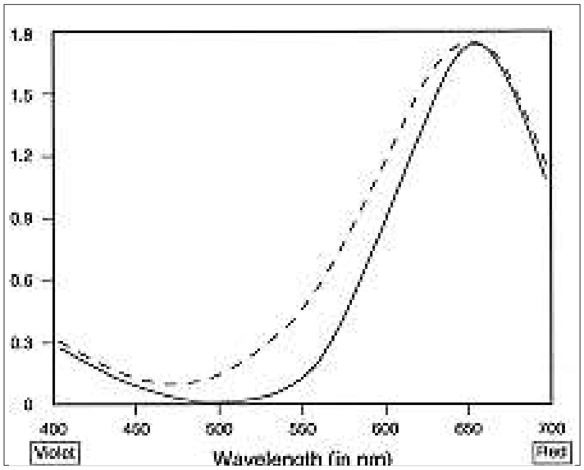


Figure 7–2 Hypothetical spectral curves for an ideal cyan dye (solid line) and a real-world cyan dye (dashed line). Violet (400 nm) is at the left and deep red (700 nm) at the right. The real-world dye has absorptions in the green part of the spectrum that give it an unwanted magenta cast.

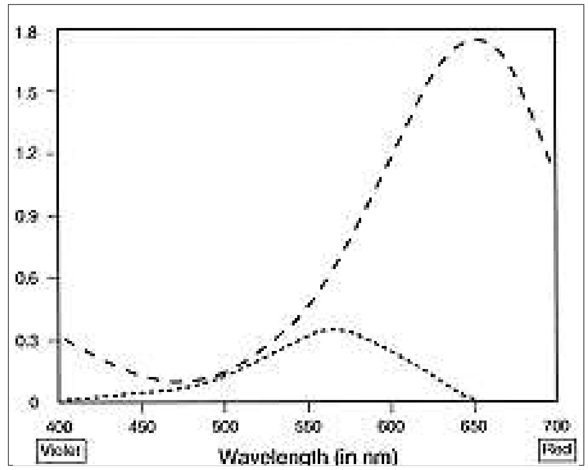


Figure 7–3 A magenta color-correcting mask dye (dotted line) can compensate for the color cast in the cyan dye (dashed line). When the absorption of the mask dye is subtracted from that of the cyan, the unwanted green absorption by the cyan dye disappears.

instance, Ilfochrome produces lower overall contrast and more accurate distribution of tones than any of the chromogenic (R-3) papers; Ilfochrome also has lower color saturation than any of the R-3 papers. However, Ilfochrome provides less highlight contrast, which is already suppressed in slide prints. If you're printing a subject in which highlight brilliance is important, Ilfochrome may not be your best choice. Kodak Radiance paper, on the other hand, has a great deal of highlight separation. For such images, I'd use Radiance combined with a contrast-control mask.

Differences in Color Rendition

On average, prints from slides are more saturated than prints from color negatives because of the higher contrast of slide prints. A color-negative print made on Kodak Ultra II or Agfa Signum paper, or Fuji Fujiflex material approaches the saturation of a slide print. This is especially true if you're printing from a high-saturation color-negative film. Contrast-control masking does not affect color saturation; with appropriate masking, it's possible to have a relatively low-contrast slide print with high saturation, which is more difficult to achieve in a color-negative print.

Saturation has a price: color fidelity. As I said, you can expect slide prints to render colors less accurately overall than color-negative prints because of the lack of an integral color-correction mask. In addition, excessive saturation tends to push colors toward the primaries. It's much harder to get a good rendition of a full palette of pastels in a slide print, although you can always adjust your filtration to correct a selected range of hues.

In addition, the higher contrast and S-shaped curve of slide films distort the hues of light and dark color by forcing their values more toward black or white. For these colors, saturation actually goes down because you cannot achieve high saturation in a color with a very high or very low value. To some degree, masking alleviates this problem, as Plates 14 and 15 illustrate. If the hues are so light or so dark as to fall well onto the toe or shoulder of the slide film, even tone correction during printing cannot restore the color.

Slide prints seem to render yellows better than color-negative prints. This is notably true of Ilfochrome material, which produces very pure yellows, but I've noticed it also holds for the chromogenic slide papers. Blues, on the other hand, almost always look darker and less accurate in slide prints. Slide-print papers produce eye-popping reds (especially Ilfochrome), but oranges come out no better than they do in color-negative prints, and pinks and magentas are much less accurate and saturated. Overall, I think that Agfachrome papers currently produce the best color palette, but this is always subject to change as new papers come on the market. No one slide paper is best for all colors, and no slide paper produces a more accurate overall rendition of hue and color than color-negative papers do. Ilfochrome has a special problem with color crossover (see "Issues with Ilfochrome").

Differences in Permanence

Here's a category in which slide prints can be better than negative prints. We used to see very marked differences in print lifetimes with older, discontinued products. Chromogenic slide prints were much inferior to color-negative prints, and Ilfochrome was much better than either, both on display and in storage. This is no longer true—the chromogenic materials have improved immensely during the past 10 to 15 years; Ilfochrome permanence has generally stayed the same.

Currently, Ilfochrome prints stored at room temperature have a dark storage lifetime that is centuries long (using the museum archival standard of no more than 10% change in any dye layer). Using casual viewing standards (30% change), the prints last two to three times longer. All chromogenic papers are three to five times less permanent than that. In general, manufacturers' RA-4 color-negative papers have about 50% greater dark stability than do R-3 color-slide papers, but the projected lifetimes of these papers cover a broad range. For details, see Henry Wilhelm's excellent book on print permanence (see Chapter 12).

For prints on display, it's a different story. Ilfochrome (and, for that matter, dye transfer) prints show no overall advantage over chromogenic prints made from either negatives or slides. Not all chromogenic prints are better than Ilfochrome or dye transfer (most are worse), but Fuji's Crystal Archive papers exhibits several times the display life under simulated daylight conditions, according to tests by Henry Wilhelm.

Display life also depends very much on the kind of light used for display. Ilfochrome material seems better under daylight than under incandescent lights, relative to chromogenic prints. The latter, especially color-negative prints, are all as good or better.

Issues with Ilfochrome

Ilfochrome presents us with some particularly vexing problems. Ilfochrome does not render colors the same way as other reversal color papers do. To some extent, this is due to the radically different dye set in Ilfochrome materials. Ilfochrome uses azo dyes, which are extremely durable, and this is what endears Ilfochrome to printers, but azo dyes don't look like the chromogenic dyes used in other kinds of color papers. Printers who expect to be able to duplicate the look of an R-3 print with Ilfochrome materials will find themselves unpleasantly surprised. Ilfochrome rendition is not worse and is often better, but as I described earlier, it is unquestionably different.

Color crossover is a more serious concern. E-6 films tend to print with noticeable color crossover on Ilfochrome material; highlights shift to the cyan and shadows tend toward the red. All E-6 films print with some degree of color crossover. Sometimes the crossover is quite minor, but at other times it is so serious that it makes an attractive print totally impossible; either way, it's not correctable by changes in exposure, filtration, or processing technique.

Ilfochrome renders Kodachromes well. A gray scale photographed onto Kodachrome prints with very little deviation on Ilfochrome—the shadows, midtones, and highlights all come out very neutral.

If you're going to be making Ilfochrome prints, it is a very good idea to photograph with Kodachrome unless you're sure your E-6 film of choice doesn't print with noticeable crossover. Slide films that look excellent to the eye and reproduce very well by other means may print terribly on Ilfochrome. Visual appearance gives no guide to the severity of this problem. There is no way to predict which films will print acceptably. For example, Kodak's Lumiere films printed horribly on Ilfochrome! The prints were usually unusable and ugly (Plate 8).

The cause of this problem is a spectral mismatch between the dyes in the E-6 films and the spectral sensitivity of Ilfochrome materials. The dyes in Kodachrome slides are quite different from those in E-6 films but match the spectral characteristics of Ilfochrome well. It is beyond the scope of this book to discuss the precise nature of the mismatch, but it's related to the problems of photometamerism and color matching I described in Chapter 1.

The masterful color printer Joe Holmes worked this out some years ago and constructed a special head for his enlarger. It contains light sources whose spectral output was very carefully tailored to eliminate the mismatch problems between the films and Ilfochrome. Not only do his prints have much better color rendition overall than the typical Ilfochrome print (or, for that matter, any of mine), they show no evidence of color crossover. They are clear proof that it is possible to get truly excellent prints from E-6 film on Ilfochrome. Unfortunately, this solution to the problem is not available without considerable expense and effort that is beyond the means of most of us.

The standard professional approach for dealing with this kind of color-crossover problem is to make a color-correction mask. Bob Pace discusses color correcting masks at some length in his book (with videotape) *A Professional Approach to Cibachrome.*[1] A color-correction mask is a negative silver mask similar to a contrast-correction mask, except you use it to change the contrast or density of only one color in the film. You correct color crossover by splitting your exposure into separate red-, green-, and blue-light exposures and using a different mask (or no mask) for each exposure.

For instance, cyan-highlight/red-shadow color crossover means that the cyan image in the print has lower contrast than the magenta and yellow images. If you make a contrast-reducing mask and use it to print the magenta and yellow parts of the picture, you can get the contrast between the cyan and red images to match; the crossover will disappear.

It's a simple theory, but the practice requires pin-registration equipment to hold the slide, mask, and print paper in precise alignment. You have to remove the slide carrier from the enlarger, add or remove contrast-altering masks, replace the slide carrier in the enlarger, replace the print paper on the print easel, and keep everything in registration for the next exposure. If you own a pin-registration setup, consider these techniques very seriously and get Bob Pace's book. Since few printers own such equipment, I feel that promoting this method as a standard one for solving Ilfochrome's problems is unrealistic, but I bring up the idea so that you know the situation isn't hopeless. If you're willing to go to the trouble of doing multiple exposure printing and dealing with pin-register equipment, you can get excellent results from Ilfochrome—much better than anything you can do with a single-exposure approach.

1. Available directly from Bob Pace, 11534 Francisco Place, Apple Valley, CA 92308 (email: BPace10552@aol.com).

CHAPTER 8

CONTRAST CONTROL IN COLOR

Thirty years ago, I made my first color print. Twenty-nine and a half years ago, I began cursing all the paper manufacturers who provided black and white (B&W) printers with different contrast grades of paper, but ignored us color-print workers. Imagine what B&W printing would be like if you could only buy grade 4 paper? That's about the situation color printers have to live with. Just like B&W printers, color printers need to be able to control print contrast to accommodate different luminance ranges in their subjects. Although one can currently buy at least three different contrast grades of color-print paper, the grades start at medium-high contrast and get higher. We're stuck when we need the equivalent of medium grade or lower. Conversely, try photographing from an airplane, through haze, or printing an underexposed slide or negative. You'll wish for the color version of grade 5+ paper.

Rarely does a subject's luminance range truly exceed the total exposure range the film is capable of. Negative films, both color and B&W, can handle almost any subject. Even with slide films, subjects of truly extreme luminance range that strain the film's capabilities are rarer than we think. If you don't believe that, look at the print from a masked slide I exposed under midday desert sun (Plate 14).

The brick wall we run into is that color films record much more information than we can get into an unmanipulated print. The exposure ranges of print materials are not adequate to handle a density range from the film that corresponds to the luminance range in the subject that we wish to portray. The best slide-printing papers have a usable exposure range of about 2.2 log units (l.u.), which means that they can handle only about two-thirds the density range in a well-exposed slide. Negative printers have it just as bad. A color-negative film can record a fantastic exposure range—10 stops or more. A color print can convey six or seven stops of that range, but it chokes on the rest. Sunny-day photos make prints with inky shadows and burnt-out highlights, although the negatives usually have plenty of detail.

What does one do when the density range of the film exceeds the exposure range of the print material? You can dodge and burn in, but you'll still be trying to squeeze images meant for grade 1 paper onto grade 4. Controlling a color print's tonal quality solely with local manipulations is about as effective as printing every B&W negative on grade 4 paper. There is always some detail one can't bring out, and the overall tonality of the print is harsh. We need an array of tools to make up for the lack of well-spaced paper grades in color. Those tools come into play when we process our film and when we make our prints.

Changing Color Films' Contrast

Every B&W photographer knows how to alter the contrast of a B&W negative film by changing its development. Hardly anyone seems to realize that the same techniques are available for films that use either C-41 color-negative or E-6 color-transparency processing. The only color photographers who cannot easily avail themselves of contrast-altering development are those using Kodachrome films (K-14 process).

Both push- and pull-processing are normal E-6 tools. Transparency photographers know they can vary the first development time in E-6 processing to alter the effective film speed. I think a better reason to push- or pull-process color-slide film is to alter the contrast of the image! It's a mistake to think of this contrast change as an incidental side effect of the processing. I find pull-processing to be far more useful than push-processing, because I do most of my photography under uncontrolled lighting conditions, in which there is too much contrast in the subject and too long a density range in the film to comfortably print. On rare occasions I like more contrast in my subject, such as when I do aerial photography.

Film manufacturers make their slide films change in speed in approximately the same way under push- or pull-processing. There is no way to standardize the processing for contrast changes because each film has a different characteristic curve. Some films change contrast a lot with push- or pull-processing; others hardly move. Unfortunately, the manufacturers don't even try to tell us how much to push or pull to change the contrast by, say, 25%. You'll just have to test your favorite film.

Almost no one realizes that the same tricks apply to many C-41 films! The overall changes produced are much the same as with E-6 film. Push-processing produces a little more shadow speed, more grain, higher contrast, and higher color saturation. Conversely, pull-processing produces less grain and film speed, lower contrast and lower saturation.

Varying the development time of C-41 film produces useful changes in negative contrast. Only a few negative films have official push-pull recommendations from their manufacturers, but my experience is that most color-negative films respond well. A few do not; pushing or pulling them produces color crossover. You need to test a particular film before you use this technique. Because manufacturers revise emulsions every few years, I'm not giving you a list of recommended films.

Very roughly, dropping the development time to 2.5 minutes usually costs a stop of film speed and produces a full grade reduction in contrast (Plate 9). Consider this the next time you photograph bright snowy peaks or harsh desert scenes. Going to 5-minute development gains a stop of speed and a grade of contrast. There are exceptions to this rule. For example, pushing Fujicolor 800 produces an increase in speed and grain but absolutely no increase in contrast, which is great for available-darkness photographers, but of no use for our purposes. In any case, test; don't assume!

The other half of the problem is how to adjust the film density range to match the print and do so in a fashion that looks pleasing to the eye. Aye, there's the rub! As any Zone System aficionado can tell you, it's not enough to take a high-luminance-range subject and rashly compress it; one needs a little more finesse. How do we make up for the absence of a wide range of paper grades and squeeze (or expand) that luminance range to where we want it?

The best and most versatile method, by far, is contrast-control masking. Masking is different from dodging and burning-in. Masking in color works the same way changing paper grades works in B&W. Dodging and burning-in are tools that complement contrast control; they can't replace it. Contrast-control masks are simple to make and to use. All the details are presented later in this chapter.

Color Paper Grades

Paper manufacturers are constantly revising their offerings and introducing new products. By the time you read this book, some of the products I describe will have been replaced by newer ones. This is both the blessing and the bane of photographic progress. Newer materials may be better, but they are also different—any hard-won wisdom must be revisited when a new product enters the scene. The following comments are not durable recommendations; they are guides to help you understand what print qualities you should be looking for when you consider a paper and to help you choose your paper.

Color paper makers don't provide a neat set of paper grades like the kind we get for B&W printing. In particular, no manufacturer offers a full range of contrast grades. Unlike B&W printing, in which one can settle on one maker and get a reasonable range of materials, color printers have to stock several brands if they want to maximize their contrast range.

Kodak color-negative papers are, on average, more contrasty than their competitors' offerings. Kodak Ultra III paper is certainly the most contrasty color paper on the market. I find it invaluable for printing long telephoto photographs, aerial images, and subjects I photographed under very flat lighting. I always try making a print on Ultra II before I resort to a contrast-increasing mask, which is much more work.

If low contrast is what you need, Agfa Portrait paper and Fujicolor Type P paper are both lower in contrast than Kodak Portra III. There's not a big reduction in contrast. I'd estimate that the difference between the Agfa and Fuji papers and Portra III is about the same as the difference between Portra III and Kodak Supra III paper (maybe one-fourth grade). I think of the difference between Portra III and Supra III as being less about contrast and more about "look." Supra III has a slightly snappier quality. Still, a trio such as Agfa Portrait, Kodak Supra III, and Kodak Ultra III give three distinctly different papers with at least a half-grade contrast jump from one to the next. It's not a big range, but it frequently makes the difference between a print that works and one that doesn't.

If you want reversal prints with the average lowest contrast, Ilfochrome materials beat out the competition—not by much, but every bit helps when you're printing slides. Ilfochrome materials also produce a more accurate distribution of tones than any of the chromogenic papers; they more faithfully reflect the tonal distribution of the original transparency. If you're wedded to R-3 or 3000 processing, Fujichrome papers are better. On the other hand, if you need the best possible tonal separation in the highlights, Kodak's Radiance paper is at the top of the list. As with negative papers, these contrast differences are small compared to what B&W printers have available. For just that reason, one must exploit every small advantage.

It used to be that one could push color papers around by changing the process time or temperature (at the risk of creating some odd color problems). This doesn't work well with RA-4 papers. The tight "official" process specifications belie these papers' robustness. Underdeveloping produces weak and bluish blacks before it produces any significant reduction in contrast. Overdevelopment gives less contrast change than going from Portra III to Supra II paper.

My experience with reversal papers is similar. In making prints from slides, we almost never need more contrast; we need less. The only process step that doesn't go entirely to completion is the first (B&W) developer. Unfortunately, as with RA-4 materials, even a modest reduction in development reduces the D-max. In a reversal print, the first-developer "blacks" correspond to white in the final print. Unless the first developer really develops all the developable image in the to-be whites, the color developer produces a color-dye image from the undeveloped silver halides. Instead of white, you'll get gray. Indeed, the contrast is lower, but this doesn't make it a fine print!

The one print material for which process changes really work is Ilfochrome. In a later section of this chapter, I describe how Dye Chrome's alternative chemistry can give a considerable amount of control over Ilfochrome's print contrast. Since Ilfochrome materials also have slightly less contrast than their R-3 competitors to begin with, they have a double advantage in taming unmasked prints from contrasty slides.

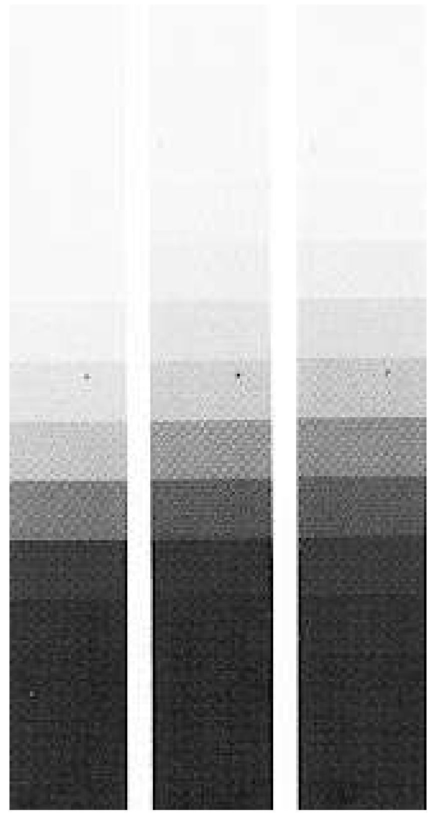


Figure 8–1 These step-tablet prints show the effect of fogging on Polymax II B&W paper, as compared to changing the filter pack to reduce the contrast grade. The strip on the left is an unfogged grade 4 print. The middle strip is a fogged grade 4 print. The strip on the right is an unfogged grade 3 print. The grade 3 and fogged grade 4 prints have the same overall exposure range, but the fogged print shows less highlight separation and more shadow separation.

Fogging to Reduce Contrast

We all know how flare and light scattering reduce the contrast of the images we photograph. Can we harness this to our advantage when printing? It's a nice idea, but it produces only modest improvements. Plate 10 and Figure 8–1 show the effects of fogging on B&W, color-negative, and color-reversal papers. In the case of color-negative paper, fogging can add 0.15 to 0.3 density units (d.u.) to the printable range of a negative. This is the equivalent of about one paper grade or a modest contrast-control mask.

Fogged negative prints have lower highlight separation. Fogging lowers contrast in the highlights more than the shadows because it's a linear addition of light.

The entries in the first column of Table 8–1 are stop differences in the base exposure. The second column shows the stop differences in terms of light intensity and adds 1 unit of fog light to those exposures. The final column is the sum of the luminances, again in stops. All the compression occurs in the first few stops in the highlights, which means that tonal separation in those areas is going to be very poor. Midtone and shadow separation remains the same, which makes this approach advantageous if you need to preserve contrast in those areas. By comparison, a thin mask that produced the same overall compression of scale would have almost no density in the highlight regions and would have little effect on highlight separation. A contrast mask does a much better job of retaining highlight brilliance and separation while compressing the midtones and shadow tones.

Table 8–1 Effect of Fogging on Base Exposure

stops	light plus fog	stops
-1	0.25 + 1 = 1.25	1.3
0	0.5 + 1 = 1.5	1.6
1	1 + 1 = 2	2
2	2 + 1 = 3	2.6
3	4 + 1 = 5	3.3
4	8 + 1 = 9	4.2
5	16 + 1 = 17	5.1
6	32 + 1 = 33	6

Fogging has the opposite effect on reversal papers. Too much fog makes the blacks go gray. Reversal papers are designed to squeeze every last bit out of the available density range, and their malleability by fogging is even less than that for negative papers. Unlike negative papers, the tonal compression doesn't degrade highlight separation; it degrades shadow separation. Although that may not be the effect you want, it is much more acceptable to the viewer as long as there's still a definite black. People notice muddy highlights much more quickly than they see muddy shadows.

A truly effective fogging exposure for color-negative prints demands careful calibration. You want the fogging exposure to be just under the point that the whites or blacks start to go gray. In addition, the light has to be entirely neutral in color from the paper's point of view or you'll add an unwanted color cast to the highlights. You must determine a new exposure and filter pack for your enlarger each time you replace your enlarger bulb, and it will be different for different papers. It turns out to be a very tricky business.

The situation isn't quite so bad for B&W or slide printing. For B&W work, you don't have color filtration to worry about, which eliminates most of the initial calibration difficulties. With slide prints, fogging lifts up only the shadows, and slight color shifts in the deep shadow detail are less obvious to our eyes. That, combined with the lower overall contrast of slide papers, makes reversal printing fogging exposures much less tricky.

Fogging demands that you remove, replace, recompose, and refocus your negative every time you expose a print. It ends up being very time-consuming. Arguably, the time and inconvenience of making a mask for a single negative outweigh that of a good fogging exposure (once you're calibrated), but I don't think fogging has any advantage if you're already making masks for more than a few images.

Color-Film Masking

Masking is the best way to reduce or (less usually) increase the contrast of an image. Long-time readers of my articles know that I am mildly obsessive about masking. In fact, my very first magazine article in 1977 was about making contrast-control masks. I keep coming back to this for two reasons. First, color printing *needs* contrast controls. Unlike B&W photographers, we can't vary the contrast of our films very much without compromising the color rendition in the image. Unfortunately, the real world is not so limited. Sometimes, a "normal" contrast negative printed on "normal" contrast paper is just the ticket. Still, any photographer who ventures out of a studio and doesn't travel with a van full of lights and reflectors is likely to have a good percentage of images that need less print contrast than color films and papers provide. The only way to eliminate the need for masking is to always photograph under controlled lighting conditions or to reject many fine subjects because their luminance range is too great. I find about 25% of my negatives can benefit from masking. Fully half the slides I expose outdoors benefit from masking when I print them. Slide films are contrastier than negatives, especially in the midtones, and all slide printing materials are fairly contrasty, including the latest R-3 and Ilfochrome materials.

Second, most printers still haven't gotten the message—masking is the great secret of color printing but is rarely mentioned in books or articles. In my judgment, you are not a fine color printer if you don't know how to mask your negatives and slides. Like most printers, I once thought masking was far too much trouble to deal with. I put it off for years. When I finally tried it, I kicked myself hard. To add insult to injury, when I saw the great improvement that masking made, I felt obliged to mask and reprint many negatives I had printed over the preceding several years. My procrastination cost me considerable time and money. Masking is now a standard part of my printing regimen. It should be part of yours.

Just what *is* a contrast-reducing mask? It's a low-contrast, slightly fuzzy B&W "negative" of the original color film. I put the word "negative" in quotes because the negative version of a negative is a positive. To print with the mask, you align the mask with the original, tape their edges together, and print them as if they were a single piece of film. The "negative" mask image compresses the density range of the original film and thus lowers the contrast of the print.

For example, suppose you photograph a subject that has three stops more luminance range than your print normally portrays. In a color negative, this subject would produce a density range about 0.4 d.u. too great to print. You can correct this density range by making a low-contrast negative mask with a density range of 0.4. When you print with it, the mask will add almost no density to the densest parts of the original, but it will raise the density of the thinnest portions by 0.4 d.u., thereby compressing the density range of the original film into something the print material can cope with.

To see how much difference masking can make, feast your eyes on Plates 11 and 12. Both prints are on Portra II paper from the same negative. I exposed them to hold the same degree of highlight detail; I did no dodging or burning-in. As you can see, this compression looks almost the same as changing paper grades does in B&W printing. If Plate 11 is equivalent to printing on grade 3 paper, then Plate 12 is like using grade 1 paper. Figure 8–2 shows the color negative and the mask.

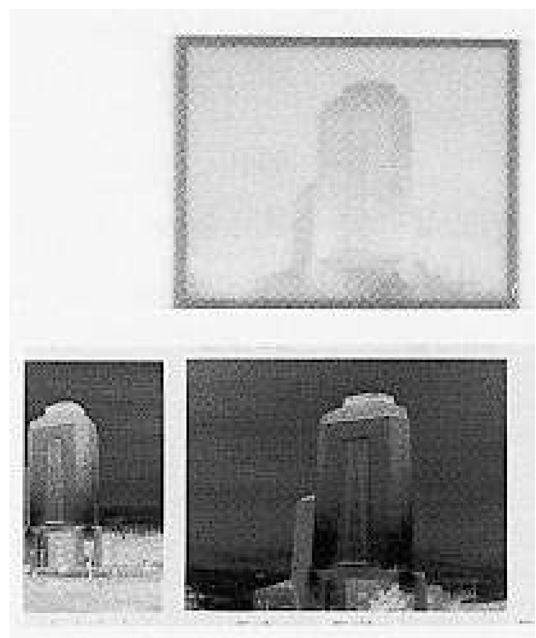


Figure 8–2 This is a fairly accurate photograph of the contrast-reducing mask used to print Plate 12 along with the negative used for Plates 11 and 12. The negative is unusually contrasty, so the mask is denser than the typical one. Nonetheless, it's a guide for what your masks should look like.

I printed Plates 13 and 14 on Kodak Radiance paper from a 35mm Ektachrome 64 (EPX) slide. The subject was the Baja Desert; the backlight source was a high sun. Fill light? What fill light? The subject luminance range fits (barely) the slide's exposure range; unfortunately, that's several stops more range than a slide print can handle. It's hopeless without masking; dodging cannot rescue this picture. The mask for Plate 14 has a density range of 0.6 d.u. The print appears lighter, on average, but note that highlights, like the sky, are actually darker than they are in the unmasked print. Colors are more brilliant because I didn't have to push them to black or white extremes.

In one weekend I can make masks for enough negatives to keep me printing for months. When I develop and proof a new roll of film, I inspect the proof along with the negatives to decide which images would benefit from a change in contrast. I mark those frames on the proof sheet, and when I've collected enough marks, I start a mask-making run.

For efficiency's sake, I gang several negatives and mask them all at once. I can print six 35mm or two 6 x 7 cm negatives on one 4 x 5 sheet of mask film and double that on 5 x 7 film. I have found that one exposure time seems to work well for most of my masks. Occasionally, I'll have bulletproof negatives that I know need extra-heavy masks; I group those together. Even so, I recently made masks for 200 to 300 negatives over a period of 4 days, and I wasn't working that hard. Slide masks need even fewer adjustments. Slides have a more consistent density range, and my objective is usually to print the full range of the slide.

Changing the density and contrast of the mask changes the print contrast. The exposure isn't actually that critical, because almost any mask is better than none. Also, the low gamma of a mask means that mask density is less sensitive to exposure changes. Mask making demands less darkroom skill than making an ordinary color print.

Making Masks for Negatives

You don't need a densitometer to make masks, although it won't hurt. I don't even own a color densitometer. Once you've done more than a little color printing, you'll develop a very good sense of which frames need masks to print well and which ones don't. This is a procedure in which seat-of-the-pants experience is usually good enough.

My usual method of making contrast-reducing masks was to use Kodak Pan Masking Film (Type 4750). Note the past tense—Kodak discontinued Pan Masking Film. I set out to find a replacement. A good masking film should be very fine-grained so that it doesn't add grain to the printed image. It also must produce a very low-contrast image; a typical mask has a gamma of between 0.2 and 0.35, depending on whether the original is a slide or negative and how great a degree of contrast reduction one needs. In comparison, a normal B&W negative has a gamma of about 0.6. Most important, a mask must be neutral in color or it will shift the color of the original's highlights with respect to the shadows and introduce uncorrectable color crossover into the final print. This is the toughest requirement, because conventional B&W film and developer combinations tend to produce brown images at such low gammas.

That genius of B&W chemistry, Maxim Muir, came up with the solution (literally!) in the form of a new developer formulation—Muir SoftShot Developer. I've refined the formula so that it will develop TMAX 100 film to a gamma of about 0.25 to 0.3 with neutral image tone. Muir SoftShot is not a prepackaged developer, and it keeps only a matter of hours; therefore, you have to make it up fresh each day. As compensation, masks made with TMAX 100 and SoftShot cost only one-third as much as masks made with Pan Masking Film used to.

