

Sensitometry Primer

Part III: Film Testing Procedures

By Phil Davis

If you worked through the paper testing procedure I outlined in the last article, you have discovered the effective contrast of your chosen paper, as indicated by its ES and ISO Range values. That information is important because it defines the density range (DR) of a negative that will print easily and well on that paper. In other words, you now know what the density range, (or relative contrast) of a *perfect* negative is for your purposes. A careful sensitometric test of your favorite film and developer will give you the working information you need to produce negatives that will *fit* your paper most of the time.

It's possible to use rollfilm for this test but it complicates things a little so I'll assume that you're using 4x5 sheet film. If you normally work with larger sheet sizes, I suggest that you cut a sheet or two down for the test. You'll need a minimum of six 4x5 sheets.

The procedure is somewhat similar to the paper test routine I described in the March/April 1988 issue. The step tablet is again used to provide the necessary range of exposures but, instead of exposing only a single test strip as you did in the paper test, you'll need to expose several sheets of film. That's because papers and films respond to development differently. Prints must always be developed nearly to *completion* to produce a full range of image tones, so varying development time is not a useful control. This is not the case with films. Negative DR increases steadily during development and we almost always stop film development long before it's run its full course. So you must sample development times to learn which range of times is practical.

If you have not yet masked your step tablet do it now, using heavy, translucent paper such as the Kraft paper that grocery bags are made of. A moderately

translucent paper is preferable to opaque paper because the film area surrounding the step tablet should be partially exposed so that the developer will have a typical amount of exposed emulsion to work on. An opaque mask will leave most of the negative area unaffected by the exposure and the developer won't

be exhausted at a *normal* rate. Alternately, an unmasked step tablet will allow most of the film area to be completely exposed and the developer will be abnormally exhausted during the test.

You can use your enlarger as a light source. Equip it with a moderately long lens (and appropriately adjusted con-



This photograph, showing University of Michigan students seining a stream, was made using a Nikon F camera and 28mm Nikkor lens.

densers if it's a condenser model), and raise it up until the projected light covers an area at least 16 inches in diameter. Focus the lens, then record the details of this setup in your notebook: lens focal length, condenser adjustment, and height of enlarger lens above the baseboard. That will let you use this same setup in subsequent tests without having to repeat the initial exposure calibration test.

This first time, though, you'll have to determine the test exposure by trial, just as you did in the paper test, but in this case you'll be printing by contact. Position your masked step tablet on the glass of your printing or proofing frame, with the emulsion side away from the glass, and tape it in place. Center the printing frame under the enlarger lens and devise some guides or stops on the baseboard so you can replace the frame in that position in the dark. Prepare working solutions of your chosen film

developer, stop bath and fixer, and bring them to your preferred temperature. I suggest that you also provide a tray of plain water to use as a pre-wetting bath before development. Set your darkroom timer for what you consider to be *normal* development time.

Set the enlarger lens aperture at $f/32$ and set your electronic enlarger timer to provide an exposure time of 0.5 second. Alternately, you can use a large-format lens in the enlarger with its shutter set to $\frac{1}{2}$ -second. Turn out the lights and place a sheet of film in the printing frame so that it faces the step tablet, emulsion-to-emulsion. Close the frame and position it face-up against the guides on the enlarger baseboard, centered under the lens. Punch the timer button to make the exposure.

Immerse the film in the presoak bath and agitate it there for one minute, then transfer it to the developer and agitate it by picking it out of the bath, draining

it for a second or two, and re-immersing it every 10 seconds or so for the duration of the development period. Rinse and fix the film normally, then wash it briefly and inspect the step tablet image against a good light. Correct exposure will produce a visible image for about 19 of the 21 steps. The last two steps should be clear. If exposure correction is necessary you can estimate it quite accurately by remembering that each step tablet step is equivalent to $\frac{1}{2}$ stop. For example, if you count only 12 steps you'll need to increase the exposure by 7 half-stops.