You need the following chemicals:

- Phenidone
- Potassium hydroxide (KOH)
- Sodium sulfite
- Edwal Liquid Orthazite (2% benzotriazole)
- Isopropyl alcohol (drugstore grade)
- Vitamin C (ascorbic acid)

With the exception of Vitamin C, none of these are chemicals that should be ingested. Potassium hydroxide is the most hazardous: it's very corro-

Table 8–2 Muir SoftShot Developer

Water	700 ml
Phenidone	2 gm (100 ml of 2% Phenidone in alcohol)
Sodium sulfite	10 gm
Potassium hydroxide	1.4 gm (14 ml of 10% KOH solution)
Edwal Liquid Orthazite	15 ml
Vitamin C	0.4 gm

Add water to bring volume to 1 liter

sive and generates considerable heat when dissolved in water. Always add KOH to water and wear goggles and rubber gloves when mixing it.[1]

Using SoftShot Developer with TMAX 100 Film

Phenidone is not very soluble in pure water, especially at room temperature. It dissolves in ethanol and in isopropyl (rubbing) alcohol. Phenidone dissolved in alcohol is reasonably stable and keeps at least 6 months. I make up a 2% solution of Phenidone in alcohol (20 gm/liter or 9.5 gm/pint) and measure it out as needed to make working developer.

I also make up a stock solution of 10% KOH in water so that I don't have to handle pure KOH every time I want to mix up developer. KOH also keeps at least 6 months. The formula for Muir SoftShot is in Table 8-2.

You will get a mask with contrast comparable to that of Pan Masking Film by developing TMAX 100 sheet film in SoftShot for 3 minutes at 70˚F. One liter of developer can process four sheets of 8 x 10 film if you increase the development time by 25 seconds for each additional sheet after the first.

If you need only a very thin mask, you can reduce the development time to two-thirds of the normal time. For a stronger than normal mask, increase the time by up to 50%. If you prefer slightly longer development times, dropping the temperature to 68˚F adds 30% to the development time.

After the film is developed, agitate the film in a 2% acetic acid stop bath for 30 seconds. Then fix the film for 4 minutes in rapid fixer diluted to film strength. Unlike Pan Masking Film, TMAX 100 film contains brightly colored sensitizing and antihalation dyes. The rapid fixer removes most of the dye, leaving only a light pink color. Wash the film in running water until the pink tint is entirely gone. That should take less than 5 minutes. If the wash time is unduly long in your darkroom, bathe the film in a solution of Permawash after fixing it for 2 minutes, and then wash it for 2 to 3 minutes. Permawash speeds clearing of the dye.

After you've washed the film, rinse it in a solution of wetting agent mixed with distilled water and hang the film up to dry. Distilled water

1. You can order the chemicals you can't find at your local stores from Bryant Laboratory, 1101 Fifth St., Berkeley CA 94710 (phone: 1-800-367-3141, fax: 1-510-528-2948, web site: http://www.sirius.com/~bry_lab) or from Artcraft Chemicals, P. O. Box 583, Schenectady, NY 12301 (phone: 1-800-682-1730, fax: 1-518-355-9121).

eliminates the need to squeegee the film, which might leave marks on it.

Making the Masks

You will need the following supplies to make contrast-control masks:

- Opaque masking or similar tape
- Scotch Magic Mending Tape
- Photo-Flo 200 or similar wetting agent
- A sheet of eighth-inch plate glass slightly larger than the TMAX 100 film
- A contact-printing easel or a large sheet of quarter-inch plate glass

Also helpful are:

- PEC-12 Photographic Emulsion Cleaner, made by Photographic Solutions
- Tetenal Anti Newton Spray and Film Cleaner Spray, distributed by Jobo[2]

Along with TMAX 100 sheet film, you'll need an appropriate developer such as SoftShot, stop bath, and rapid fixer.

When you make a mask, you contact-print (almost) the film you want to print onto TMAX 100 film and develop the TMAX 100 to a low contrast in SoftShot developer. Figure 8–4 diagrams the arrangement of films and spacer glass I prefer for mask making. The set-up shown in Figure 8–5 corresponds to this arrangement. The thickness of the plate glass allows the light to diffuse before hitting the TMAX 100 film, which makes a slightly unsharp mask. I control the sharpness of the mask by varying the thickness of the spacer glass or the angular size of the light source. You don't want too sharp a mask because it will be hard to align with the negative, and you'll wind up with bas-relief effects in your prints. On the other hand, too blurry a mask creates little light haloes around dark objects (e.g., tree branches against the sky).

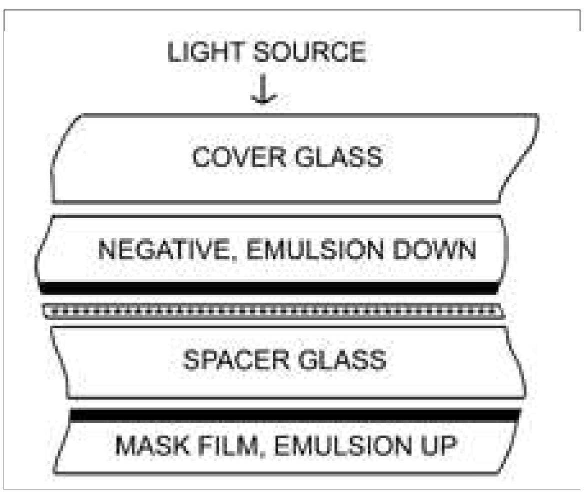


Figure 8–3 This is the Kodak arrangement for making a contrast-control mask. The negative faces emulsion-down, while the masking film is emulsion-up. The thickness of the spacer glass depends upon the negative size. Note the diffusing sheet between the negative and the masking film.

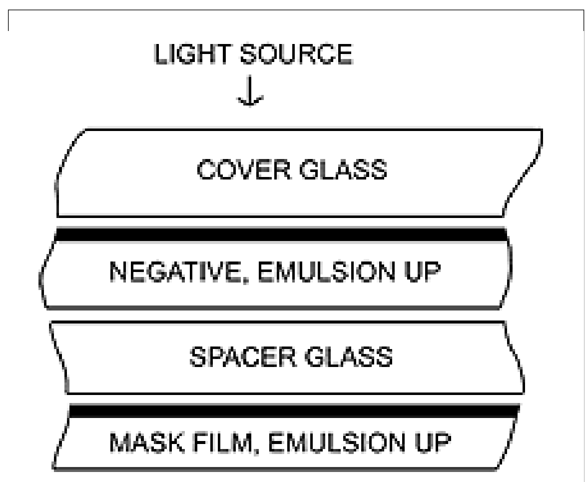


Figure 8–4 This is my preferred arrangement for making masks. Note that there is no diffusing sheet between the negative and the mask and that both films are emulsion-side up. This produces a less grainy mask.

2. Call Jobo or Photographic Solutions (see Chapter 14) for the name of the nearest dealer who carries their products, if your dealer doesn't.

My method differs from the one long-recommended by Kodak (Fig. 8–3). Kodak uses a frosted acetate diffusing sheet between the original and mask films to generate the unsharp mask. The diffusion sheet imposes a slight grain pattern on the mask. This is not noticeable with large format or coarse-grained originals, but prints from small- and medium-format negatives made with today's fine-grained films are another matter. Prints from these smaller negatives masked the Kodak way exhibit distinctly more pronounced grain.

Another way in which Kodak and I part ways is the orientation of the mask. Kodak recommends making the mask with the emulsions of the original and mask films face-to-face. During printing, the films are sandwiched with the emulsions in contact, which places the mask below the original negative. The emulsion-emulsion contact reduces the chances of getting Newton Rings, but the mask diffuses the enlarged image of the original negative. The resulting print is slightly soft; this is especially obvious with strong masks.

I prefer to avoid the grain caused by the diffusion sheet and the softness caused by interposing the mask between the negative and the enlarging lens. I deal with Newton Rings, if they are a problem, with the Tetenal spray.

To make a mask, start by cleaning your originals and the sheets of plate glass thoroughly with PEC-12. Tape the original film, emulsion-up, on *top* of the piece of plate glass or the contact frame glass. The mask film goes emulsion-up underneath the glass. For small originals, you can use the piece of eighth-inch glass to hold them down. If you are printing medium- or large-format film, you need only tape the edges of the film to the top of the plate glass.

You want the light as far from the print frame as possible. There is a slight divergence of the light rays coming from it, which will make the mask a bit larger than the negative. The effect is negligible for small- and medium-format originals if the head is at least 1 meter away. A light source with a diameter about 1/15 the distance from the light to the contact frame gives me the right amount of diffusion for medium- and larger-format work. I use my 4 x 5 color-head enlarger with the lensboard removed and the enlarger head 1.5 meters above the easel. For 35mm work, I prefer a light source diameter of 1/25 to 1/30 the working distance, so I put a medium-format film carrier in the enlarger.

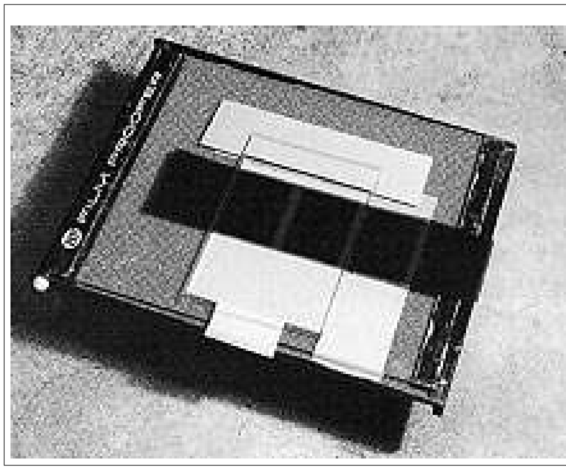


Figure 8–5 I've set up this proofing frame to make a mask. From top to bottom: there's a sheet of thin glass taped down to hold the filmstrip in place. The filmstrip is emulsion-up between that cover glass and the glass of the frame, which acts as the spacer glass. Inside the frame (under the spacer glass) is a sheet of mask film, also emulsion-up. The broad strips of white tape are placement aids to allow me to accurately position the mask film in the dark.

Add 60 B + 30 M filtration to the light source when printing negatives to offset the orange tint of the negative (using a color head, dial 90 M + 60 C filtration into the head). Because my enlarger is quite bright, and TMAX 100 film is about 3 stops faster than Pan Masking Film, I dial in the maximum neutral density filtration I can in addition to the 90 M + 60 C filter pack—an additional 110 CC of all three colors on my enlarger. I also insert a couple of sheets of white paper into the negative stage to cut the light down to a tolerable level.

You will have to determine your exposure time by trial and error. Make a test exposure of 10 seconds and develop the TMAX 100 film in Muir's SoftShot. Your goal is to make a mask that looks something like the one in Figure 8–2.

Aim for a density range in the mask anywhere from 0.3 for moderately contrasty negatives to 0.6 for very contrasty negatives. If your mask comes out much too dense or too thin, change the overall mask density by adjusting the exposure time and light intensity. Don't mess with the development time until you're experienced at making masks.

If you don't have a densitometer, don't worry. You'll find out what your ideal mask strength is by making prints, not density readings. That's what I do. My masks are usually somewhat dense, but my original negatives also tend to be dense and snappy.

Masking with Polaroid

Polaroid Type 665 P/N film is good for making an occasional mask, if you don't need the highest quality results and don't mind the high price. This film produces both a print and a negative. You'll need a Polaroid Color Pack camera to develop the film. Pawn shops and flea markets are swamped with them at very low prices.

Figure 8–6 shows how I print four 35mm frames onto one sheet of film (I can also fit two 645 frames or one 6 x 7 frame). The film pack sits face-up on my print easel. I use the same lighting and filter setup that I use with TMAX 100 film. After exposing the film, I pop the film pack back into the Polaroid camera and follow Polaroid's instructions for processing the film. After I've washed off the residual developer, I treat the negative with a quick dip in rapid fixer to clear out a bit of dichroic fog I sometimes get with this film. Polaroid says not to, but I find doing this makes a cleaner mask.

Type 665 is a handy way to make a small number of masks. Type 665's main disadvantage is that it is too contrasty to make a really good mask. You could reduce the mask in a proportional reducer to cut the density and contrast, but that process gets nearly as elaborate as using TMAX 100 film. Expose the Type 665 mask to produce the desired shadow density, and let the highlights fall where they may. Fortunately, color negatives have a short density range. You can place some of the density range on the low-contrast toe of 665's characteristic curve to preserve shadow separation in the final print. As Plates 15 and 16 show, 665's contrast flattens out the shadows a bit too much, but the prints are still much better than unmasked ones. Figure 8–8 shows the negative and Type 665 mask I used to make these prints.

Masking Transparencies

You need make only small adjustments to the negative-masking procedure for masking slides. The same contact-frame setup, lighting arrangement, and development time will produce a mask with just about the right contrast for fitting a typically contrasty chrome to the print paper. For slides, try for a density range of 0.6.

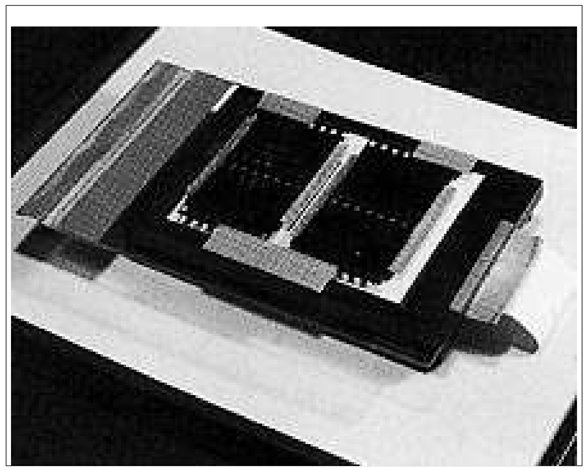


Figure 8–6 A simple setup for making Type 665 masks. The Polaroid film pack is sitting on the print easel under my enlarger. On top of the film pack is a sheet of thin glass (the same sheet that I used as the cover glass in Figure 8–5). On top of the glass I've taped down the strips of film that I want to make masks of. After exposure, the film pack goes back into a Polaroid camera for processing.

Since there's no orange mask to compensate for, don't filter the light source. You'll need longer exposures because the dense parts of the slide are several stops darker than the negative's. I mask off the sprocket holes and surround the slide with about 0.5 cm of opaque tape to prevent piping the relatively bright surrounding light into the image area, which would fog the mask. This was necessary with Pan Masking Film. It may be

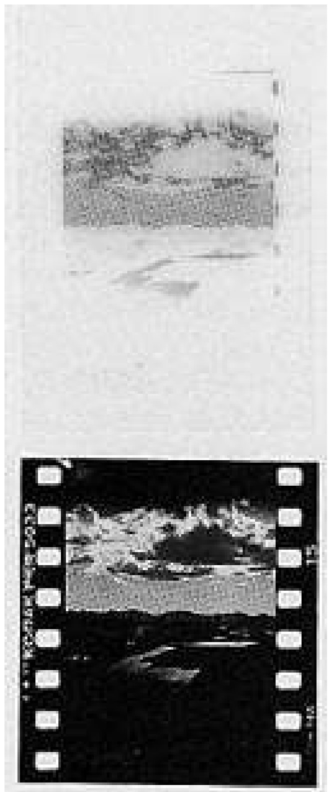


Figure 8–7 Here is a typical contrast-reducing mask and the slide it was made from. Your mask for an average slide should look much like this one, if you want to fit the full density range of the slide into your print material's exposure range.

overcautious with TMAX 100, but precautionary habits die hard.

Figure 8–7 shows a Kodachrome slide and its mask. Plate 17 is a straight print from a medium-format Lumiere 100 slide. I printed that slide with a contrast-reducing mask in Plate 18. This print required several times as much exposure as Plate 17, but is a vastly improved picture, with better detail overall.

You can use Polaroid Type 665 film to mask both slides and negatives by following the procedures in the preceding section. As with TMAX 100, use no filter pack and expect exposures to be several times longer. You definitely don't need to tape over the sprocket holes when using Type 665.

Type 665 doesn't do as good a job of masking slides as it does masking negatives. It knocks about one stop off the highlight end, but a denser mask compresses the highlights badly because of 665's high contrast. Type 665 is a weak second to TMAX 100 film, but it is much better than an unmasked print. For occasional and uncritical printing, Polaroid is an economical way to improve your prints.

Going Up!

On occasion, you will need to increase print contrast. Contrast-increasing masks are trickier to make than reducing masks. You must first make an internegative and then a positive mask from the internegative. The amount of contrast increase you want will vary greatly from photo to photo. You have to choose development times carefully for the two masks that produce the final mask contrast you need. In addition, a contrast-increasing mask has to be nearly sharp or it produces an unpleasant diffusion-like effect in the final print: light objects have slight glowing haloes, and dark objects such as tree branches against sky have dark haloes around them. The sharpness of the mask increases registration problems and aggravates dust spots in the picture.

Typically, the final mask has a contrast between 0.3 and 1.0. Anything less than 0.3 probably isn't worth the trouble. A mask with a gamma of 1.0 will change the contrast as much as jumping from grade 1 to grade 5 paper does in B&W printing.

Technical Pan Film is almost grainless and can easily produce a wide range of contrasts. Tray processing 4 x 5 Tech Pan in DK-50 1:4 at 68°F produces a gamma of 0.5 to 0.6 with a development time of 2 minutes; a time of 3.5 minutes produces a gamma of about 1.0. By selecting appropriate development times for the internegative and final positive mask, I can get a final mask gamma of between 0.3 and 1.0.

I make my internegative by using the same basic printing technique I use for contrast-reducing masks, except that there is no spacer glass between the original and the Tech Pan film. Because there is no diffusion to eliminate dust specks, one must take great care to clean the original and print frame. You may introduce a very slight amount of diffusion in the final mask, if

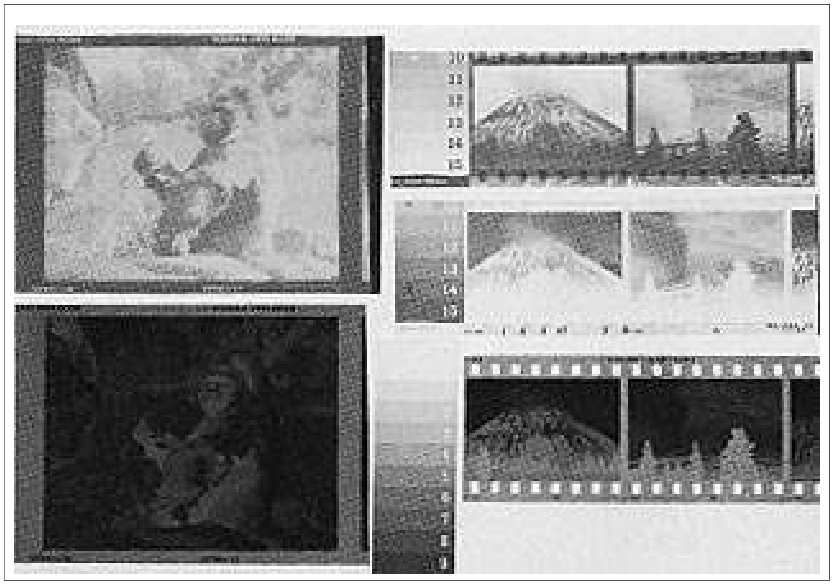


Figure 8–8 Specialized masks. On the left are a color negative (bottom) and the Polaroid Type 665 mask made from it. The prints made from these are shown in Plates 15 and 16. On the right (bottom) are a 35mm negative film strip and a contrast-increasing mask (center). Plates 20 and 21 show the prints made from this negative and its mask. The intermediate positive film used to make the contrast-increasing mask is at the top right.

necessary, with a thin spacer glass, but keep it to the absolute minimum you need to make registration easier.

Figure 8–8 and Plates 20 and 21 show a set of masks for a 35mm negative and the print that resulted. The original negative suffered from a combination of slight underexposure and aerial haze; although there was plenty of detail, the print lacked appropriate drama. The final contrast-increasing mask had a contrast of about 0.6; you can see that makes a dramatic difference in the final print.

Printing with a Mask

After the mask dries, clean it and the original film again with PEC-12 and dust them thoroughly. Lay the mask down on your light table, emulsion up, and put the original negative or slide on top of it, also emulsion up. You should be able to align the two pieces of film easily by aligning sprocket hole images (in 35mm) or the edges of the frame. Once you have the films aligned, tape the edges together.

Put the sandwich in your negative carrier, emulsion down, and print it as if it were an ordinary piece of film. The mask will be on top, which prevents it from blurring the image. Because the mask is neutral in color, your filter pack will change little or not at all. You need 50% to 200% more exposure time, depending on the density of the mask. Remember, you can still dodge and burn in. Masking works like changing paper grades; it doesn't replace local correction.

If your masked print is too contrasty, your mask wasn't dense enough. If the print is not contrasty enough, your mask is too strong. I tend to make my masks a bit heavy; if I've gone too far, I can print masked negatives on Kodak Ultra II paper or I can reduce an overly dense mask by bleaching it with RA-4 bleach-fix diluted 1:5 with water. I rarely find that I've made too heavy a mask when printing from transparencies.

You should not have a problem with Newton Rings because the emulsion side of the mask is what is in contact with the base of the film. "Should not" is not the same as "never." If you get Newton Rings, use Tetenal Anti Newton Spray (see Chapter 10). It's a great product and will end Newton-Ring problems.

Controlling Ilfochrome Contrast with Processing

Dye Chrome Research Co., Inc. makes a processing kit[3] that lets you change the contrast of Ilfochrome prints by changing the bleach time. Dye Chrome K-2 chemistry can produce both lower and higher contrast than normal Ilfochrome processing. The cost per print is about the same for Ilford P-30P and Dye Chrome K-2 processing.

Ilfochrome print material starts out with a full load of color dyes. Development produces an ordinary B&W silver negative image; the more light, the more silver in the print. The Ilford bleach step uses some of that silver to break down the dye in the print and converts the rest back to silver compounds. The more silver, the more dye breaks down, and the lighter the print gets. The bleach action stops when all the silver is converted. The fix step removes all the silver compounds from the paper, leaving only a positive dye image.

K-2 splits the bleach step into two parts—a dye bleach step and a silver bleach step. A short dye bleach step breaks down less dye, and the final image is both darker and lower in contrast. Because a longer-than-normal dye bleach time permits the bleach to attack more of the dye, the print gets both lighter and contrastier. The silver bleach step converts any unused silver back to silver halide and the fixer removes it, just as in the regular Ilfochrome process.

The K-2 process takes a few minutes longer to run than the P-30P process. The standard temperature for the K-2 process is 85˚F. At this temperature, the total time, excluding wash, is 9 to 14 minutes. Dye Chrome K-2 provides compensated process times for temperatures from 75˚F to 95˚F. I was able to make prints at 75˚F that looked identical to those at 85˚F, but the filter pack changed by 15 CC and the exposure by about a half stop. You should use the same temperature for all your printing if you want consistent results. The silver bleach and fix steps run to completion, so timing and temperature become less critical, but one should still stay within a few degrees of the correct temperature. Avoid underprocessing in the latter steps, but longer times won't hurt.

If you want to get consistent results, follow Dye Chrome's instructions precisely in every respect. Dye Chrome recommends holding the process temperature to within a half-degree Fahrenheit at least for the developer and the dye bleach steps. I fully agree—I found that temperature errors produced a color shift of about 5 CC per degree. You should hold process times to within 10 seconds for the first two steps to avoid variations in density and contrast.

Because I couldn't hold 85˚F with a manual drum in my darkroom, I used the "drift-through" method of temperature control. By starting my development step at 88˚F, I wound up reliably at 82˚F, for an average of 85˚F. I am a very precise worker, and I was just *barely* able to get consistent results with this method. I strongly recommend that you run the process within 5 degrees of room temperature if possible or use a drum that has a temperature-controlled water bath.

Because K-2 is a one-shot process and time and temperature control are very critical, I don't recommend it for tray processing or for a roller-transport machine (e.g., the Ilford CAP-40). It's suitable for manual color drums and automated drum processors such as the ones Jobo manufactures or for Nova slot processors. The K-2 developer is a metol-hydroquinone formulation, as are many B&W developers. Some people are sensitive to these chemicals and

3. Dye Chrome K-2 Chemistry is available in 1-liter kits (makes 14 8" x 10" prints or 10 11" x 14" prints) from Dye Chrome Co. Inc., P.O. Box 969, Lake Placid, FL 33852.

develop dermatitis. If you're one of those people, work with gloves.

Dye Chrome K-2 chemistry is a useful companion to the standard P-30P process. P-30P produces more brilliant and accurate colors in normal contrast prints than K-2 does. The K-2 yellows also have a slight magenta cast not evident in the P-30P print. There is a slight amount of color crossover visible in K-2 prints, but it is substantially less than the amount of crossover you get from printing an E-6 chrome onto Ilfochrome (see Chapter 7). At lower contrasts, there's no crossover.

K-2 does not produce precisely the same results as masking. Contrast-control masking alters contrast but not saturation. K-2 directly alters the contrast of each dye layer in the print; hence, it alters color saturation. When K-2 lowers contrast, it also lowers color saturation, but the results look very pleasing in real subjects, as opposed to Macbeth charts. In particular, skin tones in K-2 prints dye-bleached for only 2 minutes were excellent. I found them vastly more appealing than Ilfochrome's normal rendition, even from a masked slide.

I printed Plates 22 and 23 on Ilfochrome CF.1K material from a 35mm Ektachrome 100 Professional (EPN) slide. Plate 23 was a standard P-30P print, processed at 84°F. The Dye Chrome K-2 print (Plate 23) was dye-bleached for the minimum suggested time of 2 minutes at 85°F. I burned in the trees and sky in the background of the standard print by two-thirds of a stop to keep them from going too dark. I needed to give the K-2 print 1.5 stops more exposure and about 40 CC more blue filtration than the P-30P print, but I didn't dodge or burn in the K-2 print. It exhibits much better highlight detail along with more open shadows.

Increased dye-bleach time raises contrast and color saturation, and the yellows get purer. At maximum dye-bleach times, contrast is much higher than normal. Unfortunately, increasing the contrast also markedly increases the color crossover. Do not expect accurate color rendition at high contrasts; it's more for special effects or rescue work, in my opinion.

I printed Plates 24 and 25 on CPM.1M material from a medium-format Lumiere 100 slide and processed both of them in K-2 chemistry at 80°F. I exposed both prints for about the same amount of highlight detail. Plate 24 was dye-bleached for the standard time of 3.5 minutes. This print is very flat and uninteresting. Plate 25 was dye-bleached for 6 minutes and needed about 2 stops less exposure; the increase in shadow density and contrast is dramatically evident in this print. This late-afternoon photograph of hang gliders along the Daly City cliffs near my home clearly benefits from the higher contrast and color saturation despite the greater color crossover.

CHAPTER 9

TRICKS OF THE TRADE

SAVE A TREE: LEARN TO PRINT

A friend asked how many sheets of color paper it takes me to get a good print. It seems he had resumed printing after a moderate hiatus and found himself using 7 to 14 sheets to get the print exactly right. He felt he ought to do better than that. I felt he could do a lot better.

I use about 0.2 sheets per negative for the proof sheet (two half-sheets and one full sheet to make a good proof of 10 medium-format negatives). With the proof sheet to guide me, I need an average of two half-sheets for test prints. Sometimes I get the print after one test, but just as often I find I have to make a third test. There's another sheet for the final print. One of three or four times, I look at that print and realize I missed a burn-in or some such subtlety. That adds another 0.3 sheets, on average. Total: 2.5 sheets to get a cropped, color-balanced, masked, and dodged and burned-in final print that would make any custom lab proud.

I'm not counting the obvious blunders, such as failing to stop down the lens or flip in the filter pack in the color head. I still commit goofs like this frequently enough to embarrass me. Even counting all my brain-dead mistakes, I use well under 3 sheets of paper per final print. Part of the reason for this low level of waste is decades of experience and a very good eye. It typically takes me 3.5 to 4 sheets to get a good black and white (B&W) print. I think the difference is primarily because 95% of my printing these days is color, so I'm always a little rusty when it comes to B&W. The rest of the savings come from my economical tricks and techniques.

First, I proof all my negatives religiously. I'm 10 years behind in making enlargements, but my proof files are up to date. Good proof sheets provide accurate information about the relative color balance and density of negatives and show what areas of the image will need local exposure correction. I make my proofs with the enlarger height set for the same print magnification I would use to make an 8" x 10" print from the negatives I am proofing. I write the exposure data in my printing log and on the edge of the proof sheet for future reference (Plate 19).

If you work with slides, you don't absolutely need to make proof sheets, but remember that it is difficult to judge the relative density and color balance of two slides on a light box because the human eye tends to normalize the appearance of "luminous" objects like backlit slides. Worse, different brands of slides require different print filtration even if they look identical on the light table (see Chapter 1). You can't rely on your eye to tell you whether an Ektachrome 64 slide will need the same filter pack as a Fujichrome Velvia slide did. If you've had trouble estimating the exposure for your slide prints, start making proof sheets. They will solve the problem.

I derive my starting filter pack and paper grade from the proof sheet. I blindly use the same exposure; I treat the proof sheet like a first test print to which I'm applying corrections. I don't use a densitometer or an on-easel color analyzer. I've got nothing against them, but they don't improve my productivity. If they help you, more power to you! Video analyzers are another matter. I think they're great; if only I could afford one. I do use Kodak Print Viewing Filters. They're worth their weight in platinum.

One can't do precise color correction or selection of paper contrast (B&W or color) until the exposure's in the ball park, but one can correct gross errors. If the first test looks 40 CC too cyan, it doesn't matter how bad the exposure was—you *know* you have to wipe out some of that cyan. My print tests always include a series of exposure steps. How tightly I cluster the exposure times depends on how confident I am that I know how the negative will print. When I am clueless, the steps may run 5, 7, 10, 14, 20, and 28 seconds. They'll run something like 14, 16, and 18 seconds when I am more sure or when I'm fine-tuning the density. My final print is usually within 1 CC filtration and 3% exposure of what I want.

Don't sneak up on the correct filter pack, contrast, and exposure time from one direction, because that produces a lot of wasted prints. It is much more efficient to overguesstimate the correction. You will then have test prints that bracket the correct filter pack or paper grade. One can always interpolate more accurately than one can extrapolate.

Box-to-box consistency for any particular color or B&W paper is now very good. Kodak Portra II shows less than 5 CC variation, for example. Switching from brand to brand can be a different story. Kodak Portra II and Supra need almost identical exposures, but Ultra is very different—roughly a stop faster with about 15 CC less red filtration. Some Fuji papers have almost the same filter packs (as each other and as Portra II); others don't. Note that this can all go out the window when a product line changes. For instance, Polymax II B&W paper doesn't look at all like the original Polymax—paper grades are anywhere from a half-contrast grade to two grades different (see Chapter 2).

For color, I write the relative filter pack used on each box of paper. For example, I made prints that matched as closely as possible using my current batches of Portra II and Fujicolor FA-C. I found that FA-C needed 71% of the exposure of Portra II and a -7M, -9Y filter change, so I wrote that on the Fuji box. Thus, if I try a print on one paper and don't like it, I can go to the other with almost no waste.

You can also record relative filter packs for films. It may not be accurate without carefully matched negatives or slides, but you'll have some sense of what exposure a "normal" print from each roll of film requires. Even if your relative film data are no closer than a half stop and 10 CC, it's still a lot better than printing blind. It's also worth noting the relative packs for images shot under incandescent light, fluorescent light, and sunlight. By keeping track of films' relative filter packs, you'll save yourself a lot of frustration, wasted time, and paper. Tape a little card

(19 Color Prints 1/18/99

Sunlit Clouds at Sunset-Cabo Pulmo (071191-7E#25) 8x10 I f/16L 153-120-50 15sec 1/18 FC-FG
Dusk over Cabo Pulmo Scrub (" -7F#33) " " f/11L 145-110-50 24w/m " FP-FM
Faint Pink Dusk over C.Pulmo Surf (" -7G#37) " " f/16L 135-109-50 14sec " Ultra II
Pink Cumulus over Blue Sea (" -8A#4) " " " 132-109-50 17sec " "
" Stratus Cirrus over Blue Sea (" -8B) " " " 137-111-50 " " "

COLOR PRINTING INFORMATION -- ORDER OF PRINTING 142

TITLE	DATECODE	SIZE	IL	f/#	Y-M-C	EXP.	DATE	PAPER
Sunlit Clouds at Sunset- Cabo Pulmo	(071191-7E#25)	8x10	I	f/16L	153-120-50	15	1/18/99	FC-FG
Dusk over Cabo Pulmo Scrub	(071191-7F#33)	"	"	f/11L	145-110-50	24 w/m	"	FP-FM
Faint Pink Dusk over C.Pulmo Surf	(071191-7G#37)	"	"	f/16L	135-109-50	14	"	Ultra II
Pink Cumulus over Blue Sea	(071191-8A#4)	"	"	"	132-109-50	17	"	"
Pink Stratus & Cirrus over Blue Sea	(071191-8B)	"	"	"	137-111-50	"	"	"

COLOR PRINTING INFORMATION -- Ordered by Negative 1/28/2000

TITLE		DATECODE	SIZE	IL	f/#	FILTER (myc)	EXP.	DATE
Sand and Stone "Fall" on Beach	91	(071191-7B#11)	8x10	I	f/16L	148-117-50	15	1/18/99
Vertical Grouping of Stones	91	(071191-7B)	8x10	I	f/16L	150-119-50	15	1/18/99
Sunlit Clouds at Sunset- Cabo Pulmo	91	(071191-7E#25)	8x10	I	f/16L	153-120-50	15	1/18/99
Dusk over Cabo Pulmo Scrub	91	(071191-7F#33)	8x10	I	f/11L	145-110-50	24 w/m	1/18/99
Faint Pink Dusk over C.Pulmo Surf	91	(071191-7G#37)	8x10	I	f/16L	135-109-50	14	1/18/99

Figure 9–1 Some sample pages from my printing logs. The top illustration shows some of my handwritten notes, made while printing. The middle illustration shows what they look like after I type them up and print them out. The bottom illustration shows the same information sorted by negative instead of date of printing.

with the starter packs on the wall near your enlarger.

I save darkroom time with an old trick for previewing wet color prints. If you take a wet chromogenic print, wipe the excess water off the surface, and immerse it in a tray of Rapid Fixer or Color Fixer concentrate, the bluish veil over the image immediately clears and the print looks exactly as it will after it is dry (this trick does not work with Ilfochrome).

I rinse a print in water for about 15 seconds to clear out the orange bleach stain before the print goes into the fixer concentrate. I pull the print from the fixer, ready for inspection. If the print is good, I fully wash it. If it's bad, I can make another print a minute or so after the first print exited the processor.

I've been employing this trick for over 25 years, and I can assure you that it will not damage the print nor shorten its life, provided you give it a proper wash after the fixer bath. You haven't lived until you've enjoyed this kind of quick turn-around when making test prints.

Finally, I keep a printing log of every print I make. I write down the date of printing, print title, negative number, print size, paper used, =filter pack and exposure data, whether I had used a contrast-control mask, and any dodging or burning-in I did (Figure 9–1). This helps me home in on a correct filter pack for other negatives on that roll and on others. It beats starting cold!

Periodically, I type up my logs, which go back more than 20 years. About 12 years ago, I started typing the data into a simple Lotus 1-2-3 spreadsheet, with entry macros to handle repetitive formatting. The spreadsheet allows me to reorganize these order-of-printing logs. For instance, I've also sorted them by negative number instead of printing date. When I want to find out whether I have printed a particular negative and when (not to mention how), I can easily find it on my sorted-by-negative list.

Last year, I took this one step further and scanned my old hand-typed log pages. Through the miracle of optical character recognition and some heavy editing (my typing has never been very good), I've incorporated almost 30 years of printing into one database.

All these little tricks keep my printing bill down. My first prints may still be guesses, but they're educated guesses. If you start keeping track of these kinds of data and make good proof sheets, you'll find yourself spending a lot less time in the darkroom (or being a lot closer to caught up than I am).

Keep Those Negatives Popped

Film popping is a persistent source of trouble for those of us who don't religiously use glass negative carriers (yes, I admit it). As your film basks in the toasty glow illuminating the negative stage, it expands. As it expands it flexes, buckles, and shifts position. If you focus your image when the film is cold, it will be out of focus when the film warms up. If you focus when the film is warm, it may be out of focus after the film cools down during the time between when you focused the image and when you began exposing print paper. Obtaining precisely reproducible print sharpness without a glass carrier is impossible for many people.

Although I usually work with a glassless carrier, I manage to get precise focus with an exceptionally simple trick I hit upon over 20 years ago. I don't adjust my focus until I've given the film plenty of time to warm up and stabilize, and I don't turn off the enlarger until after I've made my print exposure. If you start doing the same thing, I guarantee you far less wasted paper due to unsharp prints.

To accomplish this, you will need an under-the-lens filter holder and a sheet of cardboard. Cut out a piece of cardboard that will fit

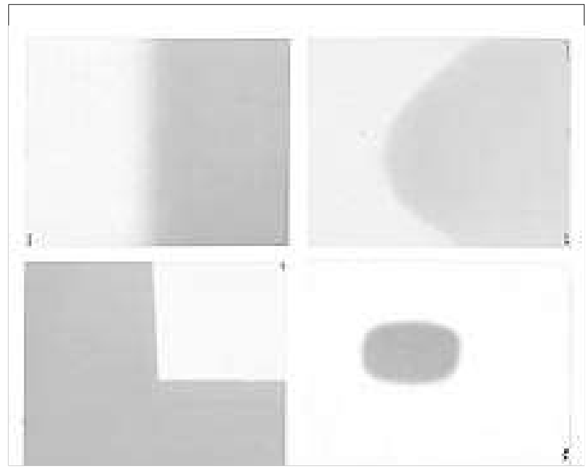


Figure 9–2 A sampling of my litho-film dodge-and-burn masks. The linears and arcs (top row) are the ones I use most frequently, in various densities and shapes. The irregulars (bottom row) come in handy in special situations.

into the filter holder. The next time you print, don't turn off the enlarger lamp after you've got the focus finally set. By doing this, you are only giving the film a chance to cool down and move out of position. Instead, put the cardboard dark slide into the filter holder to block off the light. Then you can safely load the paper into your easel with the enlarger lamp on. It won't take more than a few seconds to turn off the enlarger light, pull the dark slide, and start the exposure; there is not enough time for the film to cool off and shift focus.

I've been doing this for every single exposure for over two decades. It's the next best thing to printing with a glass carrier (which is still best at holding film flat, fixed, and in focus), and there are fewer hassles with dust and cleaning.

Dodging and Burning-in Using Litho Film Masks

The difference between a mediocre and a great photograph often rests on local adjustments to the brightness or darkness of the photographic image. I do some dodging or burning-in on almost every B&W print I make as well as on a high percentage of my color ones.

Figure 9–3 The original of this photograph of the necropolis overlooking Glasgow is a color print. This illustration shows how it looks without any local exposure control. The brightness of the sky pulls the eye out of the scene, and it doesn't look as dark and "ominous" as I remember.

Figure 9–4 The only difference between this print and the one on the left is that the sky was burned-in using two of my litho-film masks. It restores the image to the way I remember it and turns an unsuccessful photograph into something for my portfolio.

Unfortunately, there are times when these corrections are difficult or impossible to make. An extremely complex image may require so many dodges and burns that it becomes difficult for me to apply them all accurately within the limited exposure time of the print. When I need to make several identical images, extensive dodging or burning-in is an obstacle to reproducibility.

Any process that involves making more than one exposure makes manual dodging and burning-in impossible, because one cannot perfectly reproduce one's dodges and burns. Examples of such situations would be making different negatives for alternative processes such as silkscreen or gum printing, and doing tricolor printing on conventional photographic materials. My personal favorite, the dye transfer process, requires making red, green, and blue separations from the original color negative or slide.

If one tries to do manual dodging and burning-in with processes like these, one invariably ends up with color fringes in the final print, because it's impossible to perfectly duplicate a particular dodge or burn pattern in each exposure. I've overcome this problem by developing a technique for "automating" much of my dodging and burning-in. It simplifies my production printing and allows me to make local corrections in my dye transfer prints that would be impossible otherwise.

I've created a library of dodging masks on 4" x 5" sheet film. Most of my printing is done from 6 x 7 cm film; for that reason, I use 4 x 5 film, because it allows me move the mask around relative to the negative I'm printing to position the dodge and burn areas exactly where I want them. Two such masks are shown in Figure 9–2.

The masks go directly on top of the film carrier, not sandwiched with the negative or slide you're trying to print. Separating them from the negative insures that dust and scratches on the masks won't show up in the print. Working on a light table after putting the negative in the carrier, I slide the masks around on top of the carrier until they're in the right positions and tape them down.

I printed this book's cover photograph (showing the necropolis above Glasgow, Scotland) using this masking technique. The two B&W reproductions in Figures 9–3 and 9–4 illustrate the use of these masks. The print in Figure 9–3 received no dodging or burning-in. For the second print, I used two of my "straight-line" masks to provide a progressive burn-in of the clouds above the city. The improvement in the photograph speaks for itself.

I use Kodalith Ortho Type 3 film to make my masks, but any fine-grained B&W sheet film will do. Kodalith has the advantages of being relatively slow (so my exposure times are comfortably long) and not being red-sensitive (so I can work under a safelight). Unfortunately, it may be difficult to find these days, as Kodak has transferred this product to a new subsidiary, Kodak Polychrome. It's also become pretty expensive, with the minimum order being 100 8" x 10" sheets. If your local photographic supply dealer can't get Ortho Type 3 for you, try graphic arts supply dealers in your area.

I lightly fog the film by exposing it under the enlarger, using my hands or a card to block off part of the film. The silhouette of my hands remains clear in the developed film; the remainder of the film develops to a light gray. The density difference between the two portions determines how strongly the mask will work. This depends upon the exposure time and development conditions. I control how sharp the demarcation line is in the mask by holding my hands (or the card) closer or further away from the film.

For each mask pattern, I will usually make a set of masks with different exposures that produce density differences ranging from about 0.05 d.u. (equivalent to about a 10% dodging time) to 0.6 d.u. (equivalent to a 75% dodging time). Since I can sandwich several masks for combined effects, I don't need masks of every possible density difference or degree of sharpness. A box of 100 sheets of film is sufficient to create a library of masks that will work for almost any photograph you're printing. I find that I use straight-line and arc-shaped patterns for 90% of my masking, but I've made a handful of masks with various irregular shapes like squares, ovals, wedges, and right angles that come in handy when I need to modify a small portion of an image.

I develop the film in a tray in Dektol diluted 1:8 with water for a minute or so. The precise developer concentration and development time will vary depending upon how strong a mask I want to make. A standard 1% acetic acid stop bath and two minutes in a tray of fixer complete the processing. I follow this with 5 minutes of washing time in running water and a quick dip in Photo-Flo diluted with distilled water. I use distilled water to make my final wetting bath, because the film then dries free of water spots without me having to squeegee it.

Making Black and White Prints from Color Negatives and Slides

Sometimes a photographic subject shows the promise of being equally interesting as both a B&W print and a color print. The traditional way to deal with this situation is to expose both B&W and color photographs for later printing, but there are two good ways to make B&W prints from color negatives. One is by using Kodak Panalure Select paper, which is a panchromatic B&W resin-coated (RC) paper that develops in any standard B&W paper developer. The second is by using Kodak Ektamax RA paper, a panchromatic RA-4 RC paper that produces a B&W image.

There's also a bad way—printing color negatives onto variable-contrast (VC) paper. I wouldn't even bring this up except that many people seem to think it's a good idea. VC papers supposedly do a better job of printing a color negative than graded papers because VC papers are sensitive to both blue and green light. Unfortunately, VC papers are blind to the cyan-dye image; they render red and yellow as near black

Worse, color negatives are flat by B&W standards, so you'll find yourself printing with a heavy magenta filter pack to get adequate contrast. That means you're throwing away most of the green light. As Figures 9–5 and 9–6 show, VC paper prints color negatives only slightly better than ordinary orthochromatic paper does, and nowhere near acceptably. Compare these figures with the Macbeth chart in Plate 6; all were printed from the same 35mm Fuji Reala negative (a low-contrast, high-saturation film). Both the VC and graded paper prints render reds, yellows, and greens far too dark (notice what happens to

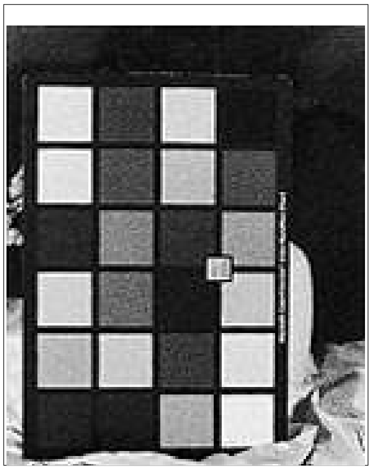


Figure 9–5 All the figures on this page were printed from the same 35mm Fuji Reala negative used to print Plate 6. This print is on grade 4 Kodak Kodabrome II RC paper. The reds are black and the yellows dark gray. The daffodil in the background is almost black.

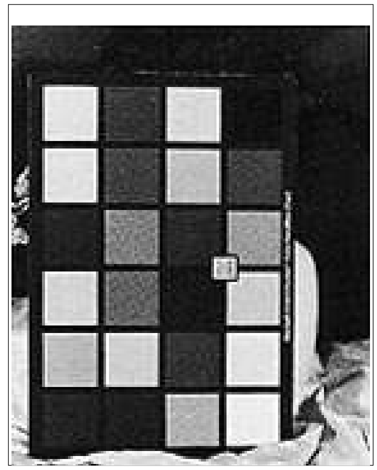


Figure 9–6 This print, printed on Ilford Multigrade IV RC paper, with 150 CC magenta filtration to produce the correct overall contrast, is barely better than Figure 9–5. This shows that variable-contrast papers are only a slight improvement over graded papers.

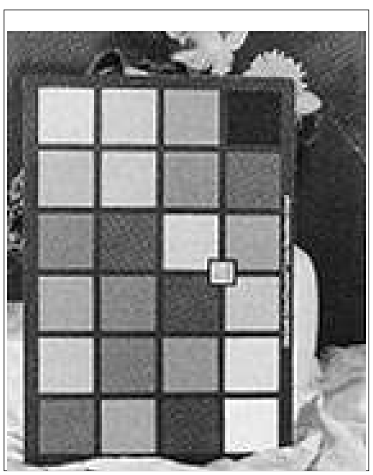


Figure 9–7 The three prints in this row are on different grades of Kodak Panalure RC paper. This is grade L, the softest. This print and Figure 9–9 were printed with no filtration; the reds and magentas are a little dark compared to the other colors.

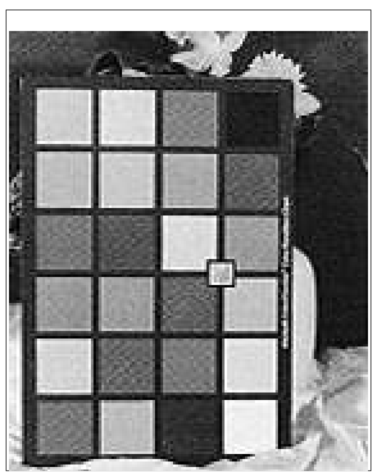


Figure 9–8 This print, on Panalure grade M paper, is a little soft, but it's close to the correct contrast. I made this print with a 35 CC yellow + 45 CC magenta filter pack to correct the tones in the reds. All the colors are a good B&W match in density to the values in Plate 6.

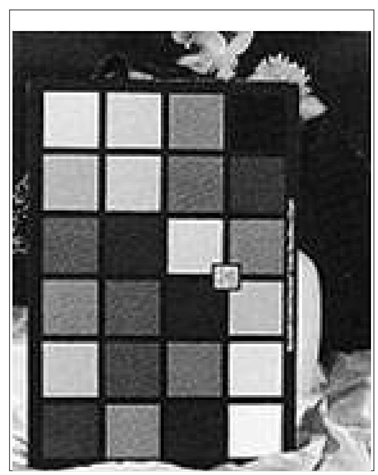


Figure 9–9 This print, on Panalure grade H paper, is much contrastier than Figure 9–8. This would be a good paper for a flat negative. The print is a little too contrasty, although Reala is a low-contrast film. I made this print with no corrective filtration to fix the tones in the reds.

the daffodil) and blues far too light. You can see the impact of these distortions on a pictorial scene in Plate 26 and Figures 9–10 and 9–12. These prints of Lake Shasta and Mt. Lassen were all made from a 120 format Konica Impresa 50 negative (a normal-contrast, normal-saturation film).

Panalure is a slightly warm-tone paper that comes in three widely spaced contrast grades. In terms of midtone contrast, the L, M, and H grades correspond roughly to conventional grades 2, 3.5, and 5 (see Figures 9–7 through 9–9). These papers have unusually long shoulders. The shadows cover a considerable exposure range before they produce a true black, so the total exposure ranges are more like grades 0, 2, and 3.5. Using the same kinds of specialized developers that B&W printers use, you can modify the paper contrasts. Unfortunately, Panalure only comes in F surface and has ugly veiling unless you heat-dry it (see Chapter 11).

You usually have to use some filtration to get accurate color rendition in a panchromatic print. I printed Figure 9–7 and Figure 9–9 with no corrective filtration. As you can see by comparing it with Plate 6, the reds and pinks are too dark relative to the other colors. Figure 9–8 shows the improvement that adding 35 CC yellow and 45 CC red makes.

We can use color filters to adjust the tonal rendition in the print in the same way we'd use them on camera with B&W film. Red filtration creates dramatic clouds; green filtration lightens foliage. I printed Figure 9–11 of Lake Shasta with a 50 CC red filter pack to approximate the tones in Plate 26. A 200 CC red filter pack produced Figure 9–13 and gave much the same effect a red-orange filter would have during exposure of B&W film. The sky and foliage are darkened, the orange rocks are dramatically lightened, and Mt. Lassen stands out clearly against the sky.

Ektamax RA paper has two grades that are barely a half-grade different in contrast. The contrastier M grade comes in both N and F surfaces. Ektamax's notable advantage is that you can make B&W prints from your color or B&W negatives without switching your darkroom over

Figure 9–10 Kodabrome II does a very poor job of printing this medium-format Konica Impresa 50 negative. Compare this to Plate 26. The shoreline is too dark and Mt. Lassen (in the background) isn't even visible.

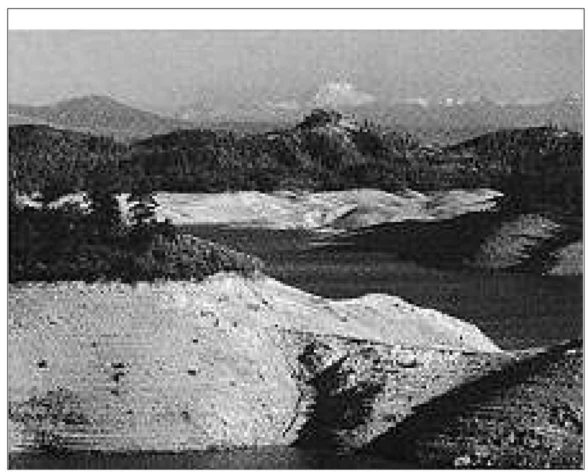


Figure 9–11 This print on Panalure M paper, printed with 50 CC red filtration, closely matches the tones in Plate 26. It's a very good B&W interpretation of the photograph. Mt. Lassen is clearly separated from the blue sky, and the yellow-orange slopes take on their proper tones.

from color to B&W processing. Ektamax produces a dye print, so you can't adjust the image after development with local bleaching, toning, or similar B&W-image-modification techniques. Dye images suffer from photometamerism (see Chapter 1), so the color of Ektamax prints

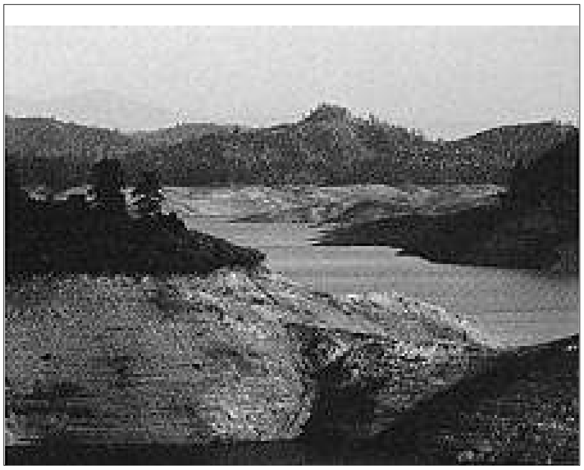


Figure 9–12 This Multigrade IV print is only little better than Figure 9–10. This print, made with 125 CC magenta filtration to correct the contrast, renders the greens somewhat better, but the blues are still too light and the yellows and reds far too dark.

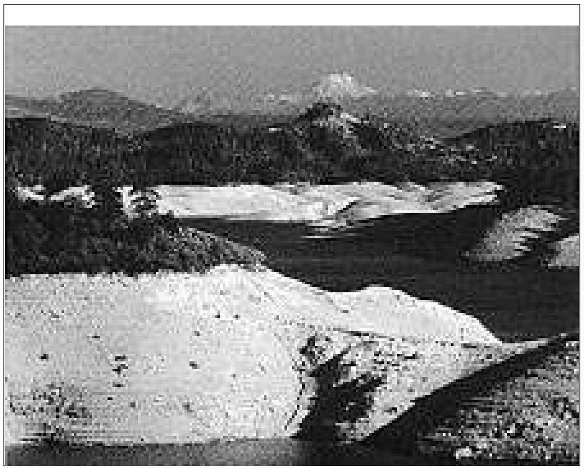


Figure 9–13 Panalure M, printed with a 200 CC red filter pack, closely approximates the effect of photographing this scene with an orange filter. The foliage and the blue sky and water are darkened, making Mt. Lassen stand out clearly against the horizon. The shoreline is rendered nearly white.

looks different under different light sources, varying from only slightly warm under skylight to brown under incandescent lights. Furthermore, Kodak warns that these prints are not as stable as Panalure prints. Kodak says these prints are less stable even than regular color prints and shouldn't be used for anything but temporary work.

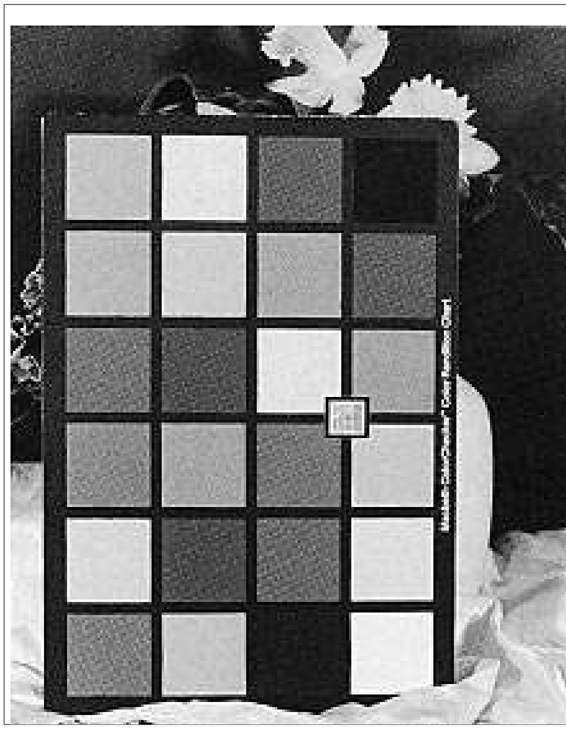


Figure 9–14 This is a Kodak Ektamax print from the same 35mm Fuji Reala negative used to print Plate 6 and Figures 9–5 through 9–9. Ektamax is a variable contrast paper. Reala being a low-contrast film, I got the best print contrast with a 120 CC yellow + 110 CC magenta filter pack. This rendered the reds a little too light relative to the other colors.

Despite these serious limitations, I think Ektamax is worth some attention. Ektamax paper is a panchromatic VC paper. Unlike conventional VC papers that rely on the ratio of blue to green light to control contrast, Ektamax's contrast changes with the ratio of red to cyan light. Adding red filtration increases contrast; removing it lowers contrast. Ektamax does not have a contrast range as wide as conventional VC papers. A 90 CC red filter pack gives me a grade 2 contrast for printing B&W negatives. Using 150 CC red raises the contrast to a maximum grade 3.5 to 4. Using 50 CC red drops the contrast to about grade 0.5. If you reduce the red filtration more than that, the midtones lose their tonal separation because of serious curve splitting.

Ektamax apportions more of its exposure scale to the shadows and less to the midtones

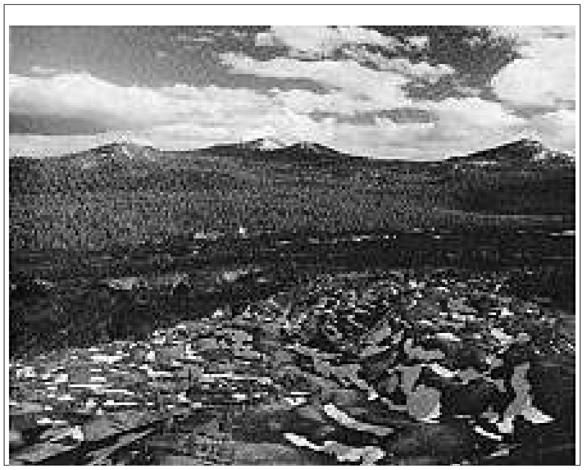


Figure 9–15 This medium-format Vericolor III negative printed adequately on Panalure M with 50 CC of red filtration, but it's not a great print of the Painted Dunes and Fantastic Lava Beds (Plate 27). The clouds are harsh and there is a lack of highlight detail, while the foreground shows poor separation from the lava fields behind it.

Figure 9–16 The same paper and negative as in Figure 9–15 but a much better print. I printed the foreground with 120 CC red filtration to bring out the orange dunes better, and I printed the sky with 50 CC cyan filtration, which let me increase the exposure and bring in the clouds. This local tone correction is only possible with a panchromatic print from a color negative.

than Polymax II paper. Midtones are very contrasty—the same exposure range produces a greater density range than it does in Polymax II. Prints on Ektamax look more brilliant than on most B&W papers of the same overall contrast. That helps provide tonal separation in prints from color negatives, in which different colors may have similar luminances, but it means a sacrifice of highlight and shadow separation. This paper is best suited to subjects whose most important detail falls in the midtones.

For color-negative printing, start with the filter pack you'd use to make a Portra III print. Because Ektamax's contrast is linked to its color balance, you can't fine-tune both contrast and color rendition. The spectral response of the Ektamax paper is excellent, but juggling the contrast and the color response presents problems. For instance, the Macbeth chart photograph from the Reala negative (Figure 9–14) renders reds too light when the contrast is best. The print with the best color rendition was too flat. Panalure printed this negative better.

On the other hand, Ektamax matched the contrast of the Impresa 50 negative of Lake Shasta well. It produced an even better conversion of color to tone than Panalure did. As long as the negative approximates normal contrast, Ektamax provides a more pleasing print than Panalure. When the negative contrast is unusually high or low and the accuracy of the color to tone conversion is paramount, I'd use Panalure.

Because they're panchromatic, Panalure and Ektamax are far more sensitive to safelight fogging than conventional B&W papers. In theory, you can use a #13 (amber) or #8 (dark yellow) safelight for a very short time. In practice, I think you're better off working in the dark, as you would with color paper, because it is *very* easy to fog these papers.

Printing a color negative on panchromatic paper opens up brand new possibilities for image control. With precise dodging and burning-in during printing, we can apply selective filtration to different parts of the photograph. No on-camera filter could do that! I made Plate 27, of the Painted Dunes and Fantastic Lava Beds, from a 120 format Vericolor III negative. Figure 9–15 is an unmanipulated print on Panalure M paper, exposed with 50 CC red filtration. The clouds have gone to dead white, losing most of the detail we see in the color print. The red dunes in the foreground are too dark. They don't separate well enough from the lava beds behind them, and there's not enough contrast between the sunlit and shadowed portions. Fixing these problems would not be easy in ordinary B&W work.

Figure 9–16 shows my corrected version of this print. I printed the sky with a 50 CC cyan filter pack, which lightened up the blues and allowed me to print that part of the picture down and pull in the details in the clouds without the sky going black. For the rest of the picture, I upped the red filtration to 120 CC, which let me lighten the sunlit foreground dunes, the reddest portions of the scene, while leaving the shadows and background unchanged. Burning-in three of the corners evened out the tones. This superior rendition shows the aesthetic potential of making B&W prints from color negatives.