The problem is more difficult if all 21 steps are visibly toned because there's no way to know the extent of the overexposure. In this case it's best to repeat the test, reducing the exposure by a stop or two by raising the enlarger or stopping the lens down, or both. Don't reduce the exposure time to less than 0.3 or 0.4 seconds, since shorter times may not be

Figure 1

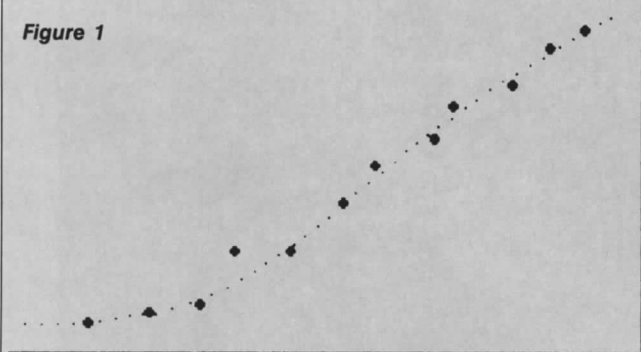


Figure 2

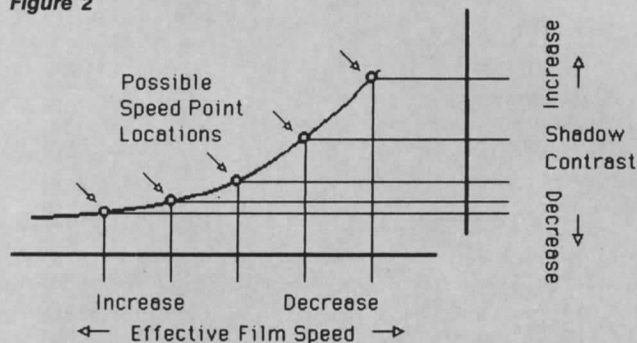


Figure 3

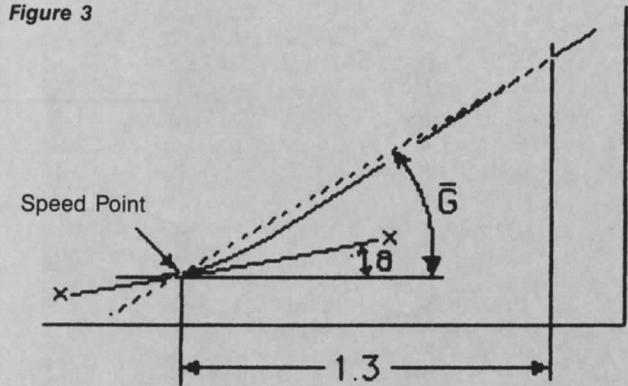


Figure 4

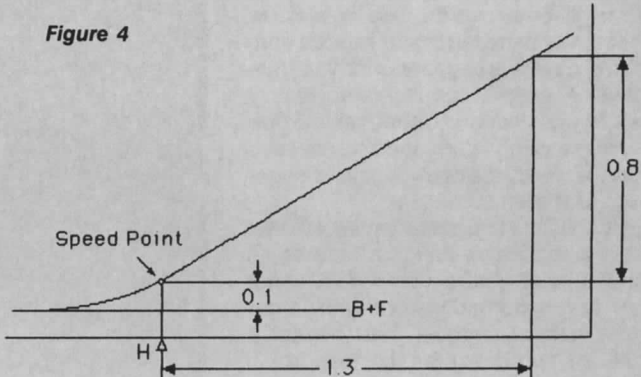


Figure 5

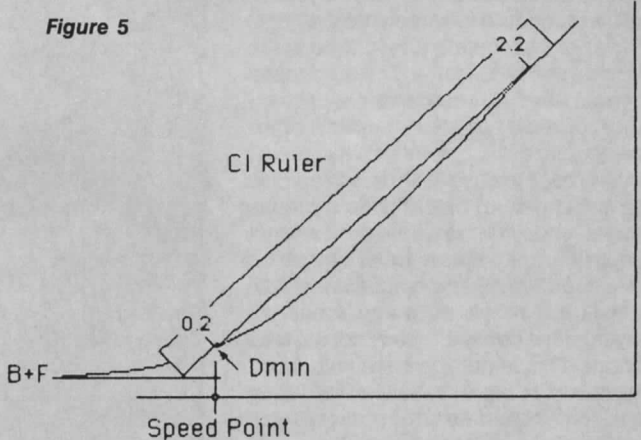
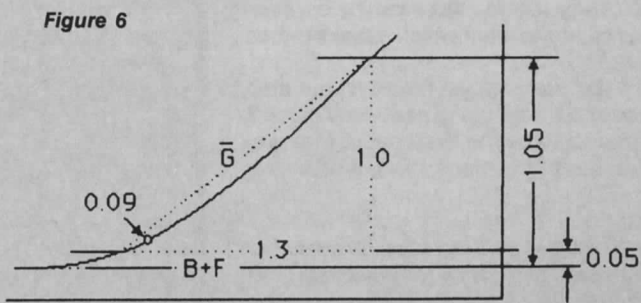


Figure 6



accurately repeatable. You probably won't have this problem if you've followed the exposure recommendations above because I've purposely minimized them.

When you've determined the proper test exposure, you're ready to proceed. You'll use 5 sheets of film for the test and develop in a tray, so I suggest that you prepare 20 ounces of working-strength developer (4 ounces for each 4x5 sheet), plus adequate amounts of presoak, stop and fixing baths. Adjust their temperatures to your chosen standard. I recommend setting the developer tray in a larger tray of tempered water—a little cooler than the standard temperature if the room is warm, and a little warmer than the standard if the room is cool. Plan to develop one of the films for your normal time, one for about half the normal time, one for about twice the normal time, and the other two for intermediate times. For example, if you consider 8 minutes to be normal, try times of 4, 6, 8, 12 and 16 minutes.

I recommend transferring the films from the presoak to the developer in quick succession so that they'll all start development at about the same time. Then remove one film to the stop bath as each time interval expires. If you're working alone and using a countdown timer such as the familiar