How to Process Black and White Prints in Color Processors

The late (and sorely missed) Bob Mitchell once wrote about the hassle of tearing down his color printing setup whenever he needed to do B&W printing. Like me, he printed both B&W and color. Like me, he used a compact tabletop roller-transport processor for handling his color prints. Unlike me, when he wanted to do B&W printing, he cleaned and dried his machine, moved it off the table, and set up trays for B&W work. When he was ready to switch back, he cleaned and dried the trays, moved his processor back in, and set it up. That kind of busywork inhibited him from printing B&W when he was doing color and vice versa.

Bob didn't realize that any tabletop processor that can handle color prints can also process B&W RC papers. With processors designed for the RA-4 process (which takes less than a minute per process step), machine processing of B&W prints is no slower than tray processing and a lot more convenient. If one is making several identical prints, it's a lot faster.

You don't need a fancy processor with adjustable process times or more than two tanks. I use a Durst/Nutek RCP 20 modified to run at RA-4 speed. I can regear the machine for different process speeds, but it's a major nuisance. When I want to run B&W instead of RA-4 color, I drain the color chemistry and rinse the tanks with a few flushes of clean water. Then I pour in Dektol 1:2, 2% acetic acid stop bath, and hardening rapid fixer at film strength. I'm ready to roll. Reversing the process gets me back to RA-4.

The reason this works is that I can trade off time against developer temperature with no loss of print quality. Most B&W papers do not develop fully in 45 seconds at 68°F but will at 75°F. I haven't found any that won't develop fully at 80°F. I've run both developer-incorporated and conventional papers made by a variety of manufacturers including Kodak, Agfa, Ilford, and Oriental. I've yet to find an RC paper I can't process this way. I have to use trays for fiber-base papers because they're too flimsy and jam up in the rollers.

Newer processors often have only two tanks—one for developer and one for fixer. Don't worry, the paper's RC base and the processor's roller squeegees ensure that almost no developer carries over into the fixer. You can check the pH of your fixer periodically with pH test paper and add a little acetic acid if you find it's rising. I'm guessing you won't ever have to.

Whenever I use a new B&W paper, I calibrate it to my machine. I make two B&W test prints in trays with fresh chemistry. The first is a sheet of paper that is half unexposed and half exposed to enough light to produce a maximum black. The second is a decent-looking print from any negative I have handy.

Next, I run a half-unexposed/half-black test print through my RCP 20. If the whites are as white as the tray-processed print and the blacks are as black, I'm set. If the whites show fog, it means I'm running too hot and I cut back the temperature by several degrees. If the blacks are lighter than the tray print, it means I'm running too cold. Typically, there is a range of 10°F wherein I get the full D-max but no fog. I set my RCP's temperature control for the middle of that range. To fine-tune the process, I machine-process a print of the test negative. If it isn't identical to the tray print, I tweak the temperature up or down a bit until it is. Usually, no tweaking is required.

Although I trust the roller transport to do a good job of developing, I am less confident about the fixing step. Most inexpensive machines don't have pumps in the fixing tank to circulate the chemistry. For RA-4 it's enough to have just the motion of the print through the bleach-fix, but I'm not convinced this is sufficient agitation for B&W fixing. Because the print motion is very uniform, I don't trust spot tests for residual fixer. I put the print into a tray of fixer after it leaves the processor, agitate it for 30 seconds, and then put it into the wash. Okay, so it isn't 100% automatic. It's close enough.

If I'm printing over several days, I pull the racks each evening, rinse them, and float sheets of Saran Wrap on the tanks of chemicals. This excludes the air well enough that the chemicals last 4 or 5 days before the developer loses potency. It's much easier than draining the tanks each night. Black and white developer and fixer are so cheap that I don't care whether it's a bit less economical than draining the machine would be; my paper costs are still over 10 times greater. Now, if I could only figure out how to feed fiber paper through those rollers.

Control Strips

I made my first color prints in 1970 with Unicolor color-negative paper and chemistry, a Unicolor tricolor filter wheel for making color-print exposures, and a Heath-Mitchell Color Canoe. The Color Canoe, invented by Bob Mitchell, was an ingenious and indestructible stainless steel tray curved into a U shape. You'd put print paper and chemicals in the canoe, set the canoe in a tray of warm water (which acted as the temperature control), and rock it back and forth.

Within a few years, I was printing on a Super Chromega Dichroic D enlarger, which served me for 2 decades. I used Kodak's Ektaprint 3 process and Ektacolor RC papers in trays. One year I processed everything from single 8 x 10s to a dozen interleaved 16 x 20s, with one arm in a cast! I used up about one-third as much chemistry per print as with a color drum or canoe. It was fast. At the very least, I'd process the final print for one negative along with the test print for the next. I could interleave up to a dozen 16 x 20 prints when volume production demanded it.

Tray processing required considerable skill. I had to devise ways to warm the solutions and deal with the pitfalls of replenishing during batch processing. I didn't give up tray processing until the early 1980s, when my Ektacolor printing became so infrequent that I couldn't economically use replenishable chemistry. I switched to color-print drums, which were a lot slower but better suited to occasional printing.

With both drums and trays, I got consistent results; Caltech-trained lab skills kept the gremlins at bay—most of the time. Every so often I'd misgauge the state of the soup and blow a batch of prints. Every so often I'd toss out some developer and bleach-fix just in case.

That changed when I started working with RA-4 materials in a tabletop roller-transport processor. RA-4 was such a different beast that I decided I better try dealing with process-control strips. I'd never considered them, in part because I don't own a color densitometer, in part because I didn't know better. With RA-4 they seemed the only way to be sure I wouldn't mistake my errors for a valid test result.

Well, it turns out that RA-4 and R-3/3000 control strips are a snap to use. If you can tell a good print from a bad, you can eyeball a control strip well enough to diagnose and correct most processing problems. Control strips are pieces of photo paper that the manufacturer precisely exposes and stores at 0°F to prevent any changes in the latent image. Modern strips, shown in Plate 28, rely on a few simple gray patches for comparison with the reference strip. The human eye is especially sensitive to differences in grays, which is why you can evaluate control strips by eye. A reflection densitometer is more precise, but if the differences between the gray patches are too small for you to see, you certainly won't be able to see these differences in the prints you make. Besides, you can't print or control what you can't see; so don't worry about it.

Any good printer will benefit from control strips. A box of control strips comes with a preprocessed reference strip. It may also have a sheet of density correction factors for the reference. If the corrections are 0.05 or less, ignore them. Consistency is much more important than absolute accuracy. (I'll cover correction factors later.) The proper method demands a densitometer and process-control plots, but we're going to be highly improper and eyeball them. Trust me, it works.

When you need to check your process, pull a packet of strips from the freezer. There are only five strips to a packet, so it warms up to room temperature in 15 minutes. Process one and compare it to the reference strip the manufacturer includes. One RA-4 control strip costs about as much as 2.5 8 x 10 sheets of paper. If you run one every 10 or 15 prints, you'll increase your printing costs by 15% to 20%, but you'll make it up saving otherwise wasted chemicals or paper. I'm sufficiently confident enough of my seat-of-the-pants replenishment rates that I run about 30 prints between control strips.

RA-4 Strips

What have RA-4 control strips done for me? They told me that, due to an error in the early instruction sheets, I was mixing the developer to the wrong strength. It was a subtle change, but it would have slightly degraded my prints, and I might never have caught it in normal printing.

Later, when I forgot to add the developer starter to a batch of fresh developer, a control strip caught my boo-boo before I wasted time on real prints. I would definitely have seen the change in those prints, but without a control strip, I would not have been able to figure out what was wrong with the chemistry and would have dumped $6 worth of developer. Recently, the strips told me my starter was getting old and weaker and that I needed to add more to the initial mix (and buy a new jug).

Control strips even told me that there was something wrong with Kodak's original Portra paper. Because the strips were fine, Kodak and I knew the image defects weren't due to processing. If you've ever been hit with defective materials, you'll appreciate how much time and effort the control strips saved. Kodak took my results very seriously. Kodak created Portra II paper, in part, to successfully fix the problems I reported. Thus, a few control strips led to a major product revision.

Here's what you do. Process a Kodak RA-4 control strip in new chemistry. To compare it to the reference, cut the strip down the middle so you can lay the two sets of gray patches directly next to each other without any white paper between them. You can see 1 or 2 CC differences that way.

The strip should be nearly a neutral match; ignore differences of less than 5 CC. If you forgot to add starter to the developer or if your starter is getting weak, the patches will be slightly dark and about 15 CC red; that's easy to fix by adding starter. If you see a large color or contrast shift from the reference, you have bad developer. You either contaminated it (a few drops of bleach-fix will ruin it) or mixed it incorrectly. Putting the wrong amount of water in the developer mix has little effect on RA-4 unless you're way off.

If the patches are a little darker than the reference, you're overdeveloping—too hot or for too long. Lighter means not enough development. Extreme underdevelopment makes the black patch look blue (minus yellow). Too little Part A in the developer makes the strip both darker and more contrasty, but it stays neutral. If you're positive that your time and temperature are right, you can add Part A to correct this, but that's a last resort before dumping the chemistry. Balance your process at the beginning so you only have to monitor for changes from that pristine state.

If you're running a replenished system, underreplenishment looks a lot like too-cool developer, but with more loss of yellow. Check your time and temperature. If it's correct, dump in some extra replenisher. It's harder to overreplenish RA-4 than to underreplenish it, although I've done it; patches then go dark and warm.

Never run EP-2 paper in RA-4; it'll ruin the developer and the results will be light and very blue.

Increased stain in the whites means either exhausted bleach-fix or seriously aged developer (especially if the gray patches look a little dark). Replace 25% of the bleach-fix with fresh solution. If that doesn't work, replace 10% of your developer with fresh replenisher. If neither of these steps improves matters, dump your chemistry.

RA-4 chemicals are hardy. I can make RA-4 prints for a week and then not make any for a month. At first, I tossed my RA-4 chemistry between runs. Control strips showed me that a batch of used developer would hold up for months in a tightly sealed jug. I didn't expect that, but the control strips say all is well with a little extra replenisher sometimes thrown in at the start of a new printing stretch, so I save money on chemicals.

R-3 Strips

Kodak R-3 (or Agfa AP-63) is easy to monitor because the B&W and color development steps are separate, and every step after the first B&W development should go to completion. I prefer Agfa's AP-63 strips, which use four gray patches and three primary color patches, to Kodak's, which use a full gray scale step tablet. It's easier to visually interpret Agfa's strips.

If you forget the color-developer starter, the patches will be too magenta and the blacks will be too dark. If the blacks are going bluish (minus yellow), the color developer isn't doing its job. Check the time, temperature, and replenishment (TT&R). It's much harder to overdevelop or replenish this step than to underdo it.

All other readily correctable errors produce neutral control strips; if you see a major color or contrast shift, you probably have bad chemistry. If the patches look too light, you're overdeveloping in the first developer. If they're too dark, you're underdeveloping. If you see too much density in the whites, it's usually due to too little bleach-fixing. Check your TT&Rs. That's how easy it is to use control strips!

To use correction sheets, remember that 0.01 density units (d.u.) of correction equals 1 CC of color shift and that the corrections are measured through additive filters, which are the complements of subtractive dyes and filter packs. For example, if the correction sheet says the green correction is +0.05, it means that the control strip should have 5 CC more magenta (the complement of green) than the reference strip. If you're good with numbers and have good eyes, you can take all this into account. For example, suppose a data sheet gives corrections of red +0.02, green +0.05, and blue +0.08. Translation: the control strip patch should look 2 CC darker, 3 CC more magenta, and 6 CC more yellow than the reference patch. You can use color-print viewing filters to help match a control strip to a reference. For most people, an easier approach is to use your first good control strip as the new reference for future tests and not worry about the correction sheet.

Some people have an aversion to paying for manufacturers' control strips and prefer to make their own calibration prints. Personally, I don't think there's enough savings to justify doing this. Remember, you still have to pay for the photo paper. I have better things to do, such as trying (futilely) to get caught up on my printing. I also believe you will have trouble coming up with a test image that will let you *objectively* judge the process variations as well as the simple gray patches of a real control strip.

For those of you who are insistent about making your own controls, here are some pointers. It's not enough to simply reprint a standard negative each time you want to check your process. Your paper batch will have changed, and your enlarger bulb will have aged, for a start. You have to expose many control prints at the same time and on the same batch of paper, using identical exposures. Freeze all the exposed sheets of paper that you aren't going to develop immediately. Keeping the paper at 0°F almost halts the changes in the latent image characteristics. I'll stick with prepackaged strips.

Room Temperature RA-4 and R-3000

As I said earlier, I processed chromogenic prints in trays for half of my color-printing life. It was tough, and I'm glad that part of my life is past. Today, it's possible to process both color-negative (RA-4) and color-slide (R-3000) prints in trays, at room temperature and without replenishment! It's as easy as B&W print processing, and it's economical. Two chemical kits from Tetenal, *Mono RA-4 AT* and *3-Step* (for R-3000 papers) allow RA-4 processing at 60˚F to 77˚F and R-3000 processing at 64˚F to 82˚F.

The Tetenal kits (distributed by Jobo) come in 1-liter and 2.5-liter sizes. The 2.5-liter kit costs about the same as what Kodak charges for a gallon kit of comparable chemistries, but the Tetenal chemicals process up to 38 prints in a liter of solution. That works out to be twice the price per print as standard replenishable chemistry but only half as much as one-shot processing.

Each chemical comes as a premixed concentrated sludge; in most cases, one dilutes 1 part concentrate with 4 parts water to make a working solution. The bottles must be shaken furiously to mingle the solids with the liquid, and they reseparate instantly, making accurate subdividing nearly impossible. I dilute the concentrates 1:1 with water and store them in larger bottles. I still get the estimated 6-month shelf-life, and the diluted sludges are much more manageable.

One can use the Tetenal chemistry in trays, print drums, or roller-transport machines. I found that the RA-4 AT chemistry was actually a little easier to use in a tray than in my converted RCP-20 processor. My darkroom is normally at 70˚F to 72˚F, and the heat of the pumps and the drive motor gradually raises the solution temperature 10˚F above ambient, which is too high for the RCP's fixed development time. Every half hour I have to pop the lid on the machine and cool the solution with some ice cubes in a bag or stainless steel film tank.

The RA-4 AT chemistry produces control strips that are outside RA-4 process specifications—they're too cyan and too dark—but this produces no visible loss of print quality. I could exactly match a print made with standard "on-spec" RA-4 chemistry by reducing my print exposure by 15% and subtracting 8 CC red from my filter pack. After I ran 80 prints through the chemistry, the filter pack had shifted by barely 2 CC, and the exposure time had gone up by 10%.

Tray processing RA-4 is just as easy as processing B&W RC paper, except that you have to work in nearly total darkness. You'll need a timer whose numbers glow in the dark. I'm used to processing sheet film, so tray work in total darkness doesn't faze me. I mixed up a half liter of solution at room temperature, stuck the probe of my digital thermometer in the corner of the developer tray, and used whatever development time matched the temperature. I processed most prints at 70˚F to 73˚F, with development times from 60 to 85 seconds. Add 20 seconds in the stop and 30 seconds in the bleach-fix, and we're talking roughly 2 minutes from start to wash.

My tests indicate that the recommended tray development times are too short. Underdevelopment causes a loss of both magenta density and overall density. For best results, use a development time 25% longer than the data sheet suggests (e.g., at 68˚F, use 90 seconds instead of 75). Overdevelopment produces a darker print but doesn't produce any significant color shift. I'd give the temperature tolerance as -0˚F, +2˚F. Letting the temperature float causes no problems; there was almost no difference between prints I made at 67˚F and 76˚F with appropriate time changes.

If you want to use the RA-4 AT chemistry in a print drum, here are two tips to maximize consistency:

1. Don't presoak the paper. A typical 8 x 10 drum retains about 20% of the presoak water, which dilutes your developer. Reusing diluted developer can produce nonidentical prints.

2. Use fresh developer for each print. Set aside the used soup until you've used the entire amount you mixed up. You can reuse the saved developer at least once (maybe twice). You'll get a change in print exposure when you go from fresh chemistry to recycled, but that's a lot better than having it constantly drift because you mix used solution with unused.

Like RA-4 AT, 3-Step is suitable for transport, tray, or drum processing. I use five process steps for trays. At 70°F, the steps are:

1. 1:55 minute development
2. 20-second water wash
3. 3:40 minute color development
4. 20-second 1% acid stop bath
5. 3:00 minute bleach-fix

The total process time is around 9 minutes. That's comparable to R-3000 processing at 95°F or Ilfochrome P-30 at room temperature. Step 4 isn't in the Tetenal recommendations; I added it to keep the bleach-fix at the proper pH.

As with RA-4 AT, you can let the solution temperature float. 3-Step prints processed for appropriate times at 70°F and 75°F were identical in color balance and almost identical in density. Avoid underdevelopment in the first developer (the other steps go to completion). Prints will be dark and noticeably magenta. Tetenal's recommended process times work fine, and 20% overdevelopment produced prints minutely lighter with no shift in color balance.

Control strips showed that this process also does not match official aim points. It's slightly too light and 5 CC too magenta compared to standard R-3/R-3000, but whites are pure and the D-max is just fine. I can adjust print exposure to produce excellent results almost indistinguishable from on-spec R-3000 prints. Over the course of a test run, the control strips ran progressively darker and more magenta, but the whites stayed white and the blacks stayed black. When the 3-Step chemicals reached their limit (after 30 prints in a liter of solution), it was like falling off the edge of a cliff. Prints suddenly had a significant amount of density in the "whites" and the "blacks" became a lighter blue-cyan.

How to Remove Black Spots from Black and White and Color Prints

Black spots on prints are a major pain! Negative prints have black spots only when the negative's been damaged or there was dust on the film during exposure. Black spots are the norm on slide prints. Folks who aren't the least bit bothered by ordinary print spotting panic when faced with removing black spots from their prints. Physical assault quickly follows. Some people gouge them out with a sharp knife, literally cutting away part of the print surface. Others take the less drastic step of putting a dab of opaque white paint over the offending blotch. Either way, the surface of the print displays an obvious flaw.

I have a better way. A modification of Kodak's R-2 reducer makes an excellent bleach, leaving a white spot one can retouch normally. Make a saturated solution of potassium permanganate (this will keep indefinitely). Mix 1 part of the potassium permanganate solution with 1 part 20% acetic acid. This mixture is your spotting bleach. Diluted, the bleach works on film the same way as Kodak's R-2 reducer, so you don't ever need to mess with sulfuric acid again.

I use a sharpened toothpick to apply the bleach; a brush puts far too big a drop on the print. You can precisely apply a minuscule drop of bleach to the offending spot; it's almost like working with a quill-point pen. The bleach stains the print brown; remove the stain with a 2% to 3% solution of sodium bisulfite. Use a fresh toothpick to apply this solution to the stain. You need to remove the sodium bisulfite from the print, so bleach out all the dark spots before doing any other spotting and rewash and dry the print. Then you can do normal spotting.

With some kinds of chromogenic papers, the chemicals react with residual couplers in the emulsion to produce a pale stain even after clearing with bisulfite. It's still less obvious than a gouge in the emulsion. Unless the small residual stain spot falls in the middle of a very important white area in your print, it'll be unnoticeable. This is not a problem with Ilfochrome or black and white prints, which bleach to pure white.

More About Spotting

Everybody spots differently. It's an art in itself, so if you don't like my method and you're more comfortable with your own, fine! If you're not happy with the quality of your print spotting, consider the following recommendations.

Most teachers instruct beginning print spotters to fill in the white specks and lines by applying minute dots of dye to fill them in (the art term for this technique is "stippling"). Stippling is easy to do and is less prone to error than painting in a fine line. Unfortunately, stippling leaves visible flaws if you're spotting a very fine-grained image. Your results will match the overall tone of the surrounding area, but they won't match its pattern. To produce truly invisible spotting, you must restore the pattern and visual texture of the surrounding region.

Filling in lines with a single smooth stroke is much faster. It takes more practice and control, but what part of fine printmaking doesn't? Use stippling to fill in the minute spots that your painting misses and to recreate the sense of grain and texture of the original image.

Let's face it, spotting is a bore. If you're fanatical about darkroom cleanliness, you can eliminate most spotting. Carefully clean your film before printing and use Edwal No Scratch when the original shows even the slightest evidence of surface scratches or unremovable dust or dirt. It adds a few minutes to your printing time, but think about how many more minutes you'll spend spotting the print if you don't do this.

Effect of Drying on Color and Contrast in Black and White Papers

Krys Krawczyk, the B&W paper expert at the Charles Beseler Company, provided me with some fascinating information about the effect of drying methods on some fiber-based B&W papers. I'm not talking about "dry-down." Black and white printers know all about dry-down. A wet print looks lighter than a dry one. The difference in lightness depends on the print paper. Some papers show almost no dry-down; others get as much a 0.15 d.u. darker when they're dried. Krys discovered something else—the method of drying can alter the appearance of the dry print.

In the days of fiber-and-nothing-but-fiber papers, just about everyone who had to turn out numbers of prints used a heated print dryer with a chromed-steel plate or rotating drum and a canvas belt stretched tightly over the chrome. The print was sandwiched between the canvas and the chrome. If you wanted a mirror-glossy "ferrotyped F" finish, you put the print emulsion down on the hot chrome. If you wanted an "air-dried F" surface, you laid the paper down emulsion up. Then you baked it until it was dry, at temperatures near the boiling point of water.

Black and white printing has changed enough that I feel obligated to write a description of what used to be a basic part of printmaking. Now, few fine printers heat-dry their fiber prints; room temperature drying racks are the norm. "So what?" you say, "Is this another expostulation by some old-timer who thinks pyro-darkened fingernails and the pervasive odor of thiosulfate are nostalgic?" No, I'm telling you this because of complaints Krys got from long-time Agfa customers who said that Agfa Portriga Rapid had gotten lower in contrast, had a less glossy "air-dried F" finish, and was colder in tone. Naturally, these folks assumed that Agfa had changed the formulation of the paper.

What Krys discovered was that the printers' drying methods had changed. Heat-dried Portriga Rapid looked as warm, contrasty, and glossy as it always had. But air-dried Portriga Rapid had a more matte luster (which reduced apparent contrast) and a colder tone. How much colder? About the difference between Portriga Rapid developed in Agfa Neutol warm-tone developer and developed in Agetol or Kodak Dektol.

The changes are reversible. Rewet a heat-dried Portriga print, air-dry it, and it becomes cold and matte. Rewet an air-dried print, heat-dry it, and it looks just like Portriga always did. The samples Krys showed me displayed striking visual differences.

Not every paper responds to heat this way. For instance, heat drying does not change surface luster or print color of Agfa Multicontrast Classic paper. It's an experiment worth trying with your favorite fiber-base paper.

"Gotchas"

A *gotcha* is a darkroom problem that lies in wait for the unwary. It doesn't affect you until you do (or fail to do) something that triggers it. And then... "Gotcha!" All of a sudden your prints aren't coming out right. When that happens, it's time to ferret out the source of the trouble.

There is an unending list of possible gotchas. What follows are few of the worst ones that have bitten me over the years.

Poor Reversal Print Washing

When you make a print from a slide on one of the chromogenic papers (R-3 or R-3000 process), you subject the paper to two developments steps. The first developer produces a conventional negative image made of silver. The second developer produces a color dye image from the unexposed parts of the emulsion that weren't developed out as a negative image by the first developer. That's the reversal step, and that's how you end up with a positive dye image in the final print. The remaining steps bleach out all the silver created by the first two development steps, so the negative silver image goes away. What came up black in the first developer becomes white in the final print; what didn't develop at all in the first developer becomes black in the final print.

Between those two development steps is a wash step. The reason for this is that if you carry first developer over into the color developer it will start competing with the color developer. The unexposed parts of the print, which need to develop fully in the color developer, will be partially developed by the carried-over first developer. Since that developer produces only a silver image that is bleached out later, it will contribute nothing to the blacks in the final print.

If the wash between the two developers is not thorough, enough of the first developer will be carried over to prevent you from getting true blacks in your final print. In my experience, many of the manufacturers' recommended washed times are just barely adequate. If your wash temperature is a little lower than theirs, or if your agitation isn't as good as theirs, you can have developer carryover.

It's hard to see this in a print all by itself. The best way to find out if you need to increase your wash time is to make two identically-exposed prints. Process the first one in your normal fashion. For the second print, double the wash time (and number of water changes if you're using a color-print drum) between the first and color developers. Compare the two prints. If the second print has a richer blacks than the first print, then you need to be using a longer-than-standard wash time. Try a wash time 50% longer than standard and see if that does the trick. If not, stay with the doubled washed time.

Selenium Toning Eccentricities

I always lightly selenium tone my B&W prints. Not only does this produce a richer looking print, as I describe in Chapter 4, it's a must for RC prints if one wants good permanence (see Chapter 12). Some folks seem to have no trouble with selenium toning, but I've always found it to be a very touchy process. From one printing session to the next it seems that the concentration of toner and the toning time I need to get the same final results vary wildly. The capacity of the toner is also something that I can't predict.

For someone like me, who's used to being able to control a darkroom process precisely, it's very irritating. It's also occasionally expensive, when I overtone a print or get a toning capacity of about 5 prints per liter of toner instead of 30. Over the years I've learned some of the variables that affect selenium toning (once again I indebted to Maxim Muir for his advice).

Selenium toning seems to be quite sensitive to both temperature and the residual amount of fixer in the print. At temperatures below about 70°F, selenium toning slows down markedly. At 60°F to 65°F it just about comes to a dead stop. I check the temperature of my selenium bath before toning prints and make sure it's somewhere between 70°F and 75°F. This goes a long way toward giving me reproducible toning times.

The amount of residual fixer in the print also seems to have a great effect. It doesn't take very much print washing, even with fiber-based papers, to remove enough fixer to prevent staining in the toning bath. But, even modest amounts of fixer will slow down the toning process and rapidly deplete the toning bath. With fiber-based papers, I now wash the print for about twice as long as I know I can get away with (in terms of staining problems). RC papers get the manufacturers' full recommended wash times (happily, only a few minutes) before going into the toning bath.

If you're new to selenium toning, be aware that selenium toning continues for about 15 seconds after you remove the print from the toning bath and put it into the wash bath. You must learn to pull the print from the toner just before it looks right. If you wait until it looks perfect, you'll end up with a print that's toned more than you want.

Safelight Fogging

In the preceding chapter I talked about intentionally fogging print paper (a technique also known as "flashing") to reduce contrast in prints and extend the range of the highlights. Flashing doesn't produce any density in the pure whites, but it combines with the photographic image exposure to produce additional density in any part of the print that received some image exposure.

Flashing is a modestly useful technique, when it's under your control. It's possible, though, that your darkroom safelight is doing flashing for you without you even knowing it.

Safelight fogging, just like intentional fogging, can occur at a level that is low enough that your whites still come out white at the same time that the highlight tones in the print are being degraded. See Figure 8–1 and Plate 10 for examples of intentional fogging; these could just as easily be examples of safelight fogging!

The print paper is most sensitive to safelight fogging during the time when the printing exposure is occurring. It's less sensitive at other times, but it usually takes more time to handle and process the paper than it does to expose it. Consequently, safelight fogging may be a problem even if you have your darkroom timer set up to turn off your safelight during the print exposure.

A safe safelight may become an unsafe safelight: safelight filters fade, bulb coatings crack, a recently-adopted paper may be more sensitive to safelight fogging than the one you're used to. If you move the safelight to a different position in your darkroom or change the wattage of the bulb, you may create a fogging problem when none existed before. It's prudent to occasionally run a safelight fogging test just to be sure that you don't have any problems

There are two tests to run for safelight fogging. Neither is perfect by itself, but in combination they make me feel pretty secure. The first is to simply make two identical prints, one working with the safelight on and the other working with the safelight off. I'm used to working in total darkness, since most of my work is with color materials, so this presents no difficulties for me. If you're not used to working in a pitch-black darkroom, plan your moves out very carefully before trying this. It's awfully easy to hurt yourself!

Compare the safelight-exposed and no-safelight prints with special attention paid to the delicate highlights. If you can see no difference whatsoever between the two prints, then it's likely that you don't have any safelight problems.

The second test begins with a print exposed normally under usual safelight conditions. Instead of putting that print in the developer, put it on the counter with a quarter placed on top of the print in an area where there are some delicate highlights. Let the paper sit there for several minutes—at least as much time as the print would normally be exposed to safelight during handling and processing. Remove the coin and process the print normally. If you can see a faint shadow of the coin in the highlight areas, then it means that safelight fogging was taking place around the coin. You're probably getting some fogging with your normal printing. Take measures to reduce your safelight exposure!

VC Filters Fade

The variable-contrast filters you use when printing, especially the kind that go between the light source and the negative instead of below the lens, will fade with time. How fast they fade depends upon how much printing you do with each filter and what kind of light source you're printing with. Eventually, though, it is guaranteed that some of those filters will fade!

In my experience, it's the higher-contrast filters that are more likely to fade; I suspect that the magenta dye in them is less light-stable than the yellow dye in the lower-contrast filters. Because of this, the place where you'll discover that you're having filter problems will be with some of your higher-contrast prints. If, for example, you normally print with a grade 3 filter, you may start noticing that your "normal" prints are coming out a little flat. If you don't check for filter fading, you may assume that the characteristics of the film have changed or that you're underdeveloping it.

Another sign of filter fading is that the spacing between the higher contrast grades becomes more uneven. Because you use some filters more often than others, they'll be subject to more fading. If you print grade 3-1/2 frequently but hardly ever use grade 4, grade 3-1/2 prints will starting to look more like grade 3 prints and there will a big jump between those supposed grade 3-1/2 prints and a grade 4 print. In a really extreme case, a high-contrast VC filter can end up printing like a normal filter. You should catch the problem long before that happens!

If you've done the kind of paper and filter calibration that I talked about in Chapter 4, it will be easy for you to identify when filter fading is occurring by repeating those calibration prints. If you don't make a habit of doing paper and filter calibration, the way to find out is to either borrow a friend's filters and see if they print differently or to pull out an old negative and print from it and make a new print from that negative.