GraLab, keeping track of these intervals can be a problem because as you proceed you'll have to subtract the accumulated times from the total to determine the next one. For example, if you use the time sequence I cited, the timer starts at an indicated time of 16 minutes; the first film comes out at 12, the second at 10, the third at 8, the fourth at 4 and the last at 0. One way to simplify this timing operation is to record your voice announcements of the times on tape—perhaps with intervals of music in between—and let your tape recorder talk you through the process.

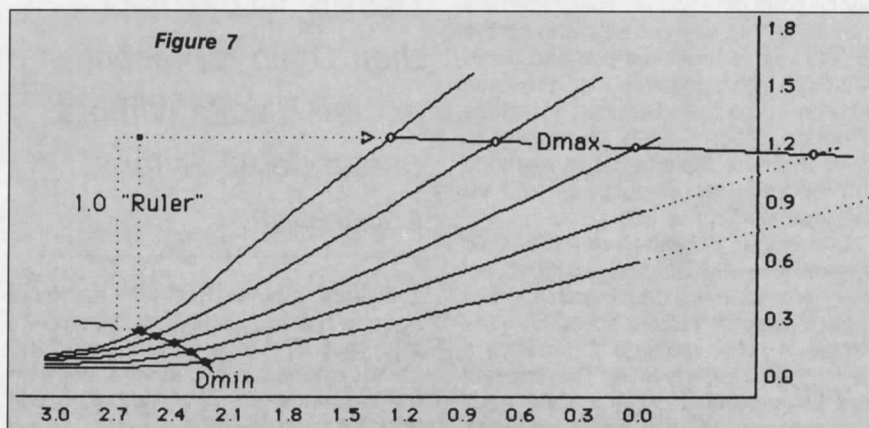
I recommend continuous agitation in the presoak and developer. Use any method that works for you. I prefer to develop the films emulsion up in the tray, and agitate by slipping the bottom film out from under the stack and placing it flat (not corner first) on top of the stack. Then gently push the stack down to cover the films with plenty of fresh developer before extracting the next film from the bottom. This agitation procedure should be repeated continuously throughout the development time at the initial rate of about one cycle every 3 or 4 seconds. That will bring each of the five films to the top of the stack, and in contact with fresh developer, for about 3 or 4 seconds every 15 to 20 seconds. Try to maintain this interval by slowing down your *shuffling* cycle after each film is removed to the stop bath. In other words, extend the cycle to about 5

seconds after the first film has been removed; to about 6 or 7 seconds after the second; to about 9 seconds after the third; and *lift and dunk* the last film once about every 15 or 20 seconds. This will help you avoid the effective increase in agitation frequency that will occur if you maintain a constant pace as the number of sheets decreases. Obviously this procedure won't duplicate your normal development routine but make it as realistic as you can.