Since essentially all my VC printing is done either with filters below the lens or (most often) using the dial-in filtration in my color head, this is a gotcha that has not actually bitten me. I have seen it catch several experienced printers, though, who trusted their no-longer-reliable tools.

What About Dye Transfer?

I'm not going to devote much space to dye transfer printing, even though I am first and foremost a dye transfer printer. In fact, I sell only dye transfer prints. Dye transfer printing is far more complex and involves many more steps than any of the conventional printing processes, color or B&W. The tools and techniques are an entire book in themselves. A condensed course in dye transfer printing would take up 25% of this book. If you would like to learn more about dye transfer, visit my Online Gallery at http://www.plaidworks.com/ctein/ where you'll find a long article I've written describing what's involved when I make dye transfer prints.

Furthermore, the future availability of dye transfer materials is problematic. Dye transfer materials were commercially available for about 60 years, until the mid-1990s. They were made exclusively by Kodak. Several years ago, Kodak abruptly stopped making dye transfer supplies, with no advance warning to printers. A few other printers and I put in the heroic effort required to stockpile supplies for future use. As of this writing, I'd guess that there are maybe a dozen or so of us left in the world actively engaged in dye transfer printing. Most dye transfer printers simply gave up the medium.

Dr. Jay Patterson has started up a company to manufacture and sell dye transfer paper, chemicals, dyes, and matrix film. I applaud Dr. Patterson for this effort! I am hoping for his company's survival, but his materials are not on the market as of this writing. To be added to the mailing list, should Dr. Patterson ever announce products for sale, write to his company.[1] The future of dye transfer is still much in doubt, but we can wish for the best.

1. The Dye Transfer Company, 3935 Westheimer Rd., Suite 306, Houston TX, 77027

CHAPTER 10

USEFUL TOOLS

DENGLAS

Denglas, manufactured by the Denton Vacuum Co. of Cherry Hill, New Jersey, suppresses Newton rings very effectively. Denglas is a special plate glass that has an antireflection coating on it. Framers use it to provide low-glare glazing over framed artwork. Because Denglas prevents most reflection, it largely eliminates Newton rings, which are caused by multiple reflections.

Replace the ordinary glass in your contact frame or glass-negative carrier with Denglas. You'll see an immediate improvement. Denglas is expensive, and you may have to sort through several sheets of it to find pieces that are truly flawless, which is what you'll need for your frame and contact carrier. But it's a one-time purchase, so go for it! You should be able to order it from any large framing store.

EDWAL NO SCRATCH

This is one of those wonderful darkroom aids that half of you have known about forever and the other half have never heard of. Edwal No Scratch is a transparent oil that has an index of refraction close to that of photographic film base and emulsion. It's the best scratch and spot killer ever invented! If you paint it on both sides of your film after you've cleaned it and put it in the negative carrier, your prints will come out nearly spot-free. At the very least, the amount of spotting you will need to do will drop by an order of magnitude.

No Scratch suppresses dust specs because most dust is really small bits of transparent matter. The dust motes look black because they refract the light away from the lens; if you immerse them in a liquid of similar refractive index (e.g., No Scratch) they just about disappear. It eliminates scratches by filling them in.

Yes, it is less convenient to make prints using No Scratch than it is to make them from "dry" film. You have to paint a thin layer of the goop onto the film before you print it, and then you have to clean it off both the film and the negative carrier after you're done. (PEC-12 is great for cleaning off No Scratch.) The way to discipline yourself into using No Scratch is to think about how long it will take you to spot that print if you don't use it! It's quite a bit longer than it will take to apply the magic oil and clean it off later. Trust me on that. No darkroom should be without Edwal No Scratch.

Jobo Processor Clean II

Jobo Processor Clean II[1] is designed specifically for cleaning up color processors, but it works just as well as a tray cleaner. Processor Clean II is very easy to use. All you do is mix it up with hot water, pour it into the tank or tray, and turn on the circulating pumps for about 15 minutes (if the processor has circulating pumps). Let the solution sit overnight and drain it. That's it! A few rinses of clean water and your tanks are spotless and ready for use. Tar and chemical deposits are gone.

According to the package, Jobo Processor Clean II works with any of the Jobo, Fujimoto, or Nova processors. It's especially useful for Nova slot processors, whose thin vertical tanks are nearly impossible to clean with a brush. I have successfully used it in the tanks of my Durst RCP 20 processor, and it should work fine with the Durst Printo processor. I do not know whether it is safe for composite-rubber rollers, and Jobo hasn't tested it on them, so I wouldn't use it on the roller racks themselves. Use Photofinish for cleaning the rollers.

Microfibre Lens Cloth

An "exciting lens-cleaning cloth" sounds like an oxymoron, but that is what microfibre cloth is. There are several brands on the market under a variety of names such as Mikros and Luminex. This cloth is a novel polyester fabric that is a tight weave of thread containing hundreds of extremely fine, rayonlike fibers only a few microns across. The result is a fabric that is a dust and oil sponge that removes fingerprints and smudges from lenses with astonishing ease.

Microfibre cloth is safe for coated and uncoated lens elements. It doesn't contain any cleaning agents or silicone compounds, so it will not damage antireflection coatings. You can wash it to restore it to pristine condition after it becomes dirty. I use it to wipe dust and dirt from my enlarging lenses and contact-printing frames. It will do a fine job on the glass in negative carriers, too.

I'm amazed at how well this cloth works. It doesn't feel as if it has the "body" to absorb oil and grease the way it does. One cloth takes up almost no room in my camera bag or darkroom. At a street price of under $10 apiece, I think it's worth having several so they're available when needed.

PEC-12 and PEC Pads

PEC stands for Photographic Emulsion Cleaner, but you'll use it on just about everything[2]. PEC-

1. Jobo, P.O. Box 3721, Ann Arbor, MI 48106; phone: 1-313-995-4192.

2. Photographic Solutions, Inc., 3907 Granston Way, Buzzards Bay, MA 02532; phone:1-800-637-3212.

12 is a waterless blend of hydrocarbon solvents that is safe for most modern print and film emulsions, both silver-based and color (it will dissolve unhardened gelatin and albumin emulsions). PEC-12 removes the most amazing assortment of grime from films and prints. Just about any stain that isn't water soluble comes off in PEC-12—oil, adhesive tape goo, ballpoint and marker inks, fingerprints, grease pencil, and mildew. I also use it to clean the glass in my carriers, contact-printing frames, and the reflectors in my quartz-halogen enlarger bulbs before I install them. Don't use it on compound lenses—it might dissolve the optical cement!

PEC-12 contains no ozone-attacking halogens. As organic solvents go, it is pretty innocuous. It's flammable, and you certainly shouldn't ingest it, but its vapor toxicity is at the low end of the scale for solvents. PEC-12 is also fully archival. Careful tests by outside institutions have confirmed that if PEC-12 doesn't cause immediate damage (e.g., dissolving albumen emulsions), it won't do any damage later. I consider that extremely important—I've seen too much ruined film in my short life. There are several look-alike products, such as QED-120. These products may be effective cleaners, but to my knowledge, none have been properly tested for archival qualities. Some contain chemicals, such as peroxides, that are definitely not good for films and prints.

PEC-12 stands out as the single most useful cleaning solvent for film and darkroom use. I consider it indispensable. If your dealer doesn't stock PEC-12, Photographic Solutions can tell you the dealer nearest you who does. They will also send you a free sample packet of PEC-12 and Photofinish and complete literature on the products if you send them a request along with 75 cents worth of loose stamps.

PEC Pads are the ideal accompaniment to PEC-12. They are lintless paper wipes of very low abrasiveness. They're perfect for cleaning film and lens surfaces. I use them and PEC-12 on every single negative I print. The small cost (pennies, literally) is more than compensated for by the reduced amount of print spotting. Most dealers who carry PEC-12 carry PEC Pads, along with cleaning kits that include a bottle of PEC-12 and a package of PEC Pads.

Photofinish

Photofinish, also made by Photographic Solutions, is a general-purpose darkroom cleaner. It's neutral-pH, noncaustic, water soluble, and biodegradable. It's good for everything from cleaning your hands after a printing session to wiping down countertops to cleaning developer tar from your color-print processor. It cleans well enough that I can use it to remove silver and developer stains from my trays. What PEC-12 can't clean, Photofinish will.

Developer tar is tough stuff to remove. Isopropyl alcohol takes it off with hard scrubbing, but it's not very water soluble, which makes rinsing residues from the machine difficult. Also, I don't enjoy inhaling clouds of the vapor. Lysol Toilet Bowl Cleaner dissolves tar and developer stains, and Kodak has even recommended it in their literature about the RA-4 process. Not all processor manufacturers agree, and they should know! Nutek, which marketed the very popular RCP and ACP series of print processors, warned me against using this extremely caustic liquid on their equipment; continued use of Lysol caused the rubber rollers in their machines to crack. Needless to say, mistreatment isn't covered by any manufacturer's warranty.

Photofinish is a completely harmless and very effective alternative. Photofinish removes tar, developer, fixer, and silver stains from equipment with light rubbing. Residues flush away readily with cold water, leaving the equipment ready for immediate use. Photofinish is chemically innocuous enough that you don't have to worry about trace contamination of your solutions, as you do with Lysol and other rack cleaners.

Photofinish is nonabrasive, so it is safe for ferrotype plates. In fact, it is mild enough that I have used it successfully on Plexiglas, although Photographic Solutions doesn't recommend doing this. Photographic Solutions does approve it for stainless steel, brass, porcelain, plastic, and Formica. I'll add aluminum, fiberglass, glass, and painted surfaces to that list. No doubt there is something I shouldn't use it on, but I haven't found it yet.

Sistan

Agfa Sistan helps protect silver images against oxidation. Sistan is not a toner; it's a potassium thiocyanate solution. If oxidized silver compounds form, potassium thiocyanate reacts with them to form silver thiocyanate, which precipitates back onto the silver particle being attacked. This compound is transparent and resists oxidation. Sistan not only prevents silver compounds from migrating through the print but uses them to build up a protective barrier at the point of weakness.

Sistan is a good accompaniment to regular toning. I still use a dilute solution of selenium toner to tone all my black and white (B&W) prints. I like the improvement in tonal quality and maximum black. After toning the prints, I give them a final bath in Sistan. I figure that if selenium toning doesn't protect the silver image by itself, Sistan should repair any breach in the supposedly impenetrable barrier of silver selenide around each silver grain. This definitely falls under the heading of "it can't hurt, and it will probably help."

You can use Sistan immediately after the final wash before you dry the print, or at a later time. It's never too late to treat a print with Sistan.

Sistan is quite easy to use. Mix up a working bath from the concentrate: 25 ml per liter of water for treating fiber-based prints and 50 ml per liter for RC prints. A liter of working solution will treat about 40 prints. I mix up just as much as I need for one session and toss it after use.

Bathe the print in the working solution for 1 minute with occasional agitation. Pull the print from the bath, let it drain, and lay it face up on a hard, flat surface. Remove all the excess liquid from the surface of the print with wipes, a chamois, or (my preference) a rubber print roller. Pools of Sistan left on the print can cause damage after the print dries. Dry the wiped print as you would any other print. You're done!

Sistan resides in the emulsion, waiting to do its job in case of chemical attack on the image. If you need to rewash the print at some future date for whatever reason, remember to treat it again with Sistan after you've washed it.

I've determined that both Sistan and selenium toning retard oxidation of B&W resin-coated prints (Chapter 12). Using them together does not work any worse, according to my tests, and may work much better.

Stouffer Step Tablets

My favorite source for good step tablets is Stouffer Industries.[3] They make a wide variety of step tablets, of different sizes, step spacings, and density ranges. They are offered in both calibrated and uncalibrated form. As I explained in Chapter 4, a good step tablet is an invaluable tool for quickly testing and characterizing a new print material or methodology. Stouffer makes this tool both invaluable and inexpensive. You'll find listings and prices for all their products on their Web site.

Tetenal Anti Newton Spray and Film Cleaner Spray

Tetenal Anti Newton Spray and Film Cleaner Spray are both distributed by Jobo[1]. Anti Newton Spray is a wonderful solution to the vexing prob-

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3. Stouffer Industries Inc., 1801 Commerce Drive, South Bend, IN 46628. ph: 219-234-5023; fax: 219-232-7989; URL:http:\\www.stouffer.net

lem of avoiding those pernicious Newton rings when you use a glass film carrier or sandwich pieces of film together. Anti Newton Spray deposits a transparent, slightly pebbly, plastic layer on the film's surface to prevent the film from making intimate contact with another smooth surface, which is what creates Newton rings. I've tried offset powder and cornstarch, and I can't ever manage to get enough to separate the surfaces without making opaque spots. Anti Newton Spray is much easier to use.

In my cool, humid darkroom (a preferred breeding ground for Newton rings) I have to spray both contacting surfaces with Anti Newton Spray. Under most circumstances, spraying one surface should do the trick. The plastic film is tough, which is where Tetenal Film Cleaner comes in. I don't know whether it is safe to leave the Anti Newton Spray layer on a piece of film permanently, so I remove it from original films after I print them. Regular film cleaner does not strip off the layer; both Tetenal Cleaner and PEC-12 will.

Zig-Align Alignment Systems

Zig-Align[4] manufactures a series of kits for checking the alignment of view camera standards, copy cameras and stands, and enlargers. They are fast to use, convenient, and accurate.

The principle behind the Zig-Align kits is simple. Hold a small mirror up to your bathroom mirror and you will see multiple reflections of the mirror. If you were to drill a small hole in the center of the hand mirror and look through it, you'd see a "tunnel" of receding reflected images of the small mirror. If the mirrors were perfectly parallel, each would reflect the other, ad infinitum, producing a straight tunnel of reflections. If the mirrors were slightly out of true, the error would compound with each reflection, and the tunnel would appear to veer sharply off to one side.

It works as simply in practice as in theory. Performing alignments with a Zig-Align is a snap. Zig-Align's key component is a precision-made, round mirror that has a white circle engraved on it and a sighting hole in the precise center of the circle. When you look through the hole at a target mirror, you see a bull's-eye pattern. When the pattern looks perfectly concentric, the mirrors are parallel.

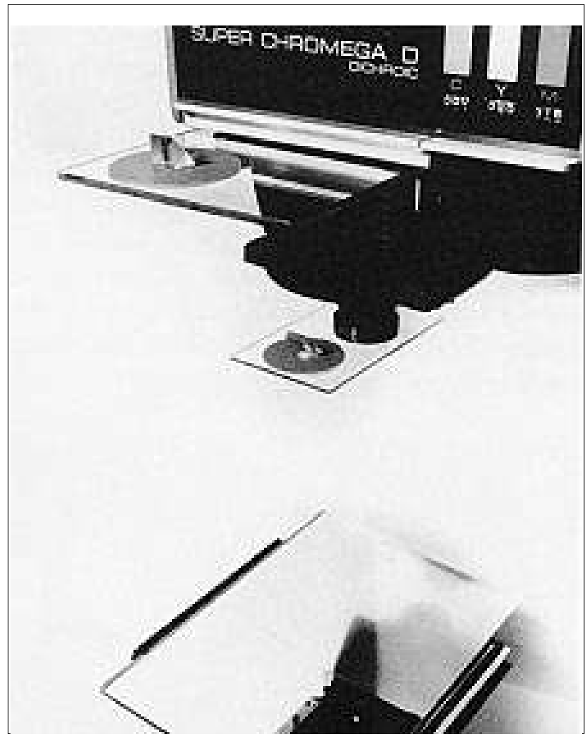

Figure 10–1 Here's the Zig-Align ZE3 kit set up on a Super Chromega D enlarger. The primary mirror sits on the paper easel. The two round target mirrors sit on sheets of plate glass, one inserted in the negative stage and the other screwed onto the lens.

The ZE3 lets me simultaneously check and align the baseboard, lens stage, and negative carrier in my enlarger. Figure 10–1 shows it in use on a Super Chromega D enlarger. The target mirror sits on the paper easel, a sheet of plate glass goes into the negative stage, and another

4. Zig-Align, P.O. Box 765, Menlo Park, CA 94026. ph: 1-415-324-3704.

sheet of glass with a threaded mount attaches to the front of the enlarger lens. A round mirror with a diagonal viewer sits on the plate glass. I view the bull's-eye pattern by looking horizontally into the viewer. Using the ZE3, I can detect a change in height of one corner of the easel of 0.25 mm. That's far tighter than the tolerances established by the diffraction-limited depth-of-focus of the enlarging lens.

Aligning the Chromega drove me nuts. It took about an hour with the best of mechanical aids, adjustable levels, and grain focusers. I never seemed to get it perfect, and it was so much work that I did it much less often than I should. Fifteen minutes after I opened the ZE3 box for the first time, I had the baseboard, negative stage, and lens completely parallel. My Peak Focuser confirmed that I had all four corners of the field in identical focus. With practice, I could align the baseboard, lens stage, and negative stage of that Omega D chassis enlarger in 10 minutes and recheck the alignment in under 5 (for example, when I changed lens boards).

With the Zig-Align, I got into the habit of aligning my enlarger regularly (at the least, before every really important printing session). You know what I found out? The alignment always had shifted from the previous time I'd aligned the enlarger. Now I've got a wall-mounted Beseler 45 VX-L instead of the table-mounted Omega, but things still manage to shift. Without that ZE3, I'd probably be making lots of prints with less-than-perfect focus.

The ZE3 currently sells for about $225. Zig-Align sells a variety of kits for enlargers, ranging in price from roughly $130 to $325. That may sound expensive for a couple of pieces of glass, but they are worth every cent in saved time and improved photo quality. If I should break something, Zig-Align has a generous replacement policy. If a Zig-Align owner sends them the broken part, they'll usually replace it at cost! Prices currently vary from $15 to $35, depending on what you broke. Every really critical photographer and printer should have a Zig-Align. (And, you should check your enlarger alignment frequently. You'll be unpleasantly surprised by what you find.)

While I seem to get excellent results with the Zig-Align, no alignment method is foolproof. One reader, Dan Frisby, who's a precision machinist sent me some interesting test results he'd gotten measuring the physical alignment of enlarger lenses. He set up a gauge to measure the run-out of the front of the lens mount (where the Zig-Align tool seats) relative to the lens mount. He found that the front ring of the lens really isn't parallel to the lens mount! Presumably, the optical elements of the lens are aligned with the mount, not the front of the lens. This raises some serious questions about the limiting accuracy possible with any front-element-aligned tool like a Zig-Align.

Lest folks think this makes mount-based alignment tools a clear winner, Dan has found some problems in methodology with the use of those as well. He thinks the fundamental concept is good, but this assumes that the lens manufactures have actually kept the optical axis precisely perpendicular to the plane of the flange. Have they done so? Without precision optical bench measurements, we have no way of knowing.

The several lenses Dan tested showed run-outs ranging from almost insignificant to very serious. One cannot simply assume that an alignment tool has produced perfect alignment. The most prudent course is to carefully check the focus in all corners of the print easel after performing an alignment. Spending that couple of extra minutes is inexpensive insurance against fuzzy prints.

CHAPTER 11

Special Concerns of Variable-Contrast Paper Users

Split-Filter Printing vs. Graded Filter Printing

Split-filter printing is a widely used method for getting very precise control of contrast and tonal placement. Authors such as Joe Englander have written at length about it, so my discussion is a rather perfunctory treatment of a very rewarding technique.

Variable-contrast (VC) papers contain different emulsion components that are sensitive to different parts of the spectrum. Typically, there is a blue-only sensitive component and a component that is sensitive to green light. In modern papers, these two components exist in the same layer of the paper. We get different contrast grades from the paper by varying the relative exposures of the two components. A blue-light exposure gives high contrast, and a green-light exposure gives low contrast. A mix of the two gives an intermediate contrast.

That's the entire story of VC papers in one paragraph. Just how the two components work together isn't important; it's different from paper to paper. In some, the two components have similar individual contrast; the increase in contrast comes from exposing both of them rather than predominantly one of them. In other papers, the green-sensitive component is lower in contrast than the blue. The consequence is the same, regardless of details. The more blue light in the exposure, the higher the contrast; the more green, the lower the contrast.

How you produce the exposure also doesn't matter. You can use commercial filter sets that contain varying amounts of yellow and magenta dye. The yellow dye filters out blue light, which makes the exposure more dominated by green light. The magenta dye filters out the green light, thus passing the high-contrast-making blue light. Today's filter sets contain filters that are a mix of yellow and magenta dyes in different proportions to keep the print exposure roughly constant when you change paper grades. (I say "roughly" because, as I discussed in Chapter 4, constancy depends on which gray level you consider most important and want to hold constant in a particular photograph.)

An alternate approach for those with color-head enlargers is to dial magenta or yellow filtration into the enlarger head. The more yellow, the softer the print; the more magenta, the contrastier the result. You don't have to buy filters, your exposure times will be shorter, and you can fine-tune the contrast to a fraction of a grade. I can't tell you how often I need something like a grade 2.75 and neither a standard grade 2.5 nor grade 3 filter will do. That's especially true when I'm trying to duplicate a print I made at an earlier time (usually on a paper no longer available) or on a different enlarger.

One disadvantage is that you have to do your own calibration of filtration vs. paper grade and paper speed (see Chapter 4). The filtration recommendations of paper and enlarger manufacturers never seem to correspond to standard filters. Since I strongly advise making a set of calibration prints for commercial filters, this isn't as important as it sounds. It does mean, though, that you can't simply print with published filter packs and exposure times and hope to get results comparable to standard filters.

Another is that most enlargers' filters cannot produce the maximum possible contrast from most VC papers, so you'll have to buy a filter for grade 5+. All enlargers offer more than enough yellow filtration to get minimum contrasts.

The third approach is to do away with VC filters and print with a blue filter and a green filter, making a separate exposure for each. Doing this doesn't require a color head, and you buy only two filters. That's it! Split-filter exposures do not produce a print that looks any different from one produced by the other two methods. As long as you match grades exactly, a grade 3 print produced with a commercial filter will look identical to one made with color-head filtration and one made with appropriate exposures with blue and green filters. There's no magic to two filters.

Then what's so special about split-filter printing? First, you get just as fine control of contrast as you get with a filter head, but you get it with any light source. If you like printing with a condenser head, split-filter printing is the only way to get this degree of control. This factor alone may make it worthwhile. Second, you can dodge and burn-in separately during the two exposures. This gives you local control over both contrast and density, which is difficult to achieve by any other technique.

Here's an elementary example of split-filter control. Suppose you are printing a high-contrast negative. Overall, you'll have to print on a low-contrast paper. If you make the paper grade too low, the midtones will look flat and lifeless, even though you'll capture the highlight detail. Such negatives usually have shadow detail you'd like to see, but because dark tones are hard to distinguish and the print is so low in contrast, you can't clearly distinguish the dark grays and near blacks from true black. Burning-in can help the highlights, but it may be hard to keep the burn area from standing out harshly. Dodging won't help the shadows much because the problem there is the low contrast, not the overall exposure.

We can give the print a pair of overall exposures suitable for grade 2 with good midtones. By itself, that would still lose the highlights and block up the shadows. With split-filter printing, we can dodge the shadows during the green-light exposure so they don't go muddy, and burn them in during the blue-light exposure so that we get a true black but plenty of contrast and tonal separation. We burn-in the highlight areas with the green light, to build up low-contrast detail with much less risk of getting the dark patches that give away a burn with higher-contrast printing.

Figures 11–1, 11–2, 11–3, and 11–4 illustrate how I used split-filter printing to make a much better print than I could with a single-grade print. Figure 11–3 is a single-grade print of a very difficult negative. Despite considerable local control, it fails to reproduce tones as I'd like. Until I took up split-filter printing, I'd never made a print from this negative that pleased me. It's just one frame from a whole roll

Figure 11–1 This is the low-contrast (green light) exposure that went into making Figure 11–4. I dodged the water and island so that they received no exposure. I picked an exposure for the rest of the print that would produce just a bit of detail in the white surf and the brightest clouds.

Figure 11–2 This is the high-contrast (blue-light) exposure that went into making Figure 11–4. The pure white areas were not dodged: they are highlights beyond the exposure range of the paper. In fact, the sky was burned-in by half a stop to improve the contrast in the clouds.

of problematic negatives that I'd written off as being not printable to my satisfaction.

Figures 11–1 and 11–2 are prints made with the individual low- and high-contrast exposures that I combined to make Figure 11–4. I printed Figure 11–1 with a deep-green filter. I gave the same exposure to the line of surf, the clouds on the island, and the water and sky above the island in the picture. I feathered the edge of the exposure of the sea about one-third of the way down from the top of the picture so that it would blend smoothly with the high-contrast exposure. The darker water and the island in the lower two-thirds of the picture received no exposure at all.

I exposed the high-contrast print in Figure 11–2 using a deep-blue filter. I picked an overall exposure that just produced true blacks in the deepest shadows. I did no heavy dodging in this print; the parts that printed as pure white are the higher negative densities that were beyond the exposure range of this high-contrast print. I dodged back the very darkest part of the island in the lower right by about 15% to keep this area from going solid black. I burned-in the top quarter of the picture by half a stop to add just a bit more contrast to the sky and clouds.

Figure 11–4, the finished split-filter print, shows how well these efforts paid off. Note the vastly-improved tonal quality in the surf, clouds, and island. This is a print I'm happy with! Several other negatives on this troublesome roll have since yielded fine prints with split-filter printing.

You can do a lot more than this with split filtration. Any trick you can use to manipulate density with a normal burn or dodge can manipulate both density and contrast with a split-filter

Figure 11–3 I made this aerial photograph of the Hawaiian Islands on medium-format Kodak Technical Pan film. I processed the film to a gamma of 1 in D-76 in order to get a negative of good overall contrast. This negative has considerable amount of tonal detail spread out over a long density range. This print is on grade 3 Agfa Multicontrast Premium. I burned-in the clouds over the islands by 0.5 stops and the skyline by 0.7 stops. This conveys most of the exposure range, but the shadows have too little contrast, while the clouds and surf have too much.

Figure 11–4 Split-filter printing produces a much better print than Figure 11–3. The contrast in the islands and water is greatly improved, and there is more detail in the surf line and the clouds. I used a blue-light exposure just sufficient to produce a good black in the darkest areas. I burned-in the background water and sky by 0.4 stops to provide a little more snap to the midtones there. Next, using green light, I burned-in that same background region by 0.4 stops and the surf line and the clouds over the islands by 0.5 stops. This added low-contrast detail to the highlights.

burn or dodge. If you don't think you need fractional paper grades or local contrast control, don't bother. If you've ever been unhappy because you couldn't get a print's tones exactly right, this control will make your prints a lot more pleasing

Are there any disadvantages to split-filter printing? You need to make two exposures for each print and change filters in the dark. As with color-head filtration, you'll have to develop your own calibrations for paper contrast and speed. Doing split-filter printing well also requires considerable skill at dodging and burning-in.

Above or Below the Lens?

You may have noticed that I've made no mention of whether I use VC filters above the negative stage or between the lens and the print paper. According to my tests, it makes no difference. I set up a high-resolution target with my 55mm Computar lens at optimum aperture and examined the projected aerial image with no filter under the lens, with modern thin filters under the lens, and with older cast-plastic filters under the lens. In all cases, I could see a clean, 320 line pairs per millimeter (lp/mm) in the center of the field and more than 280 lp/mm at the corners. I could not convince myself that I saw any degradation in image quality with the filters in place, no matter how hard I looked. That surprises even me, but it's true. As long as your VC filters are not scratched enough to create serious flare (see Chapter 5) I can see no reason for avoiding below-the-lens filters.

Differences in Image Quality Between Variable-Contrast and Graded Papers

At one time, a printer could make blanket statements about the obvious inferiority in tonal rendition of VC papers as compared to graded papers. VC papers have greatly improved during the past 30 or 40 years (and many of the generalizations are that old). Today, overall, VC papers are not inferior to graded papers; they are merely different. There are so many VC papers on the market that most generalizations are moot.

However, in one respect, many VC papers remain second rate, and that is in the tonality of very-low-contrast prints. The overall characteristic curve for a VC paper comes from the overlapping characteristics of two (or more) distinct emulsion-component curves (Fig. 11–5). In a low-contrast print, the curves are drawn apart, which extends the exposure range of the paper. If the individual curves do not have sufficient exposure range and if the higher-range curve doesn't produce a true black by itself, a flat spot appears in the middle of the combined curve where the toe of one curve overlaps the shoulder of the other. In an extreme case, the curve will look like Figure 11–6. This is called curve splitting.

Unfortunately, that flat spot falls right in the midtones. As I said in Chapter 6, midtone separation gives a sense of brilliance in a print. Curve splitting creates a region in the midtone range in which the paper has extremely low contrast and shows very little tonal separation. Such prints look lifeless next to ones with a straighter characteristic curve. Thus, the very first test I run to check out a new VC paper is to look for curve splitting. A paper that shows serious curve splitting never becomes part of my routine.

There is not usually a problem with curve splitting at normal or higher-than-normal contrasts. It only shows up when the two curves are separated beyond their linear range. I have an especially nasty negative that barely prints well on grade 0 paper (Figures 11–7 and 11–8). This negative has a lot of important subject detail in the midrange along with shadows and highlights that won't quit. It would be a great candidate for reduction in a proportional reducer, but it's more useful to me as a test image. I keep a file of prints from this negative made at grade 1, 0, and 00, with the name of the paper written on the back of each print along with the indicated paper grade. When a new paper comes in, I make a couple of prints on it with this negative and compare them to the prints in my file. Immediately, I know how well the new paper compares to the best and the worst that I've seen.

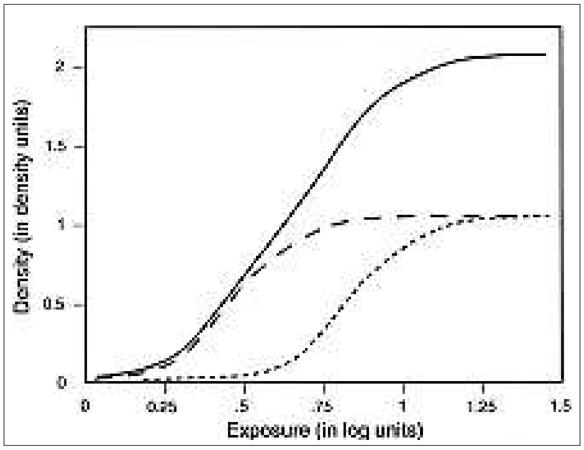

Figure 11–5 Characteristic curves for the two components (dashed and dotted lines) of a hypothetical variable-contrast paper. Changing the ratio of blue to green light in the exposure shifts the curves horizontally relative to each other. The characteristic curve we see in the print (solid line) is the sum of the two component curves.

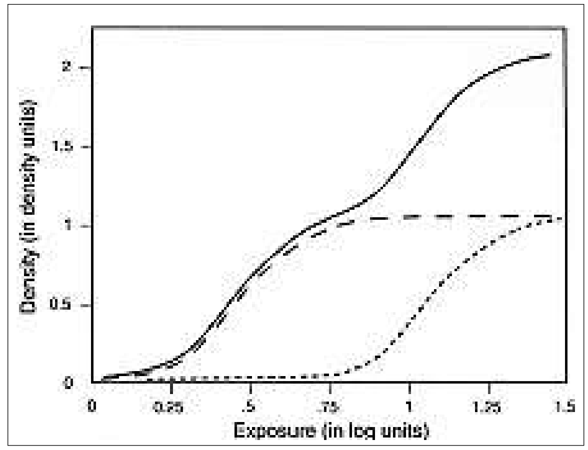

Figure 11–6 At low contrasts (low blue/green light ratio), the curves are spread so far apart that the toe of one curve may fall on the shoulder of the other. The result is the double-S curve shown here. This curve-splitting produces poor midtone contrast and dull prints. Different VC papers have different susceptibility to curve splitting.

Of the VC papers I've tested so far, Agfa Multicontrast Premium maintains the best midtone separation at low contrasts. Try this paper if you feel that your low-contrast VC prints lack a certain liveliness.

Focusing Problems Specific to Variable-Contrast Papers

When researching the unknown, I've found that the realm of Murphy's law borders on that of Serendip. With proper application of scientific detective work, unexpected glitches can lead to new knowledge. While investigating the printing characteristics of different enlarger heads (see Chapter 6), I stumbled on a completely unexpected source of fuzziness in my prints. I discovered that there can be a huge difference between the plane of best focus seen by our eyes and the proper focal plane for VC print paper. I've seen as much as a 15mm focus error when making 8 x 10 prints from 35mm negatives, which results in a serious loss of print quality! My research suggests that this problem affects many (fortunately, not all) users of VC papers.

Figures 6–17, 6–18, and 6–19 on pages 72 and 73 illustrate the magnitude of the focus problem. Figures 6–18 and 6–19 show highly magnified sections of two prints. Figure 6–18 was made at the lenses' true best focus for the print paper. Figure 6–19 was made at the best visual focus I saw using the Peak Focuser. This visual focal plane differed from the best focal plane by about 14 mm.

The cause is an optical defect called longitudinal chromatic aberration (LCA, Plate 29). It's the dominant residual aberration in most good enlarging lenses, although such lenses are adequately corrected for LCA over the red-green-blue part of the spectrum. Unfortunately, modern VC papers respond into the near ultraviolet (UV), where the lens may not be well corrected and the human eye sees almost nothing.

Even when we focus our enlargers through a deep-blue filter, we're using a different part of the spectrum than the print paper sees. Because the print paper is reacting to light outside the normal spectral range for which the lens is corrected, the paper may see a different plane-of-best-focus than the eye does. This is a different source of focus error than the one Patrick Gainer has discovered (see Chapter 6).

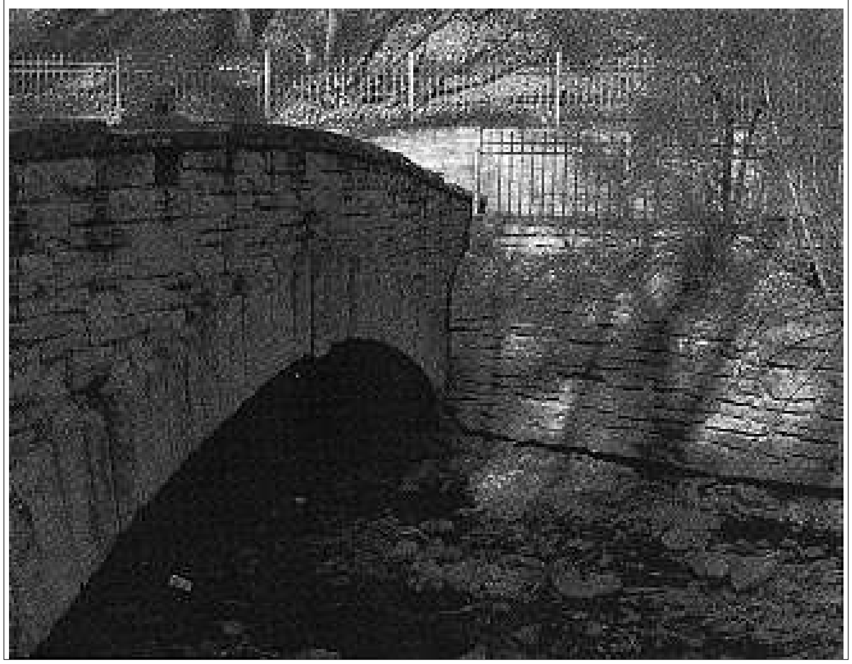

Figure 11–7 This medium-format TMAX 100 negative of Minnehaha Creek has an extremely long density range and demands a very low contrast paper. This grade 0 print (on now-discontinued Oriental Seagull VC paper) exhibits a very severe case of curve splitting. There is little tonal separation in the shaded stonework in the wall and bridge; it's almost uniformly gray.

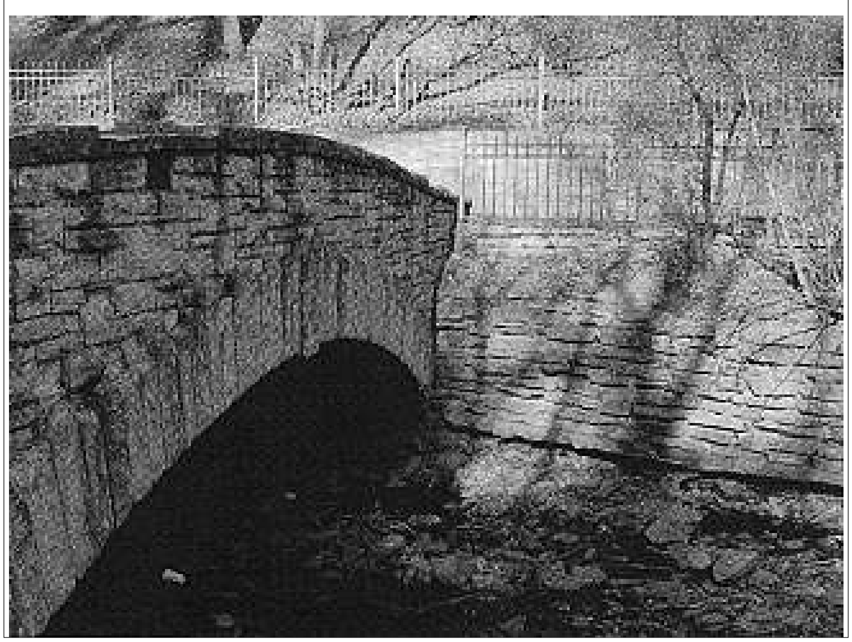

Figure 11–8 Agfa Multicontrast Premium paper exhibits very little curve splitting. Even in this grade 0 print, there is good separation of the dark and middle grays of the wall and the bridge.

I encountered this nasty problem while running printing sharpness tests on a carefully aligned Beseler 45 VX-L chassis with a Dichro 45S diffusion head. I was printing a glass high-resolution bar target with a Computar 55mm f/1.9 lens at its optimum aperture of f/4 onto Kodak Polymax resin-coated (RC) paper. My bar target goes to almost 500 lp/mm, and the Computar resolves over 300 lp/mm in the negative plane, so it can project more than 30 lp/mm onto the paper plane at 10X.

To enhance print contrast, I had dialed 150 CC of magenta filtration into the enlarger head (about grade 4 contrast). I focused the image in blue light using my Peak (formerly Micromega) Critical Focuser. The resulting print displayed far less than 15 lp/mm and was visibly unsharp. I knew Polymax was capable of resolving about 100 lp/mm, so it wasn't an obvious paper problem.

The Computar has an adjustable front element that lets me very precisely adjust focus. I made two new prints with the focus tweaked a few millimeters above and below the paper plane. The "below" print was worse; the "above" visibly better. Eventually, I found the point of best focus. That print showed an on-paper resolution in excess of 30 lp/mm. This was near what theory told me I should get and proved that the lens was capable of delivering that level of detail to the print paper. Unfortunately, the correct plane of focus was over a half inch from the one I arrived at visually! I checked the Peak Focuser against two other grain focusers. One produced an aerial image like that of the Peak Focuser and the other presented a ground-glass image. Neither were remotely as precise as the Peak Focuser, but all three focusers reported a focus that was wrong by a half inch. I got the same results with both the diffusion and condenser heads for the enlarger. Maybe it was my eyes—I was in my mid-forties—or maybe I was losing my ability to focus the dim blue image. Yet, when I focused by white light, the focus shifted only slightly, nowhere near a half inch.

Then I made a print with no filtration. Removing the magenta filtration from the enlarger eliminated the focusing discrepancy—the actual plane of best focus shifted to where the grain focuser said it was. I got a new surprise—the unfiltered print was fuzzier, at best focus, than the grade 4 print. Contact prints of my resolution target showed that the paper didn't get inherently fuzzier at lower grades. Grade 0 prints also showed no focus error, and they were as sharp as properly focused grade 4 prints,

Quick, crude test prints made with a 50mm f/2.8 El-Nikkor N and a 105mm f/5.6 Rodagon lens showed that this wasn't an oddity peculiar to my Computar. The other two lenses showed anomalous focus errors, although not as severe as the Computar's. The situation was getting stranger and stranger. After 2 days and many dozens of prints (you're getting a highly abbreviated chronicle of events), I could feel madness lurking in the shadows. I resolved to put this matter aside over the weekend and do something (anything!) that had nothing to do with focusing.

I had learned several important things. First, this combination of enlarger lens and print paper was capable of producing far sharper prints than I was getting in enlargements. Second, there was a real focus error that was responsible for the lack of sharpness. Third, the error was not due to the design of the focusing aid or a misalignment in my Peak Focuser. Fourth, it wasn't just one lens. Fifth, the focus shift disappeared if I removed the magenta filtration, but the best focus became much fuzzier.

After considerable frustration and puzzlement, I developed the hypothesis about LCA. Perhaps VC papers were sensitized so far into the violet that I wasn't focusing with the right color of light. If VC papers were sensitized far enough into the violet and LCA was only being minimized over the normal visible wavelengths, I might see larger focus shifts when printing with those very short wavelengths.

That would explain why a print made with 150 CC of magenta filtration (about grade 4) showed a pronounced focus shift, but an unfiltered print (which exposed both the green- and blue-sensitive emulsions) and a grade 0 print (which exposed primarily the green-sensitive emulsion) didn't show a shift. It would also explain why the unfiltered print was less sharp than the others, because the two emulsions have different planes of best focus. To prove this, I first needed to find out whether there was even enough short-wavelength light to matter.

Identifying the Culprit

Kodak makes several kinds of UV-cutoff filters. A 2B filter cuts out essentially all the light below 400 nanometers (nm). A 2A filter cuts off light at 410nm, and the 2E does so at 420nm. 2B is the standard color-printing filter that used to be recommended for all color printing when color papers had a lot of UV sensitivity. Current color papers have far less UV response, so this filter is no longer de rigueur. Some color heads have 2B filtration already built into them.

With these three filters, I could trim off slices of the spectrum to see how that affected print exposure. All three filters look very pale yellow because the eye sees very little of the light they absorb. Even when viewed through a 47B deep-blue filter, they have optical densities of only about 0.05. If a printing paper has little short-wavelength response, these filters do not cause more than a 10% change in the exposure time because the paper is not sensitive to the wavelengths they cut out. I found that this was not true for Polymax paper. I got the exposure times in Table 10–1 for comparable grade 4 prints. Without a doubt, my enlarger and lens were passing enough of these very short wavelengths to expose the paper, and the paper was unquestionably sensitive to those wavelengths!

I made phone calls to some very helpful people—Dennis Kloppel of Charles Beseler Company and Dave Valvo and Ken Nelson of Eastman Kodak—who provided me with invaluable (and sometimes unpublished) technical information on their products. They provided valuable suggestions, alternate hypotheses for me to consider, and a stack of faxes containing spectral information on the Beseler enlarger and VC and graded papers.

All that data went into my computer. I added in the spectral transmission characteristics of the Computar lens, the UV-cutoff filters, and the 47B deep-blue viewing filter. Finally, I stirred in the light-source curves and the spectral response of the human eye. I used the data to compute the graphs shown in Figures 11–9 through 11–12.

Figure 11–9 shows that the theory agreed with my experimental result; there was indeed plenty of short-wavelength light available to expose prints. The scale along the bottom of the graph is in nanometers. The visual spectrum runs from deep red at a wavelength of about 700nm to deep violet at about 400nm, but the human eye's response drops off very rapidly below 450nm. The vertical scale is linear, not logarithmic, which makes the variations a little easier to see. By pure mathematical accident, the curves look similar when plotted on a log scale.

The top curve shows the spectrum of an unfiltered tungsten-halogen lamp at a temperature of 3200 Kelvins (K). There's a surprisingly large amount of energy at extremely short wavelengths compared to that emitted in the blue-green part of the spectrum.

The second curve factors in the transmission of my Computar lens, which absorbs all light below 380nm and half at 410nm. My lens seems to be about average—some absorb more UV-violet light, others less.

Table 11–1 Exposure Times with UV Filters in Light Path

UV Filter Used	UV Cutoff Wavelength (nm)	Exposure Time (sec)
none	——	10
2B	400	15
2A	410	20
2E	420	26

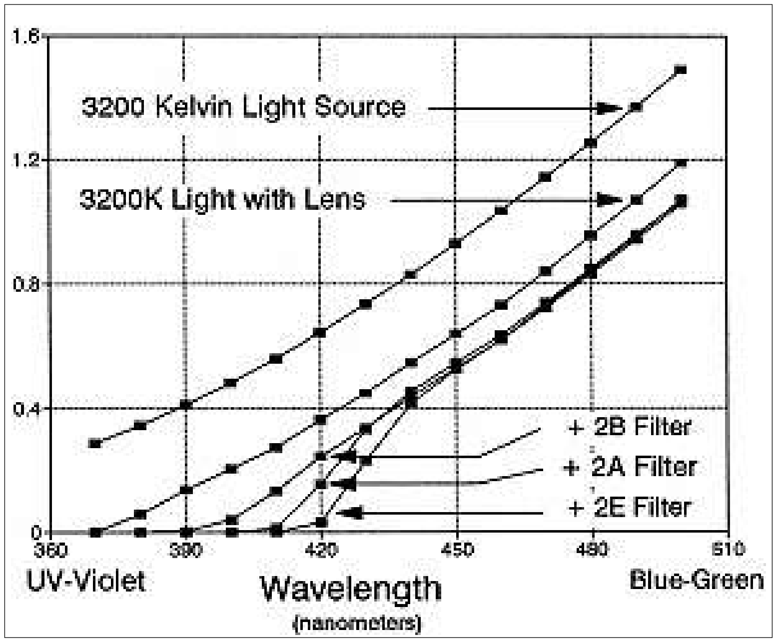

Figure 11–9 This graph shows the spectral characteristics of the light used to make prints. The *x*-axis indicates the wavelength of light. The *y*-axis is in linear relative units, not logarithmic (i.e., on this axis, a value of 0.5 is half as intense as a value of 1.0). The top curve represents an unfiltered 3200 K lamp. Note that the lamp puts out quite a bit of light below 400nm. The second-from-the-top curve shows the relative light output when the absorption of the Computar 55mm lens is taken into account. The curve is lower overall because the lens absorbs some light at all wavelengths. This lens absorbs all light below about 380nm. The three bottom curves show the effect of introducing different UV-absorbing filters into the light path. A 2B filter cuts out essentially all light below 400nm; a 2A blocks light below 410nm; and a 2E filter blocks light below 420nm.

My lens significantly reduces the amount of deep violet, but you'll see that it still leaves enough to have a big effect with UV-sensitive papers. The three lower curves show the effect of adding each of the UV-cutoff filters.

The color temperature of incandescent enlarger bulbs varies; it's 2800 K for a 75-watt lightbulb, 3300 K for some tungsten-halogen lamps. I computed all my graphs for 3200 K (Beseler data say their lamp is 3200 K to 3300 K), but the curves would be similar for other color temperatures. At 3200 K, the ratio of energy emitted between 500nm and 420nm to that emitted below 420nm is roughly 3:1. At 2900 K the ratio increases to 4:1. Including the Computar's transmission characteristics, the respective ratios are 7.5:1 and 8.5:1. Even an incandescent lamp radiates short-wavelength light. All bets are off with a cold-light head because each model has unique spectral characteristics. In general, I cannot predict which heads will produce a focusing problem. Reports I've received from readers say that some heads do produce a focus shift while others don't. If you're using a cold-light head, the quick test I describe at the beginning of the next section will tell you if you have a problem.

The graphs in Figure 11–9 tells us the spectral characteristics of the light that's being projected onto the paper. How does the paper respond to this light, and does it see it differently from the way we do? Figure 11–10 shows the spectral response of unfiltered Polymax paper compared to that of a human eye focusing with a deep-blue (47B) filter. Because I calculated the

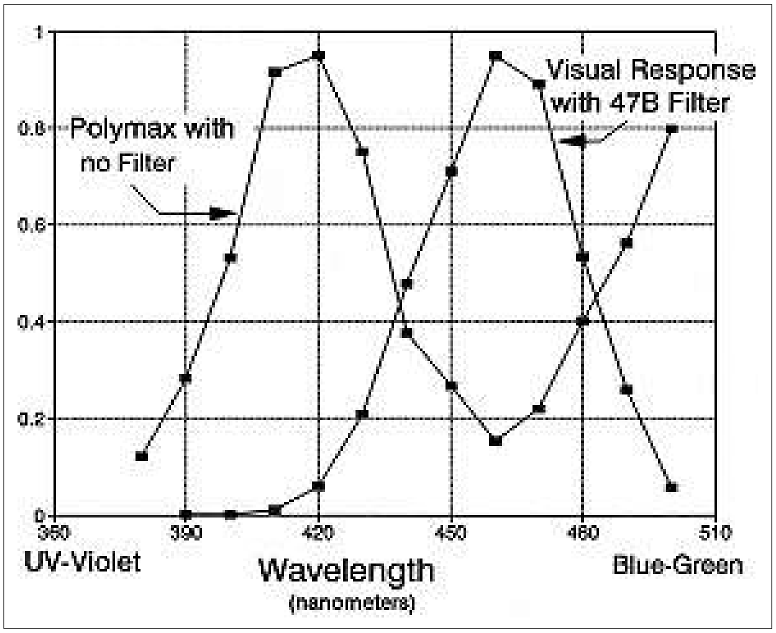

Figure 11–10 This graph shows how the spectral response of the human eye focusing through a 47B deep-blue filter differs from that of Kodak Polymax paper. As in Figure 11–9, the *x*-axis is the wavelength in nanometers and the *y*-axis is the relative response in linear units. The right curve shows the response of the human eye plus a 47B filter for the enlarging setup used in my tests. This curve takes into account the spectral characteristics of the 3200 K lamp and the light absorption by the Computar lens. The human-seen spectral peak, at 460nm, differs from the flat-response "official" value of 430nm. The left curve shows the predicted response of Polymax paper, taking into account the spectrum of the lamp and the characteristics of the lens. The curve rises at longer wavelengths because of the response of the green-sensitive emulsion in the paper. Polymax's blue response peaks at 410nm, a full 50nm from the visual focusing peak. Polymax has minimum sensitivity where the eye plus 47B filter is most sensitive.

curves for 3200 K light that had passed through the Computar lens (the second curve in Figure 11–9), they represent what we actually see in the projected image. They do not look like the curves in the manufacturers' filter and paper data sheets because those curves do not take into account the human eye's spectral response nor the spectrum of the projected enlarger light. For example, a 47B filter has its peak transmission at 430nm, but when you factor in the eye's response and spectrum for the light source, the visual peak sensitivity is 460nm. As in Figure 11–9, the vertical scale is linear.

Unlike our eyes, the Polymax paper has a lot of sensitivity at the short wavelengths, and its peak response is below 420nm. In fact, the eye is most sensitive where the paper is least sensitive. The UV-filter exposure tests and these curves prove that the paper responded strongly to light that I couldn't even see.

Figure 11–11 shows the computed effects of adding different UV-cutoff filters to the light path. Theory (these curves) matches well with practice (my exposure time tests in Table 11–1). To make the graph clearer, I represented the eye's response with a shaded box; the precise curve for the eye is the same as that in Figure 11–10.

Next, I ran a precise series of focus tests on Polymax paper (grade 4) with the different UV-cutoff filters. I used a TMAX 3200 negative

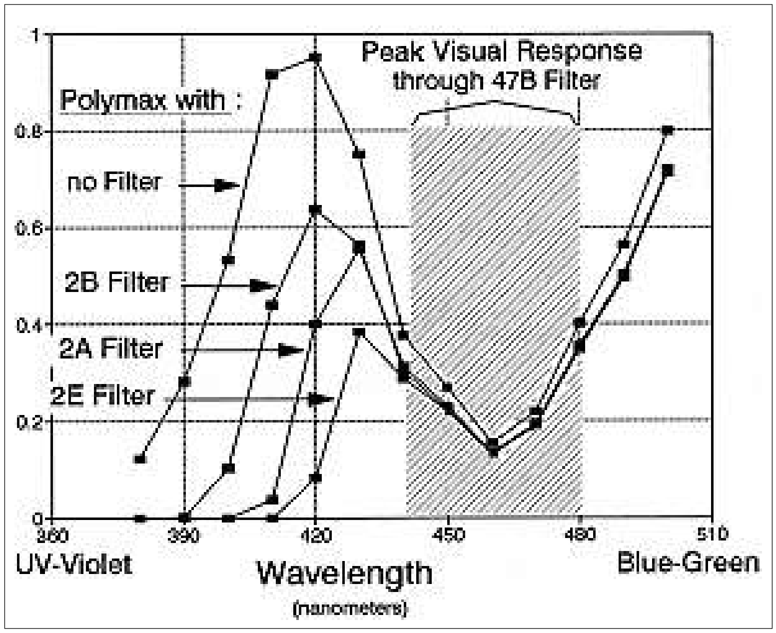

Figure 11–11 This graph shows the effect on Polymax of adding the three different UV-cutoff filters to the light path. Adding UV-cutoff filters brings Polymax's blue peak closer to the visual response and reduces the focus shift but at a loss of printing speed. In this graph, the spectral response of the human eye is indicated with a shaded box for clarity; the actual curve is the same as that in Figure 11–10.

tightly sandwiched between two pieces of optically flat glass because it proved easier to see slight differences in focus in a grain pattern than in a bar target. Besides, I was interested in the effect the focus shift had on print quality, not merely on resolution figures. I made all the prints in this series with 150 CC of magenta dialed in to the Dichro 45S head (I also tested different paper grades and other papers—more on that later).

As you can imagine, doing this was tedious in the extreme! I used shim blocks of varying thickness under the paper easel to expose prints at precisely different distances from the plane of visual focus. I made such prints for each of four filter setups: no UV cutoff, 2B, 2A, and 2E.

I carefully compared the grain structure and sharpness in each print in a series with its neighbors until I found the print that was sharpest. That told me the precise amount of focus error. Table 11–2 on the next page shows what I got:

I did my experiments before Patrick Gainer made his discoveries about focusing errors. I've determined that in my setup, the focus shift caused by the Gainer effect was not nearly as large as the one associated with the VC paper; it contributed only 2mm to 3mm of focus shift. I've corrected for the Gainer effect in the third column, which brings the results even more in line with theory. Others may find they have a much larger Gainer shift.

I reran the experiment several times to determine how large my experimental error was. The differences corresponded to a millimeter or so—small compared to the focal shifts I was looking for. I computed the margins of error at about 2 mm, which is only a little bigger than the most critical diffraction-limited depth of focus. Therefore, when I report a 7mm shift with the 2A filter, I'm saying the shift could fall between 5 mm and 9 mm (7 +/- 2) or between 2 mm and 7 mm (4.5 +/- 2.5) when the Gainer effect is included.

(I must digress here to point out that folks who glue pieces of print paper to the bases of grain focusers to get sharper prints are deluding themselves. Such submillimeter changes in the focusing plane are invisible and undetectable.)

Table 11–2 Measured Focus Shifts with UV Filters in Light Path

Filter Used	Amount of Focus Shift	Amount of Shift Corrected for Gainer Effect
No UV filter	14 mm	11–12 mm
2B filter	8 mm	5–6 mm
2A filter	7 mm	4–5 mm
2E filter	4 mm	1–2 mm

Did the experiments back up the math? Indeed! Figure 11–11 shows that the UV-cutoff filters move the Polymax peak closer to the visual peak. The more UV-violet light I eliminate, the better the agreement between my eye's focus and the print paper's focus. The shift in spectral peaks correlates well with the focal shifts I measured. Unfortunately, the 2E robs the paper of so much of its blue-light response that it is impossible to get higher than grade 3.5 prints even when I use a Polymax No.5+ filter, so it's not really suitable for this purpose. But an ordinary 2B printing filter reduces the problem by at least half.

At the suggestion of the people at Eastman Kodak, I investigated the UV brighteners contained in most papers because I was told that they absorb light at 380nm and reradiate at 420nm. These brighteners might have been causing a loss of sharpness by converting a fuzzy "invisible" near-UV image into one that exposed the paper. Fortunately, this was easy to check because Polymax Fine Art paper contains no brighteners. Polymax and Polymax Fine Art papers showed similar image structures and focus shifts, which proved that the presence or absence of brighteners makes little difference.

Is this problem unique to the combination of the Computar 55mm lens and Polymax paper? Unfortunately, the answer is a loud and resounding NO! I tested Polymax paper with a 50mm f/2.8 El-Nikkor N and a 105mm f/5.6 Rodagon. The Rodagon gave me a focus shift of about 12 mm and the El-Nikkor about 10 mm.

I printed several other papers with the Computar lens. Kodabrome II paper (a graded paper) showed a 3mm to 4mm focus shift, nearly zero within experimental error, depth of focus, and the Gainer effect. Even with my 10X loupe, I couldn't see any evidence that the visual-focus print was less sharp. I have plotted Kodabrome's spectral response for this light source and lens in Figure 11–12; as you can see, it peaks only 20nm from the eye's 47B peak. Oriental Seagull Select VC paper showed an 8mm focus shift, and prints were visibly a bit fuzzy. Prints on Ilford Multigrade IV Deluxe showed an 11mm shift and looked almost as bad as those on Polymax.

One VC paper I tested produced no focus shift—Agfa Multicontrast Premium. I knew this paper had deep-violet sensitivity. When I got that result, I doubted my entire hypothesis. I added the spectral characteristics of Agfa MCP to my spreadsheet and plotted the results (Fig. 11–12); To my surprise, Agfa MCP had no pronounced peak in its deep violet response with this light source and lens. Rather than contradicting my theory, this provided more confirmation.

Polymax paper printed with the Computar lens seems a particularly bad combination, but my results with other papers and lenses show this problem is not limited to Polymax or Computar. More important, many or most enlargers filter most of the very short wavelengths. They produce small or no focus error (the presence of even a 2B filter equivalent cuts the error in half).

Now we can understand why the focus shift changes with paper grade and why middle-grade prints are less sharp even at best focus. When you change VC filtration, you change the ratio of blue and green light in the exposure. This has no effect on the focus until the blue-sensitive emulsion starts to dominate the image. Polymax prints made with 60 CC yellow filtration (comparable to about grade 1) were sharpest at the plane of

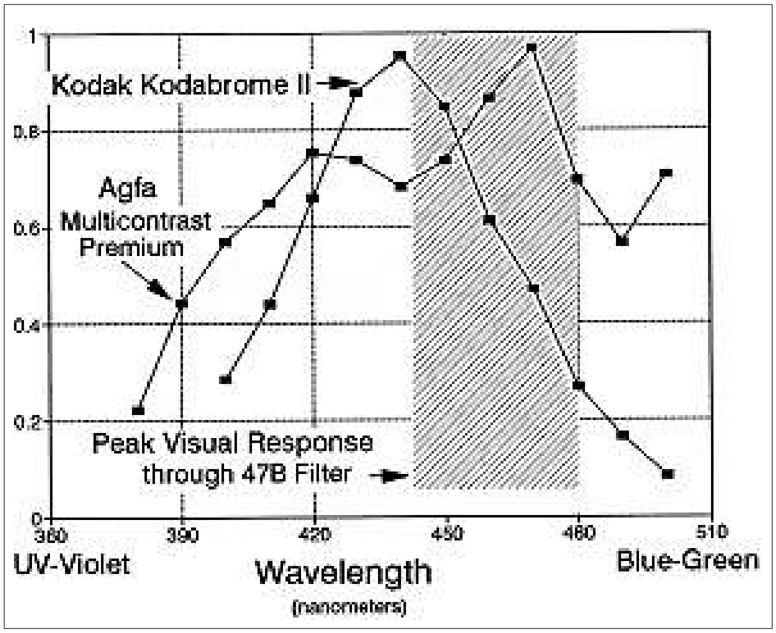

Figure 11–12 This graph shows how the spectral response of the human eye focusing through a 47B filter compares with that of Kodak Kodabrome II paper and Agfa Multicontrast Premium paper. As in Figures 11–10 and 11–11, the curves take into account the spectral characteristics of the Computar lens and the enlarger lamp. The shaded box shows the range of response of the human eye viewing through a 47B filter, just as in Figure 11–11. The response of the Agfa paper is very broad, without a pronounced deep-blue peak. Peak response is close to the visual 47B peak response. I measured no focus shift with Agfa MCP paper. The peak response of Kodabrome II paper is at 440nm, only 20nm from the peak visual response. This is a better match than Polymax paper produces, even with the 2E filter. There is only a small focus shift for Kodabrome II.

visual best focus and their sharpness was excellent. Because they're being exposed almost entirely by green light, the UV-violet paper sensitivity doesn't come into play. With no filtration, the best print focus was almost at the visual best focus, but that print was fuzzier than either the high- or low-contrast prints because both the blue-sensitive and the green-sensitive emulsions contributed to the image and can't both be in sharp focus. The high-contrast prints were sharp, but only if I corrected for the focus shift—they're being created mostly from the blue-sensitive emulsion with little green-light contribution.