As you remove each film from the developer, drop it into the stop bath (be

two or three points on each curve are seriously out of line, or if one or more of the curves is obviously out of place in the family. Don't take chances at this point—working data you derive from badly flawed curves will be misleading.

Analysis of the finished curve family may tax your mechanical drawing skills but it isn't particularly difficult. Begin by locating the Dmin points on the curve toes. If you've thought of sensitometry as a rigorous discipline, the process of placing these Dmin points may surprise you because although the proper loca-



sure to use an acid stop, not just plain water) and leave it there until all have been developed. Then transfer the films to the fixer and agitate them through several cycles before turning on the lights. Complete the fixing, washing and drying operations in your normal manner.

When the films are dry, read their individual step densities and plot those density values against their corresponding step tablet densities (or step numbers if you prefer), as you did in plotting the paper curves. There is no need to presort the negatives because the densitometer readings will sort them for you. If you've been reasonably careful in executing the test procedures the test densities should plot to form reasonably smooth curves and the individual curves should fit together comfortably in the family without touching each other.

However, there will undoubtedly be some "smoothing" to do. Minor errors in reading the densities of either the original step tablet or the test negatives will cause obvious lumps in the curves and these should be blended into the curve contours as gracefully as possible (Figure 1). Pay attention to the general shapes of the curves themselves and try not to distort them as you work. The curves should bear a distinct family resemblance and the spaces between them should be smoothly proportioned. Unless the curves are grossly distorted or actually cross each other, you can probably use them. On the other hand, it's better to repeat the test if more than

conditions can be described easily enough, there isn't any hard and fast rule for actually positioning them.

The shape of the curve toe region must obviously influence your decision. If you assume that the Dmin point must lie well up on the toe toward the straight line portion of the curve to insure good shadow separation, you'll have to accept reduced film speed and long printing times. If, on the other hand, you can be satisfied with somewhat less contrast in the shadows than is present in the middle tones, the Dmin point can be located farther down the toe contour. The result will be effectively higher film speed and reduced negative density for shorter printing times (Figure 2).

After wrestling with this problem for close to 50 years, researchers finally admitted that while scientific methods for locating the Dmin *speed point* could be formulated and applied easily, the resulting negatives didn't always yield satisfactory print quality. In an attempt to find a realistic solution, researcher L.A. Jones assembled a panel of viewers to identify the *first excellent prints* made from various films, variously exposed and developed. After careful analysis of the results he and his associates concluded that the minimum useful film exposure (for excellent print quality) resulted from placing Dmin at a point on the curve toe where—in very general terms—the shadow contrast was $\frac{3}{10}$ as great as the midtone contrast. More precisely, this located Dmin on the curve

toe at a point where the toe gradient, or slope, was $0.3 \times$ the average curve gradient ($0.3\bar{G}$) over a specified range (Figure 3). This so-called "fractional gradient" method of speed point location (with the addition of a substantial safety factor) was used for some time as an industry standard.

The main problem with the fractional gradient method is simply that it's extremely awkward to use. In the first place, any inaccuracy in the contour of the curve toe can cause serious error. In the second place, you can't locate the speed point until you've determined the curve's \bar{G} , but you can't determine the \bar{G} until you've located the speed point. Although it's possible to construct measuring gadgets that can solve this dilemma, it isn't really necessary to solve it. There are alternative methods that work well for our purposes and are more convenient to use.