This focus shift has serious implications for the print quality from VC papers. As I point out in Chapter 5, fuzziness degrades print tonality by blurring out small details in the grain structure. It causes the blacks to block up and the most delicate highlights to vanish. A paper that looks fine when used for contact printing may look much worse when it is used for enlargement, solely because of this phenomenon.

By the way, color printers don't have to worry about this focus problem for two reasons. First, the focus shifts I've measured over color paper's red-green-blue range of wavelengths are many times smaller than the shift going from blue to deep violet. Second, the blue-sensitive layer in color papers controls the formation of the yellow dye image in the print. That image can be quite fuzzy without our seeing it. Thus, lenses that perform superbly for color work, like those I own, may still have this focusing problem when used with VC B&W papers.

What Can We Do?

The very first thing is to determine whether you are in the unlucky minority that has a focus problem. It's not too hard to run a simple test. Set up your enlarger with a glass-sandwiched negative and place your paper easel on a 5mm-thick stack of cardboard. Make a very carefully focused print using a grade 4 or 5 filter, working at your lens's optimum aperture (probably f/4.7 for 35mm work). Without refocusing, make two more prints—one with no cardboard under the easel and one with 10 mm of cardboard underneath. Finally, make a fourth print (again without refocusing) with the original 5mm spacer to double-check that your focus didn't shift during the tests.

When you look at all the processed prints, the first and last prints should look identical. The two prints made with 10 mm and no spacing should be slightly less sharp than the first print. Ideally, they will be equally unsharp, but as long as the first and last prints made with the 5mm stack are sharpest, you don't have a big enough focus error to matter. You'll need to perform this test for all your lenses and all your VC papers.

What if you find you have a problem? I don't have a nice fix for this. A 2B filter cuts the problem by half in exchange for a 50% increase in exposure times. You can shop for a new lens, but this failing falls outside the normal spectral range of correction. A lens that is superb for color and graded B&W printing may prove awful when used with VC papers. I've seen some of the largest residual LCA in expensive "apo" enlarging lenses (excepting the Apo El-Nikkor). Manufacturers' specs are of little help. Further, different lens designs absorb very different amounts of UV-violet light. It's a trial-and-error process.

No special viewing filter will work. Kodak's Wratten 36 deep-violet filter had a peak visual response at 435nm, much better than the 47B. But Kodak no longer makes that filter, and, as Patrick Gainer has shown, the eye's LCA may give trouble if you focus far from the middle of the visible spectrum. I found it very difficult, if not impossible, to focus precisely with the dim violet image from the #36 filter.

I made some shim blocks to use under my focuser. They raise it up by an amount equal to my focus shift so that the best focus for the paper falls on the print easel. Fortunately, most of my printing is nearly full-frame on 8 x 10 paper, and I use relatively few papers. The shims would be different for each paper/lens combination and each enlargement size.

None of this fixes the fuzzy images when you print at grade 2. The real solution for this problem has to come from the lens and paper manufacturers. Paper manufacturers only recently started sensitizing VC papers this far into the UV-violet range in order to get better spectral separation between the emulsions to make it easier to produce a long contrast range in the paper with good tonal gradation. My research proves that the paper manufacturers have gone too far; the deep-violet sensitivity actually compromises print quality and tonal gradation in many enlargements.

About 6 months after my original article on this subject appeared, the lens manufacturer Rodenstock issued a report, based on their tests of my research (reprinted in *PHOTO Techniques*, Mar/Apr. 1996). Rodenstock confirmed my hypothesis that excessive short-wavelength paper sensitivity in combination with enlarger lens LCA was responsible for the focus error I investigated. Unfortunately, their report says that it isn't feasible to produce a lens with extended LCA correction without compromising the image quality in the visible wavelengths, which seems to mean that it can't be done with current technology at a cost any of us are willing to pay. I doubt that the other lens makers know tricks that Rodenstock doesn't, so that puts the problem squarely in the paper manufacturers' laps.

In the future, paper manufacturers should increase the wavelength of the low-contrast peak sensitivity rather than shorten the wavelength of the high-contrast sensitivity. Improved sensitization dyes in the paper and better filter dyes may give sharper spectral discrimination between the two emulsions. This would allow the spectral peaks to be closer together without reducing contrast range or print quality.

CHAPTER 12

The Issue of Permanence

"My name is Ozymandias, king of kings: look upon my works, ye Mighty, and despair!"

Nothing beside remains, round the decay of that colossal wreck.

Shelley wrote those words. They apply all too well to my poor images in Plates 30 and 31. I made both prints at the same time, a few days after the launch of the first space shuttle in April 1981. I exposed and processed them identically. Except for one print that was circulated among editors for a few months right after printing, the two prints stayed together in my files ever since. It takes no discerning eye to notice a difference between the two. Plate 31 has lost about half (30 CC to 40 CC) of its cyan dye image.

This astonishing degree of deterioration was my own doing. To "protect" the print from spills and fingerprints, I spray-lacquered it before I sent it out. Believe me, I'd name the spray-lacquer brand if I could; I only remember it was one of two major brands of photographic lacquer, both of which came highly recommended for photographic prints. It's not an isolated case; the box of prints from this launch contains 50 to 100 prints, and most are okay. But a half dozen or so show massive cyan image loss; all were prints I'd lacquered.

The unlacquered prints I sent out show dye loss, too, but in the pattern of people's fingerprints. That loss is no greater than what the lacquered prints show overall; I'd have been better off not wasting my time and money spraying prints. All the lacquer did was guarantee that the entire image would be destroyed.

Unfortunately, I didn't know any better. What other horrors have I committed that I don't know about yet?

Simply put, once you have made your precious photograph, it starts to deteriorate. Our medium of expression is usually impermanent—sometimes quickly, sometimes slowly. A scandal of our industry is how the film and paper manufacturers have failed to fully inform us of the durability of the images we produce. Stability data are often released only on request, if at all. Kodak once produced a series of stability data sheets called CIS No. 50 that reported their tests on every color product made, and they were available on request if one knew enough to ask. For many years, though, I have been unable to get specific information on image permanence from Kodak (and I have extensive contacts directly into the bowels of "Big Yellow").

Fuji is a partial exception; some of their recent product data sheets include stability information along with the usual information on sharpness, and spectral and exposure characteristics. Fuji appears to provide data when it suits their marketing interests. Fuji papers, which test out well compared to those of other manufacturers, have stability data. Films, which don't rank as highly, do not.

Imagine if manufacturers didn't release information on sharpness and sensitometry unless it made their product look good. Failing to provide stability data because they treat it as marketing, not technical information, is just as ludicrous to all of us who are trying to do serious work.

Furthermore, manufacturers treat stability questions about a product as obsolete the moment they discontinue the product. They claim there is no point to releasing stability data for products they no longer make. That stance denies the existence of the billions of images already photographed and printed on those "obsolete" materials. The same companies that exhort us to treat photographs as long-term memories make believe those memories cease to matter the moment the company ceases to make a buck off them.

Well, listen up manufacturers. Stability information is technical data that we need to take care of the images we've already made with your products, regardless of whether you still make the product. You've an obligation to provide us with it, and it is shameful that you don't!

There is a better way to learn than trial and error. Read *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures,* by Henry Wilhelm, with contributing author Carol Brower[1]. This book is vital! It's been 20 years in the making, and it's arguably the most important single book on the craft of photography to come out in that entire time. I don't think any single volume relating to the craft of photography has been of greater import since Ansel Adams wrote his Basic Photography series. Admittedly, I wax hyperbolic. Here's why I am so excited about this book, and why you should add it to your library:

Henry has done the job the manufacturers should be doing. Henry is the leading independent expert on color photographic permanence. He refuses to take company money to test products; he runs the tests freely and disseminates his test results equally freely. Wilhelm Imaging Research's Web site contains his most recent results, in particular his permanence tests on a wide variety of digital print media. Henry is only one person and not infallible, but his test results correlate well with the data that manufacturers issue. If I must trust any work, I trust Henry's.

The book is a monster. Between its archival binder boards it contains 750, 8.5" x 11" alkaline-buffered pages. These pages convey about 400,000 words of text and well over 500 illustrations. The scope is extraordinary. The book is roughly split between extensive information on the keeping properties of films and prints and on

1. Wilhelm Imaging Research, Inc., P.O. Box 775, Grinnell, IA 50112. Ph: 515-236-4284; Fax: 515-236-4222; e-mail: hwilhelm@aol.com. Go to http://www.wilhelm-research.com for information on ordering this book.

the techniques for preserving images in storage and on display. The book's first half concentrates on color, but the information in the second half, on storage and display issues, is applicable to both black and white (B&W) and color.

Henry provides extensive and specific information on dark stability and light fading for almost all color materials used between 1970 and 1992, including negatives, slides, motion picture film, and display and print media of all types. There are chapters devoted to the light fading of displayed prints, the effects of print lacquers and laminates on images, and the dark stability of prints and films. You'll find tidbits such as the names of the most- and least-stable color-negative films. If you need recommendations on safe mount boards, adhesives and markers, envelopes, sleeves, and storage boxes, it's in this book. Two chapters are devoted to cold storage. Although they come at the end of the book, you ought to read them early. You'll be surprised how easy it is to set up your own cold-storage facility for your all-too-fragile images. (It's called a frost-free refrigerator. Henry tells you how to pick the right one.)

Here are more tidbits gleaned from this book. Did you know Kodak's Vericolor III Type S was the most dark-stable color-negative film on the market (as of 1992) and that Vericolor II Type L (discontinued in 1996) was the least? Did you know that so-called protective print lacquers and laminates do more harm than good? (I learned that the hard way!) How about the fact that Fujicolor Type 3 paper is five times more light-stable than Agfacolor Type 8, but that UltraStable and Polaroid Permanent-Color pigment prints are at least 10 times more light-fast?

Did you ever make Agfachrome-Speed prints, as I did? If so, better not hang them on the wall—their probable display life is barely a year; Fujichrome paper is at least 20 times better. Dark-keeping is another matter! Agfachrome-Speed prints are right up there with dye transfer, pigment prints, and Ilfochrome—all are incredibly dark-stable.

Projection is bad for any slide, but there's a fivefold difference in fade rates between Fujichrome and Kodachrome. However, Kodachrome is still three to four times more dark-stable than Fujichrome. The moral? Photograph on Kodachrome for permanence, but project only duplicates.

In a modest attempt to maintain objectivity, let me acknowledge that Henry has been a friend of mine for over 20 years. Furthermore, I was part of an "underground railroad" that provided Henry with product samples and test images during the years in which many manufacturers wanted nothing to do with him or his research. I may be biased in favor of this book and Henry. If I am, it is for legitimate and professional reasons. Henry and I are not friends because we wear the same school tie or enjoy the same hobbies (I don't even know what Henry's hobbies are). What we share is mutual respect and a deep interest in photographic permanence and in seeing that today's photographic art and remembrances will be around for audiences to enjoy in the future. Furthermore, I deeply admire Henry's dedication to uncovering, discovering, and publicizing information about print permanence.

This is Henry's higher calling. Henry is willing to wade into the thick of controversy, if need be, to convey the truth, as best as he can determine it, to us who need it. I've listened to him attack, with complete justification and documentation, the pronouncements of giants such as Polaroid and Kodak. Henry has labored for 2 decades. He has produced an epic worthy of those labors.

The book is dense and occasionally poorly organized. It is not an easy read—it's a reference textbook, not a tutorial. Every chapter is extensively footnoted and has a bibliography. Fortunately, each chapter also has a single page of recommendations, and there is an extensive index of a few thousand entries. At about $40, this book is a bargain; if any regular textbook publisher produced it, it would cost several times as much.

Are Black and White Resin-Coated Papers as Permanent as Fiber Papers?

News flash! I have good reason to believe that resin-coated (RC) papers offered today have a serious permanence problem. Untoned B&W RC prints on display in frames may develop bronzing (image turning yellow-brown) and silvery blemishes in a matter of a few months to a few years. I've seen prints visibly deteriorate in as little as 4 months! I've completed experiments proving that the prints literally self-destruct. In many cases, the culprit is not air pollution or chemical contamination. I've seen damaged prints on Agfa, Ilford, and Kodak RC papers. This is not theory; it's a real danger, and it's happened to me!

A sad tale led to my research. Laurie Toby Edison is a superb B&W photographer and printer (and my best friend) who lives in San Francisco. Laurie's collaborated with me on a series of works combining my color dye transfer prints with her B&W prints (Plate 32). She's also produced a successful book, *Women En Large: Images of Fat Nudes*,[2] has a touring show, and has many B&W prints in circulation. Her nudes and our collaborations have been bought by people all over the United States. We also have quite a few of these prints hanging in our own homes.

Laurie prints on two papers—fiber-based Ilford Gallerie and Agfa Multicontrast Premium RC. I don't use Gallerie, but I use a lot of Multicontrast; in fact, I was the one who introduced it to Laurie. In September of 1994, one of the owners of a collaboration work told me that Laurie's B&W print was "turning yellow." The owner shipped the work back to me the following month so we could replace the print. When Laurie and I examined the Agfa Multicontrast Premium RC print, we were shocked to see extensive tarnishing, bronzing, and silvering-out (mirror-like spots forming on the surface)! Plates 32 and 33 and Figure 12–1 illustrate these defects. The print had been on display for less than 2 years.

Figure 12–1 The same B&W print as seen in Plate 33, with the light placed so that it reflects off the print towards the viewer. The brightest patches are silvering-out spots, not highlights—note that the position of the mirrorlike bright spots corresponds to high-image-density areas in Plate 33. To the human eye, silvery spots like these are usually the first obvious sign of print damage because they're readily seen when light bounces off them. The overall low contrast print in this illustration (and Figure 12–3) is because the paper surface itself reflects a lot of light, so we're looking through veiling glare.

I had another matted-and-framed copy of that work in my closet. I examined it and found that the B&W print in it was in pristine condition. All the other collaborations we had framed and stored away looked fine. So did all of Laurie's as-yet-unframed prints that were still in storage boxes. Because Laurie and I both work to exacting archival standards, we hoped this was a fluke. No such luck.

2. Laurie may be reached by phone (415-826-8262) or e-mail (ltedison@candydarling.com). Her Web site is at http://www.candydarling.com/lte. For information on ordering *Women En Large: Images of Fat Nudes*, write to: Books in Focus, P.O. Box 77005, San Francisco, CA 94107 (ph: 1-800-463-6285, URL: http://www.candydarling.com/wel).

We inspected all the B&W prints on our walls, both Laurie's nudes and prints in our collaborations. The prints made on Gallerie paper looked fine, but every one of the Agfa RC prints was visibly deteriorating. None of the works had been on display for more than 2 years, many for only 6 months. We'd framed all of them under acrylic and used only archival materials.

I called all the customers who had collaborations hanging in their homes and asked them to closely inspect the B&W print. Every Agfa RC print was deteriorating. In one very significant case, the collaboration that hung in someone's home was absolutely identical to one in my closet. Laurie and I had made the prints for both copies at the same time from the same boxes of materials. I had matted and framed the two works on the same day and had used the same batches of framing materials for both. The displayed work had deteriorated; the closeted one hadn't.

The deteriorating prints came from several different emulsion runs of paper used over more than a year's time. They hung in a wide range of locations. Laurie lives in a flat in San Francisco. I live in a house in the suburbs outside San Francisco. The customer who first reported this problem hung the work in her office in Princeton, New Jersey. We had other prints silvering-out in homes in central Minneapolis, in Minnesota farm country, and in apartments in the south of Silicon Valley. Whatever attacked these prints was present in many parts of the country and display environments.

This was a nightmare. Short of being unable to make photographs at all, I cannot think of a worse fate than having my prints fall apart a year after people buy them. Our reputations and careers could have been destroyed. All that saved us was that every owner of a deteriorating work was someone who'd known us for years. Laurie and I both have reputations for producing work of extraordinary quality and for standing behind what we produce. Still, we had a big problem. The evidence suggested an inherent flaw in the materials, not mistakes in our handling of them, but that was hardly proven. I needed to do some serious research.

Background on RC Permanence

Twenty-odd years ago, when B&W RC papers started to become popular, manufacturers discovered that prints displayed for some length of time were breaking down. Images tarnished and silvered-out, and sometimes the base itself would develop cracking. Archival toning with selenium did not always protect the image; the attack was vigorous enough to penetrate selenium's normally protective coat. Strangely, framed prints suffered more from this problem than unframed ones did.

The source of the trouble was the opaque whitener used in RC papers. Fiber-base papers use barium sulfate (also known as baryta) as the white pigment layer between the emulsion and the paper base. For a variety of reasons, baryta isn't suitable for RC papers. RC paper manufacturers use titanium white (titanium dioxide, TiO_2). Titanium white is a photoactive compound. A molecule of it can absorb a photon of light and go into an energetically excited state. It can transfer that energy to other molecules including oxygen. The excited oxygen is highly reactive and forms peroxides and ozone, a highly oxidizing molecule containing three atoms of oxygen.

The oxidants attack the polyethylene layer under the print emulsion (the "resin" in resin-coated), which makes it brittle and produces cracking and crazing when enough of the polymer bonds are damaged. The oxidants also attack the fine silver particles in the image and convert them into mobile, unstable silver compounds. When these compounds migrate to the surface of the print, they readily react with reducing agents. The silver either plates out as a shiny layer of metallic silver, breaks down into superfine particles (colloidal silver), which look brown or yellow instead of black or reacts with sulfur compounds in the air to produce brownish silver sulfides. Sulfur compounds are ubiquitous in human societies in small concentrations and are a given in any display environment. Framing makes the problem worse because it creates a small, dead-air space in front of the print, where oxidants generated by the TiO_2 can accumulate and attack the image.

Everyone agrees on this much of the history, although few talked about it openly at the time. David Vestal, in the late 1970s, produced the only public account of this problem I know of. Kodak, Ilford, and Agfa stayed silent, but once they characterized the problem they redesigned their papers to use much less titanium white and they incorporated antioxidants. By the late 1980s most of us thought and stated that the RC print problem was solved, that self-oxidation was a thing of the past.

Henry Wilhelm, the notable exception, stated all along that there was a continuing problem. In *The Permanence and Care of Color Photographs*, he discussed the light deterioration problem at length and specifically recommended against displaying RC prints. He included illustrations showing light deterioration and presented evidence that accelerated testing did not predict long-term print stability. The only RC paper he considered might be acceptable was Kodak's Polymax paper.

Several important researchers and I now believe that we were wrong and that Henry was right. Henry now believes that even Kodak RC papers are inherently unstable when untoned prints are on framed display. My work, and that of at least one paper manufacturer, confirm Henry's suspicions.

Grass-Roots Experimentation

Returning to our immediate problem, Laurie and I had prints going bad at a ferocious pace. We didn't know why, and we didn't know how to fix it. First, we contacted Agfa. At times like these, it helps being a respected and (mostly) well-liked writer. Agfa took my complaints *very* seriously and has been most cooperative throughout this affair. Agfa's testing lab reported that the prints appeared to be properly processed but that the surface tarnish showed the presence of sulfides. The tarnish could have been initiated by oxidation, but it could also have been caused by poor washing or improper fixing. It could also be evidence of attack by atmospheric sulfides. Further tests showed our processing left only trace amounts of residual chemicals in the prints, well within archival standards. We'd eliminated bad processing as a possible explanation.

Since our pattern of faded and unfaded prints indicated that display was a factor, Agfa began a series of light-fade tests of their own. In less than a year (by mid-1995) these tests turned up evidence of light damage to some degree or another in prints from all the major paper manufacturers. Unfortunately, Agfa did not provide further information, so I don't know which papers they tested or what kind of deterioration they saw. Meanwhile, conversations with Kodak and Henry Wilhelm suggested that Kodak's Polymax RC paper might be the one paper on the market immune to light deterioration. Henry had no damage reports about this product as of early 1995, which was more than we could say about any other RC paper on the market. I decided to test it.

Agfa introduced me to Sistan, a product that seems to be virtually unknown in the United States (see Chapter 10, "Useful Tools," for information on how to use Sistan). According to Agfa's technical papers, Sistan not only prevents silver from migrating through the print, it uses it to build up a protective barrier at the points of attack. Sistan is *not* an antioxidant, nor does it convert image silver the way selenium and other toners do. Sistan's active ingredient is potassium thiocyanate. If soluble silver salts form in the emulsion, the potassium thiocyanate immediately reacts with them to form silver thiocyanate, which precipitates back onto the silver particle being attacked. This compound is insoluble, immobile, transparent, nearly insensitive to light, and resists oxidation. Rather than being an alternative form of toning, it seems like a good accompaniment, assuming there are no antagonistic reactions between the treatments. If toning's protective barrier is breached, Sistan should come in to plug the holes.

Laurie and I began the laborious process of reprinting several dozen images on fiber paper and on Kodak Polymax. We treated all prints with a light selenium toning followed by a bath in Sistan. I began a series of experiments to provide more conclusive evidence about what was going on. In June of 1995, I prepared three prints for

Figure 12–2 One of Laurie's nudes as it was set up for fade testing. The upper half of the print was lightly toned with selenium. After thorough washing, the left half of the print was treated in Sistan before drying. This procedure provided four different test conditions on the same print; clockwise from upper left: selenium toning and Sistan, selenium only, no special treatment, and Sistan only. The prepared print was returned to its matte and hung for light-fade testing. (© 1997 by Laurie Toby Edison)

testing—an Agfa Multicontrast Premium print just as Laurie had processed it, an Agfa print of Laurie's that had been thoroughly rewashed several months before the test, and a Kodak Polymax print of mine. All prints had been kept in the dark, and all appeared undamaged.

I marked each print off in quadrants (Fig. 12–2). I lightly toned half the print in selenium toner until a just-barely-visible color change took place. I thoroughly washed the print and bathed the orthogonal half of the print in Sistan solution for the recommended time. This procedure gave me four test regions on each print: a quadrant with no postwash treatment, one with selenium toning only, one with Sistan treatment only, and one that had both selenium and Sistan treatment.

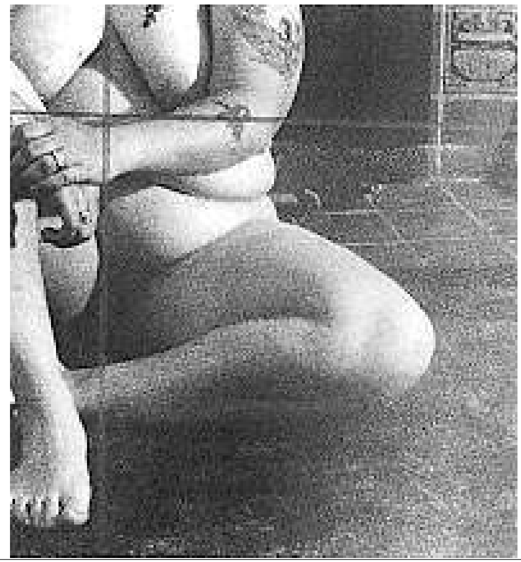

Figure 12–3 A close-up, by direct reflected light (as in Figure 12–1) of the lower-right (untreated) quadrant. After four years exposure to light, large numbers of silvering-out spots can be seen in the untreated quadrant. Bronzing (not visible in this photo) has also occurred. There's no evidence of deterioration in the other three quadrants. Note the very sharp boundary between silvered and undamaged sections, 1 mm to 2 mm below the line of visible toning. The slight amount of selenium toner that was sloshed over that line was enough to block silvering-out.

I put the three prints into frames with acid-free, unbuffered, 100%-rag mattes, backed them with aluminum foil to act as a chemical barrier against contamination from the rear, and covered them with acrylic. I hung them on the wall in a well-lit room. A large window provided ample daylight, but no direct sunlight ever hit them. At night, incandescent lamps lit the room. It wasn't a regulated environment, but the temperature was almost always between 65°F and 75°F, and the humidity was usually around 40% to 50%.

Both Agfa prints began to silver-out in their untreated quadrants in 6 to 8 months. The Kodak Polymax print started to show deterioration in its untreated quadrant after about a year. The level of damage in the Polymax print was at least an order of magnitude less than that in the Agfa prints, but its display life was still far short of archival or even acceptable.

After 2 years, all prints showed extensive silvering-out and bronze patches in each of their untreated quadrants, but there was no visible deterioration in any of the treated quadrants (Fig. 12–3). As of this writing, almost 6 years after the tests began, the three treated quadrants of all test prints still look fine. Postprocess treatments definitely inhibit light-induced oxidation. We still don't know whether these treatments prevent self-oxidation indefinitely, but Laurie and I are hopeful.

Back to the testing: because I treated the prints by holding them part way out of a tray of solution and gently agitating them, there was no sharp boundary between treated and untreated regions. Instead, there was a band a few millimeters wide, running from full treatment to no treatment. The very sharp line of demarcation between the damaged and undamaged regions indicates that even minimal treatment with selenium or Sistan is enough to confer protection against this kind of damage.

This test confirmed that I could reproduce the problem with more than one paper. It didn't pin down the cause. As I said, we had duplicate, unframed prints that were not on display and didn't show the same fading, but that wasn't a well-controlled test. I designed my next experiment to narrow down the possible sources of the problem.

In early 1996, I directly tested prints in the dark against ones in the light and prints in the open air against ones in frames. I constructed two special frames from acrylic sheets and solvent cement (Fig. 12–4). After assembling the frames I baked them at 175°F for over a day and then let them sit for another week to finish outgassing.

The frames were sealed on three sides and had a slot on the fourth into which I could insert a print. I took an untoned Agfa RC print of Laurie's and cut it in half. I slipped each piece halfway into one of the frames and sealed the slots with archival tape. I hung one frame in the light. The other frame went behind a dresser on the same wall, with a black cloth hung over it to block out all light. Then I waited.

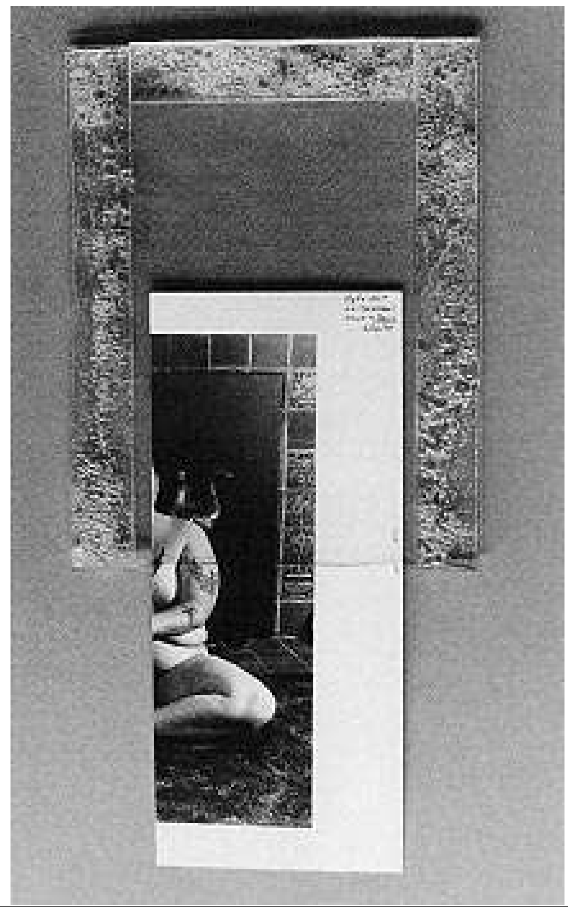

Figure 12–4 This is one of two acrylic slip-frames that I made for the second round of tests. The prints were fixed halfway into the frame, as shown, and the slot sealed. One such assembly was hung in the light, the other in the dark. The section of print inside the frame in the light deteriorated. None of the other print sections have to date. This is the most conclusive evidence demonstrating that atmospheric pollutants are not responsible for the deterioration and that light display is required to produce it.

After a matter of months, I began to see silvering-out in the portion of the print that was sealed in a frame and exposed to light. After over four years, I've seen no deterioration in the portion of the print hung in the light that was outside the frame or in either section of the print in the dark. What did this tell us? First, it proved that atmospheric pollutants were not causing the deterioration in my tests. Had they been, the print portions outside the frames would have deteriorated as much as or more than the ones inside because they were more exposed to freely circulating air. It also proved that light was necessary to produce the silvering-out because neither print section in the dark deteriorated.

Finally, I had clear evidence that something generated within the frame had attacked the prints only in the light. It wasn't produced by matte board or backing board because the frames contained none. There were three possibilities. Most probably it was the paper itself. Possibly, my baking and outgassing didn't drive out all the cement solvent, or the acrylic itself might produce a compound that attacked the print. I baked and outgassed the acrylic frames a second time when the enclosed, lit print started to show deterioration. Any residues left after the first bake cycle should have been driven out by the second. The enclosed print section in the light continued to deteriorate, which showed that solvent residues weren't causing the problem.

I set up a final test to settle the question about the acrylic. I constructed a glass-and-metal enclosure for another test print. I backed the print with aluminum foil and used steel spacers to keep the print from touching the glass in front. There was no other material inside the enclosure where the print was, no plastic, adhesive, or matte board. From a photographic viewpoint, the enclosure was chemically inert and unreactive. I set up that enclosed print in the light next to the others.

Within a year, that final test print began to silver out. The only possible source of the oxidants was the print itself. This settled the matter. There is a permanence problem with B&W RC prints, and it is inherent in the material.

To recap, my acrylic frame experiment proved that air pollution and matting boards weren't the cause of the deterioration and that light was necessary for the silvering-out to occur. My glass-and-metal frame experiment proved that the print itself had to be the source of the oxidants. Self-destruction was going on. My findings directly contradict the claims of some manufacturers, but they confirm what many conservationists have suspected.

What We Don't Know

We have many unanswered questions. The most obvious is why doesn't this happen to every untoned RC print on framed display? It certainly happens to many, but equally certainly, it never happens to many. What unknown factor determines whether a particular print will self-destruct? Or, to turn it around, why do Laurie and I have this happen every time?

Conservation science often uses medical analogies. For instance, we talk about performing "triage" on a collection—deciding which prints need and will benefit from immediate treatment, which ones are stable and can wait, and which ones are beyond saving. That kind of analogy applies here. My prints have been afflicted with a "disease" of unknown origin. I've proven that this illness requires light, but no other apparent external cause; it's self-induced.

It's as if I proved that the flu is caused by an infectious virus, but I can't explain why my housemate catches the flu and I don't. That doesn't disprove the virus theory; it shows that I don't understand how immune systems work or how other factors contribute to overall health and susceptibility. Similarly, I isolated a virus that causes RC print to self-destruct, but I cannot explain why some prints don't get sick.

Uniformly processed and handled prints don't deteriorate uniformly. Silvering-out and bronzing usually start in one area of the print or along one edge instead of gradually appearing over the entire face of the print. Deterioration may never hit some portions of the print; sometimes the boundary between the deteriorated and pristine portions is extremely sharp. Something either selectively attacks or protects the image in different parts of the same print. We have no idea what it is or how it works.

I also didn't prove that the culprit is the TiO_2. Since this problem appears in RC prints but not fiber-based prints, the finger of suspicion points that way, but that's not proof. We've only proven that RC prints have a special problem.

Henry tells me that he's not heard of any untoned prints that begin silvering-out later than 2 years or so after going on display. Therefore, if the problem is ever going to appear, it seems it will be within the first few years. Henry is not willing to make the same prediction for toned or Sistan-treated prints, though.

He also thinks that freshly processed prints may be more susceptible than prints that have sat around for months or years before they are displayed. Again, this doesn't refute my research, but it tells us that a lot is going on that we don't understand.

One hypothesis is that very slight sulfur contamination in the print helps protect the silver image against oxidation by coating the silver particles with a thin layer of silver sulfide. If so, it would explain why older prints are less susceptible—they acquire such a coating from the ubiquitous trace sulfur contaminants in the environment. Once that happens, they're more resistant. It might also be true that minute levels of residual fixer in the emulsion, within archival limits, work to protect some prints, and that better (or differently) washed prints don't have enough residual fixer to provide sulfide coatings. Maybe it will turn out that framing creates problems because it both traps oxidants *and* prevents environmental sulfur from getting to the print. We don't know, but we need to find out if we're ever going to defeat this problem.

On the Other Hand

Not all RC print deterioration is self-induced. Some, possibly most, *is* caused by air pollution. In 1996, in the Midwest, I visited an art institute and museum that was having serious problems with print deterioration. The head of their photography department showed me many Ilford Multigrade RC prints that were turning brown. The museum uses one of Ilford's dry-to-dry roller-transport processors to make publicity photographs and annual group photographs of the employees. Prints are given as keepsakes to each staff member. Many employees post the photos in their offices. Those photographs showed visible deterioration within a few months and serious reddening within a year. Some keepsake!

In this case, there's no doubt in my mind that air pollution caused the problem—"sick building syndrome" for photographs, if you will. The most significant clue was that the prints were turning reddish-brown everywhere *except* where there were fingerprints; those areas remained a pristine neutral gray. With a magnifier, I could even read the whorls and ridges in the fingerprint. It was the first time I'd ever seen a fingerprint protect a print! The oil in the fingerprint had obviously kept something from getting at the print, which meant the damaging compound was something external to the print. Since it was happening to unframed prints, it wasn't a framing problem; obviously, it was due to an airborne contaminant.

The machine's processing is exactly right and the wash is superb. Unfortunately, the processor does not allow any kind of postfix treatment, such as toner or Sistan. For production purposes, such as publicity photos and the annual gift photographs, it's simply not practical to hand-process the prints. There's no easy solution to their problem. Similarly displayed fiber-based prints showed no changes, even after several years of exposure, but fiber isn't feasible for production volumes.

What Can We Conclude?

I believe that incontrovertible evidence now exists to show that RC prints, as presently formulated, are inherently not as stable against deterioration as fiber-based prints. Some of this evidence is epidemiological. Researchers such as Henry and James Reilly of the Image Permanence Institute have increasing numbers of reports of displayed RC prints showing the kind of deterioration I've seen. We are not seeing comparable reports for fiber-based prints. The vast majority of prints made today are RC, but the ratio is not so extreme for framed prints on display. If fiber prints were as subject to deterioration, I am convinced we'd have a body of reports for them, too. We don't.

Kodak and Ilford both have taken official positions that disagree with this view. Kodak now acknowledges and accurately reports the history of the RC paper problem in *Black and White Tips and Techniques for Darkroom Enthusiasts* (Kodak Pub. 0-3, Sept. 1995). Kodak recommends toning for maximum print durability. Yet Kodak's public position is that the oxidant problem is solved and that RC prints are fully as stable on display as fiber-base prints. Ironically, Kodak bases its view on a report by James Reilly. I contacted Jim, who says that this report is about 6 years old. Then Jim believed that RC prints were as durable as fiber-based ones, as did I. He no longer believes this, based on reports and examples he's seen of the deterioration of prints on display independent of the work I've been doing. He believes that light is a contributing factor to modes of deterioration to which RC prints are far more susceptible.

Ilford does not acknowledge light as a primary factor in print deterioration; they attribute print deterioration almost entirely to pollutants and contamination. Ilford acknowledges oxidative fading as a potential source of trouble and (like other paper manufacturers) says, "We suggest toning the prints for the best protection of resin-coated papers."

The message conveyed is that toning merely improves an already good situation. Epidemiology and experiment indicate this is a highly misleading understatement. Postprocess treatment appears to be even more necessary for RC print permanence than does stabilization for color-film permanence.

Agfa officially holds a third point of view. Agfa has long experience studying oxidative deterioration—Agfa's Dr. Edith Weyde analyzed the "speckle disease" that began affecting microfilm in the late 1960s. Not surprisingly, Agfa gives the problem more importance than Ilford but doesn't address the part that light may play. Agfa does say that RC prints may show deterioration more readily than fiber prints because the solubilized silver in a fiber print can migrate, unseen, into the base. In an RC paper, the mobile silver would mostly migrate to the print surface.

Agfa recommends toning prints or treating them with Sistan for maximum permanence. In their public literature, Agfa doesn't suggest that untreated RC prints are in serious jeopardy unless they're exposed to pollutants. However, in its more technical literature, Agfa strongly advises protective postprocess treatment for all silver images, film, and paper.

But this is an area of constantly changing knowledge. In 1997, I learned that Agfa researchers had been studying this problem as a result of my observations, and that they had concluded my analysis was largely correct. In particular, untreated, framed RC prints exposed to light are at risk and can silver-out or bronze in the manner I report. One interesting possibility is that prints that are framed within a few hours of production are more at risk than ones that sit around for even a few days.

Agfa's research said the source of the trouble *was* a reaction between the TiO_2 and the silver particles that form the image. What is more important, Agfa quietly took steps to try to address this problem. They stopped delivery of Agfa Multicontrast Premium paper while they changed the formula and added compounds to the emulsion that were supposed to retard this type of deterioration.

Today's Agfa Multicontrast Premium paper should exhibit improved light stability, making it comparable to other RC papers on the market. While that may sound like damning with very faint praise, it's clear to me that Agfa is taking this seriously. I would like to see some evidence of the same from other paper manufacturers.

The manufacturers' disagreements do not come entirely from wishful thinking. Most permanence tests rely on accelerated aging (aging under conditions of intense light, heat, and/or humidity) or fuming tests using peroxide compounds. Some modes of deterioration do not accelerate. In particular, deterioration involving exposure to light often turns out to have a rate-limiting step in the chain of reactions that prevents the deterioration from occurring rapidly regardless of the amount of light.

As an analogy, think of many water hoses of various sizes hooked together, with a narrow hose in the middle. When you turn on the tap, water starts to come out of the far end of the chain. As you open the valve more, the flow rate from the end increases a bit, but you quickly reach the carrying capacity of the narrow hose. From that point on, opening the tap more doesn't increase the output, nor does putting larger hoses before or after the narrow one. The narrow hose is analogous to a rate-limiting reaction step.

That's precisely why (as Henry Wilhelm showed many years ago) turning up the light to 100 times normal intensity doesn't let us reproduce the deterioration in a matter of days instead of years. Forced oxidation tests also don't give the same results as normal-condition tests. My tests show that weak selenium toning or treatment with Sistan strongly inhibits light deterioration, but I've seen in the past that weak selenium toning does not protect against heavy concentrations of oxidants. Jim Reilly reports work indicating that neither weak selenium toning nor Sistan is effective against strong atmospheric pollutants for any B&W print. To protect prints against concentrated attack, heavy image conversion during toning (e.g., with selenium or polysulfide toners) seems to be necessary.

These are important matters, although they're peripheral (I think!) to my investigation. I mention them because it's important that you not generalize my experiences and results to conditions beyond those I've examined. For example, just because I find a treatment that seems to be effective against light-driven oxidation, it doesn't mean it will protect a print against air pollution.

Lack of accelerated tests creates a real problem! Suppose manufacturers can make papers that take 5 or 10 years to bronze or silver out. We still don't have anything resembling an archival print, but to uncover such a problem we'd have to test paper samples for longer than the typical production lifetime of the paper. Nonetheless, I think the paper makers have been remiss in not identifying and warning us about a mode of deterioration that can take place in less than a year. That's not excusable; it's barely credible. Manufacturers' recommendations about toning are so watered-down as to be misleading. We went through this in the 1960s and 1970s when we discovered that the disclaimer on color materials—"color dyes may fade in time"—should have read "color dyes *will* fade in time, and frequently that time will not be very long."

All B&W paper manufacturers should urge postwash treatments for displayed prints just as they urge stabilizer for color-film processes. It's not merely advisory—they make it very clear that failing to stabilize films compromises their permanence. Correspondingly, manufacturers should stop saying that weak toning (or Sistan treatment) merely "improves" print permanence. They should state directly that display permanence will be unacceptable if one doesn't perform these steps.

To summarize what I've learned:

1. Framed and displayed prints made on untoned Agfa Multicontrast Premium and Kodak Polymax papers develop silver and bronze blemishes that similarly framed fiber-based prints do not. Reports by others also implicate Ilford RC papers; no manufacturer is free of this problem.

2. Deterioration occurs only when the prints are exposed to light; identically prepared works kept in the dark do not deteriorate.

3. Deterioration occurs only with framed prints; unframed prints exposed to the same ambient conditions do not deteriorate.

4. The source of the damaging agent is the print itself, not the frame. The prints self-oxidize on exposure to light. The frame confines the generated oxidants near the print.

5. Prints that have been lightly selenium-toned and/or treated with Sistan show no deterioration (so far).

6. Many prints on display never show this kind of deterioration. We do not know why some prints deteriorate and others do not.

7. There are other types of deterioration that are due to airborne contaminants, to which some RC prints are more susceptible than fiber-based prints.

At this time, on the basis of Henry and Jim's collected data and my tests, I believe that all RC papers on the market can suffer problems in a moderately short time on display, regardless of the manufacturers' claims to the contrary. Unfortunately, we don't yet know whether Sistan and/or mild toning completely stops the image deterioration. We don't know whether either treatment protects the polyethylene layer. I suspect not. And, we don't know whether low levels of oxidants will cause the emulsion to crack 20 or 30 years from now.

It would be nice to say, "To blazes with RC papers." Unfortunately, every paper has its own unique look, and some of the looks I like the best come from RC papers. Should I make prints that look the best but may not last as long as prints that are artistically second-best? When "not as long" translates to "only a year or two," there's no question that such prints are unsuitable for serious work. But what if "not as long" turns out to be 25 years? It's no longer a simple question, is it?

Whatever you do, *don't* wait for me to give you the final word. Start toning your prints and using Sistan now. Otherwise, you could lose a lot of prints, time, and money. Laurie and I certainly did.

Many people provided advice, support, and commentary as I researched the causes of RC print deterioration. They do not necessarily agree with all my results, statements, or conclusions, but they've all been generous with their time and help: Henry Wilhelm, Stan Anderson, and Dr. Dick Dickerson of Eastman Kodak, the folks at Agfa, and Jim Reilly of the Image Permanence Institute.

Presentation Factors That Affect Permanence

Poor display techniques can do your prints considerable harm and sabotage your efforts to produce fine, long-lasting works of art. Henry Wilhelm's *The Permanence and Care of Color Photographs* addresses this complex subject well; accordingly, I limit my comments to the most common pitfalls.

As I say in Chapter 1, lighting is always a compromise. Incandescent lights do the least damage to prints; direct sunlight does the most. Fluorescent lamps are also deadly. If you know that your prints will be exposed to considerable amounts of daylight or fluorescent light, frame them under ultraviolet (UV)-absorbing acrylic. Depending on the kind of print and the display conditions, this can improve the display life of color prints by as much as 20% over prints covered with ordinary glass, and 50% over prints that have no covering at all.

Many modern chromogenic papers don't gain a lot from UV-absorbing acrylic because these materials already include some degree of UV protection. The improvement seems to be greatest with prints that are inherently longer-lived, such as Ilfochrome and dye transfer prints.

As a rule, inkjet and color-copier prints do not have this built-in UV protection. Even ordinary glass may more than double their display life; UV-absorbing acrylic is even more effective.

Covering B&W RC prints may create other hazards (see Chapter 12). Do not display untoned prints under glass or plastic; they should never be displayed or exposed to the elements.

Be careful about the materials you use for framing. Wood contains compounds that break down and volatilize over time and that are very damaging to all print types. Metal frames that are bare, anodized, or painted with baked enamel are safe. Spray-painted frames may or may not be safe, depending on how much the paint outgasses with time.

Always use archival museum-grade boards for matting prints. Do not use buffered board with color photographs of any type because the alkaline compounds in the board shorten print life. Buffered board is fine, even preferable, for modern B&W prints. Buy board from a reputable company that knows about photographic conservation, for example, Light Impressions.[3] Don't rely on your local art supply store to know photographically good board from bad.

Bainbridge Artcare is a new type of matte board. It acts as a chemical sponge to scavenge oxidants and acidic compounds in its vicinity. As of this writing, I don't know of tests on its suitability for photographic purposes, but I am very

3. Light Impressions, 439 Monroe Ave., Rochester, NY 14603, phone: 1-800-828-6216.

hopeful. It is certainly safe to use as long as the board does not directly touch the image area of the print. It may help preserve prints such as B&W RC prints that are at risk from self-generated oxidants. Artcare should help preserve your prints if there is something else in your frame that can release oxidizing compounds that would otherwise attack your print.

Be careful about your backing board. Fiber-based prints can pick up harmful compounds directly from the backing board. Compounds in the backing board can't directly diffuse into an RC print, but the board may still release volatile contaminants. I put an impermeable and chemically inert barrier between the board and the print, which permits me to use any convenient type of rigid board as the backing board. A sheet of drafting Mylar (available from any good art supply store) works very well. Even ordinary kitchen aluminum foil provides an inert barrier.

Finally, don't hang your prints in a freshly painted room. Latex paint airs out completely in a few days, but oil-based paints continue to release harmful compounds for months. You should also avoid working with lacquers and varnishes near your photographs; the solvents in these materials can damage prints, especially color.

CHAPTER 13

My Darkroom

Readers have an understandable curiosity about my darkroom. Over the years, I've designed 4.5 darkrooms. The first 0.5 was a kitchen/dinette in my small two-bedroom apartment more than 25 years ago. In the evenings, I'd black out the windows with a double layer of black plastic sheeting (available from gardening supply stores), drop a curtain over the door, put the trays on top of the stove, and use the enlarger set up on a small table. It wasn't a permanent darkroom, but I produced hundreds of 16" x 20" color prints therein.

I made my first serious darkroom in an enclosed, L-shaped utility porch that had a water hookup off a walk-up flat. I crammed in a Super Chromega Dichroic 4 x 5 enlarger, a long counter with shelves underneath and enough trays and chemicals to let me make 16" x 20" dye transfers, which I'd just taught myself how to do. The space was so narrow that my heftier housemate couldn't squeeze past the enlarger. It was dirty, drafty, and leaked light like a sieve. I solved those problems by stapling double sheets of black plastic to the ceilings and all the walls. Not only did it keep out light and wind, but I discovered that the plastic practically sucked dust out of the air and was easy to clean with a damp cloth.

The plastic also cut stray light fog to insignificant levels. Every enlarger leaks light, and I go to some lengths to baffle mine to keep any light from hitting the print easel. I can't entirely block light leaks upward or to the sides without interfering with the airflow over the lamp. White walls and ceilings would bounce that light back onto my print paper. Black shiny plastic sends all the errant rays into oblivion.

Figure 13–1 The photographs in Figures 13–1 through 13–3 show nearly a 360° view of my darkroom. Note the liberal use of shiny black plastic.

When I bought a house in 1985, I finally had a chance to make a darkroom exactly the way I wanted. My original plan was to have a contractor put in a room on the lower-level corner where the laundry hookup was, but that would take time and money. I was low on the latter, and I wanted to be up-and-running in 2 weeks. As a temporary measure, I put up temporary wall frames made of 2 x 4s with a door and frame I picked up cheap.

Guess what went over both sides of the frame and the ceiling? Guess what I'm still using? That "temporary" frame covered with plastic has served me so well I never got around to having a real room put in.

My black plastic walls have only two disadvantages: (1) there are only two real walls, so I can't mount anything heavy, such as shelves, on the faux ones; (2) black plastic sucks up light. My room, which measures about 12 x 15 feet, has 800 watts of overhead illumination for lights-on work.

I left the door white to make it easy to find in semi-darkness if there's an emergency (Fig. 13–1). Above is a suspended pipe with film clips; I use it for hanging film and prints to dry. The films looped up there are test images for various projects I'm in the midst of analyzing. Most will be trashed when I'm through. I pull film with "real" photographs down within a day or two of processing because I'm fanatical about filing and proofing my negatives.

The gray table in mid-scene holds my 8 x 10 cold-light head (left), miscellaneous printing aids such as my proofing easel, bottles of PEC-12, negative sleeves, and the like. On the faux wall are my negative carriers hung on nails driven through the plastic into the 2 x 4s. To the right (far left in Figure 13–1) is my printing area with my wall-mounted Beseler 45 VX-L chassis and a

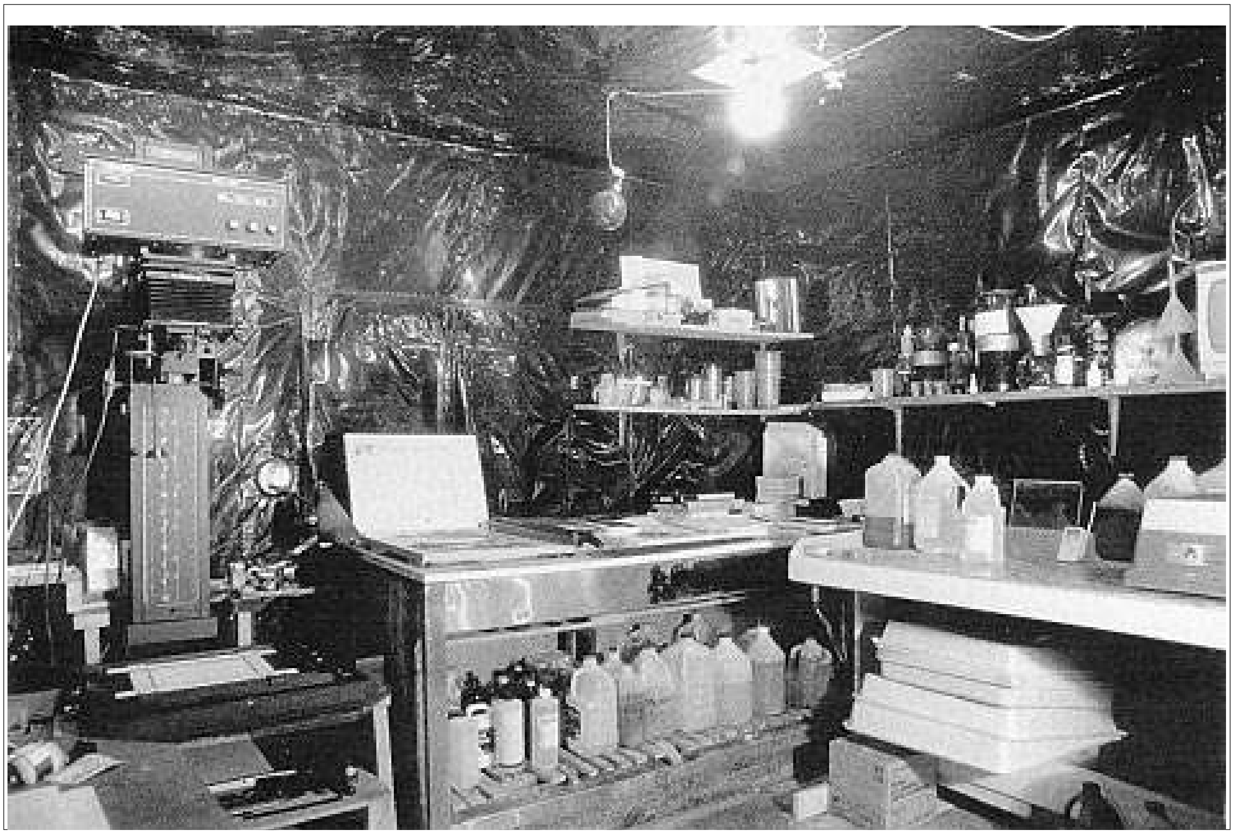

Figure 13–2 I mounted my enlarger as far from any wet materials as possible. I've never had chemical or water spots appear on prints during processing, and I hope I never do.

Dichro 45S color head. On and around the printing table are my vacuum easel (for making dye transfer matrices), a four-blade adjustable easel (for conventional prints), and tools such as timers, filters, focusers, dust brushes, and dodging and burning-in aids. There's a small gooseneck lamp wall-mounted next to the enlarger for checking negatives for dust.

Next to the enlarger is the film and paper counter (Fig. 13–2). There's a light box against the (real) wall and a large paper cutter in front of it. Here reside boxes of paper, processing manuals, printing notebooks, and dodging film masks. In the far corner are the shelves for film processing tanks, plastic graduates, notebooks, spare bulbs, and other miscellany.

The light gray table to the right in Figure 13–2 is actually a motorized rocking table. When I make dye transfer prints, the trays of dye on the table gently rock back and forth, saving me the trouble of manually agitating them to dye the matrices. Currently on the table are chemistry jugs, a digi-thermo thermometer, and my souped-up-for-RA-4 RCP-20 print processor.

Below the table are the large trays I use for dye-transfer work and for 20" x 24" developing. The shelf above holds small color drums and more assorted glassware and processing aids. To the right (Fig. 13–3) is a small black-and-white television set, an electric heater (average unheated temperature is a too-chilly-for-me 60°F to 65°F), and a clock radio. Perched on the radio are squeeze bottles of dye and an ancient HP-67 pocket computer, which now serves as a processing timer because it has glowing red LEDs I can read in the dark.

Next to the rocking table are waterproof countertops, a cart to hold smaller processing trays and print transfer easels, and a utility sink. I recently installed a secondhand

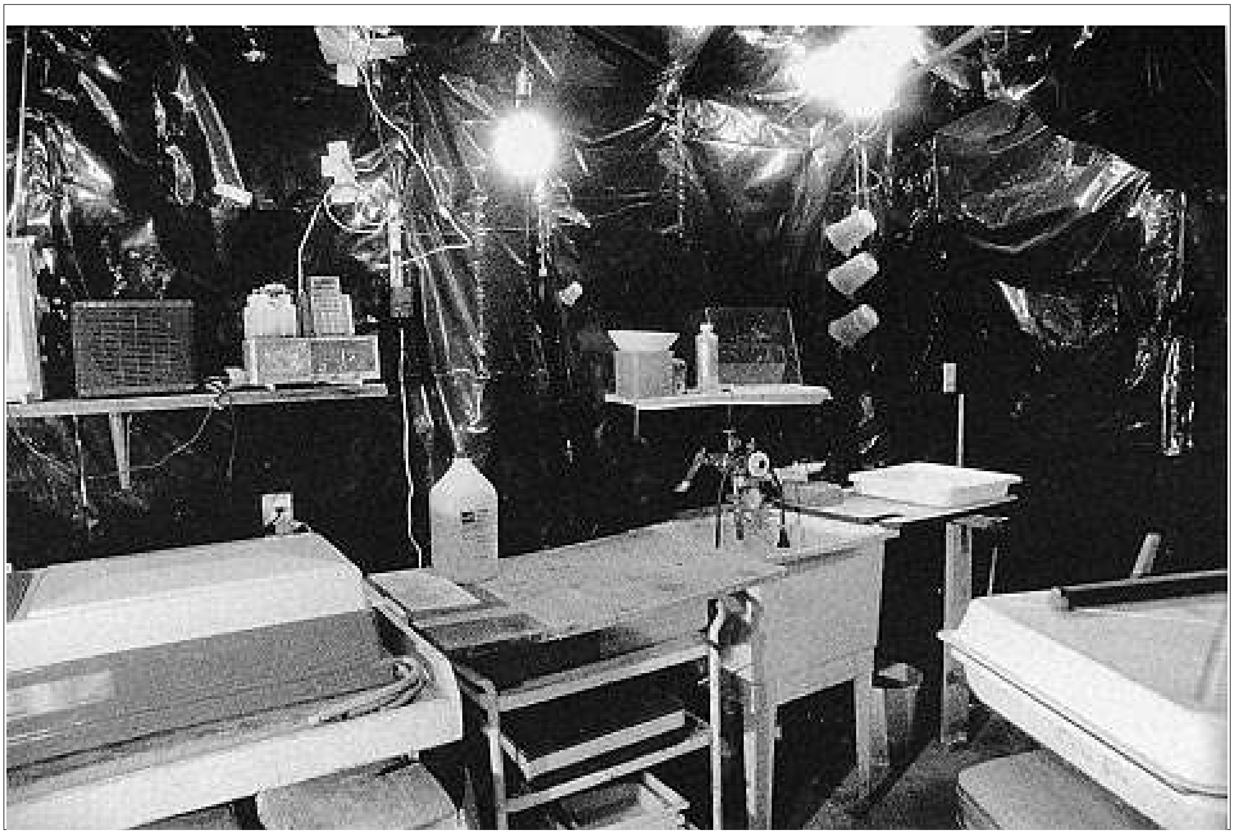

Figure 13–3 The darkroom is set up for RA-4 processing. When I'm making dye transfer prints almost every square inch of counter space has a tray or a transfer easel on it.

temperature-control valve and water filters. Nails driven into the wall support wet beakers while they dry. The little shelf above the sink holds small beakers of solutions, a bottle of glacial acetic acid (I use gallons of 1% acid in dye transfer work), and a book holder to prop up magazines for me to read while I develop film, wash prints, or make dye transfers.

Most of my supplies are not in the darkroom. There's my famous deep-freeze, loaded with the world's last supply of Pan Matrix Film, rolls of color film, boxes of color paper, and my older negatives, all deep-frozen to slow deterioration. There are shelves of B&W paper and film, many boxes of photographic chemicals, and dozens of 40-inch-wide rolls and 250-sheet boxes of double-weight 20" x 24" dye transfer paper. The darkroom is where I work; it doesn't have to be where my supplies live.

Are you surprised that I don't have a state-of-the-art photographic laboratory, equipped with the most modern and expensive of equipment? Yes, I'd certainly love to have that. Unfortunately, I'm not independently wealthy; fortunately, fine printmaking doesn't demand it. I have only two luxuries in my darkroom: a lot of space and a very nice enlarger. Don't let your unrealized dreams of a perfect darkroom inhibit your printing. Luxury is nice, but it's rarely a necessity.

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Photography

Post Exposure, Second Edition

Advanced Techniques for the Photographic Printer

Ctein

Written by an expert printmaker, *Post Exposure, Second Edition* teaches photographers the underlying principles as well as practices needed to produce truly excellent photography prints. Distilled from over thirty years experience and addressing both black-and-white and color printing, its purpose is to teach photographers the refinements of photographic printmaking, taking them from making merely competent prints to making excellent ones. The book provides clear explanations of principles and theory, but the focus is on practical techniques and examples of fine printmaking.

In keeping with the level of technical excellence of the previous edition, this new edition has been expanded and updated to provide the reader with detailed technical. This new edition includes: a section on the differences in producing prints with various enlarger heads; an updated "Tricks of the Trade" section, covering safelight fogging, adequate wash steps in reversal print processing, and using litho film masks for dodging and burning in; and new coverage on how to do split-filter printing, and how to use Sistan and color film masking.

Praise for Post Exposure:
"The short review is this: buy the book. It is not just another how-to-book, but is filled with theoretical backgrounds to a wide range of photographic questions; it will be an invaluable reference work on your shelves. The section on development inhibiting couplers, for example, is brilliant."
– Shutterbug

"Step-by-step, detail by intricate detail, Ctein takes us from the very beginning of the photographic process, to the most advanced and sophisticated techniques as no other author ever has. From subjects as essential as determining if an enlarging lens is properly centered, to procedures taking the image from exposure to the making of the fine print, Ctein leaves no detail unexplored and wipes away long perpetuated ideas that have no basis in fact. This book will be the key reference text in just about every darkroom dedicated to quality work. It is truly a masterpiece of technical analysis and instruction that answers every elusive question photographers have long wondered about."
-Arthur Kramer, author of "Kramer's Korner" for Camera 35, "View from Kramer" in Modern Photography, and "Pro View" in Popular Photography.

"*Post Exposure* provides unique background information for printers, including all of Ctein's significant researches into a variety of issues of importance to serious darkroom workers. More intelligent and scientifically literate by far *than the standard fare, it is the best such synopsis to be found in any current book directed at a lay audience. Post Exposure* is the essence of Ctein's distinguished career as one of the nation's leading magazine writers on photographic technique."
-Mike Johnson, editor, PHOTO Techniques

Ctein is a photographer and artist. He has a degree in both English and Physics from Caltech and has written over 150 articles and manuals on photographic topics for such magazines as *Photo Techniques* and *Darkroom User*. Specializing in dye transfer printing, Ctein has been recognized as one of Kodak's featured photographers.

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