In a paper published in 1956, C.N. Nelson and J.L. Simonds outlined another procedure for deriving an approximate fractional gradient speed from the exposure value required to produce a density of 0.1 over B+F. This method eventually evolved to become the basis for our current ISO film speed calibration standard (Figure 4).

It's tempting to conclude that, since the ISO standard places the speed point at 0.1 over film B+F on this one specific curve, it should be similarly located at 0.1 over B+F on all the curves in the family. In fact, I recommended that procedure in the first edition of my book, *Beyond The Zone System*. In practice, though, this leads to potentially severe overexposure of very long range subjects, possible underexposure of short range subjects, and excessive variation in the effective speed of the film as development is varied. Although these effects are generally tolerable they're undesirable. It is preferable to raise the Dmin point as curve gradient increases and lower it as gradient decreases. In other words, although the original fractional gradient method is too fussy to be generally useful, it was basically a good idea.

The popular Contrast Index (CI) method for locating Dmin (introduced by Kodak) combines the best of both systems. Although CI is still sensitive to erratic variations in curve toe contour, it requires only a simple "ruler" that you can make yourself and it's easy to use (Figure 5).

A similar, even simpler procedure is one that I call the "Fractional Density" method. It places the speed point at a density level that is a fixed fraction of the curve's average gradient (for example, $\frac{\bar{G}}{9}$) as measured between specific curve points that you can select as your personal standard. Although this method is not as elegant as the fractional gra-

dient or CI methods, I recommend it for personal testing and analysis because it's relatively unaffected by inaccuracies in toe contour, it's easy to use, and it produces negatives of consistent quality. It's also easy to adjust. If you find that your negatives are consistently too thin, divide \bar{G} by a number less than 9 to effectively increase film exposure. If your negatives are consistently too dense, use a number larger than 9 to reduce exposure.

Density values less than Dmin represent accent blacks without useful detail or tonal separation.

Assume that you'll use my fractional density method with a fraction of $\frac{\bar{G}}{9}$, and your ES value is 1.0. Taking the curves one at a time, locate a point on the toe that's 0.05 over B+F, then add your ES to 0.05 to find the density of a second point (1.05 over B+F). These points—0.05 and 0.05+ES—are arbitrary but they define a curve segment that's representative of a real negative and I suggest them as a standard. Now connect these two points with a straight line. This line can be considered to be the hypotenuse of a right triangle formed by dropping a vertical line from the upper point and projecting a horizontal line to the right from the lower point. Construct that triangle with light lines, then measure the base and altitude dimensions and calculate the slope of the hypotenuse by dividing the altitude dimension by the base dimension. That number is the average gradient value of that segment of the film curve. Now calculate $\frac{\bar{G}}{9}$ and mark the curve at that density level over B+F (Figure 6). Repeat this calculation for each of the curves and mark their speed points. Then connect these points with a smooth line and label it Dmin.

Again, this Dmin line marks the lower extreme of the useful image range. Densities greater than the Dmin value (with reason) will represent useful image tones. Density values less than Dmin represent accent blacks without useful detail or tonal separation. Remember that this distinction is an arbitrary one. It's usually possible to extract some useful tone from below the Dmin line and it's also possible to print down a negative so that some of the useful shadow tones that lie above Dmin are lost in black. But you have to make a decision, and the Dmin line you have

just drawn defines the boundary that you have chosen (at least temporarily) to separate accent black from image gray.

Now that Dmin has been located the worst is over. The corresponding Dmax value can be found by adding your paper's ES value to Dmin for each curve in turn. For example, if the Dmin value of a curve is 0.08 (over B+F) and your ES value is 1.0, the Dmax point should be located at a density level of 1.08 (over B+F) on that curve. If you cut a little strip of paper to the length of the ES in log units (1.0 in this case) you can use it as a ruler to find the vertical location of the Dmax point above Dmin. Then project this point horizontally until it touches the curve. Locate Dmax on each of the curves, then connect the points with a smooth line and label it Dmax (Figure 7).

You have now defined the *working range* of the film curve family for your personal use. The individual film curves represent the specific test developing times, but it's clear that other curves, representing intermediate times, can be drawn into the family quite readily. In other words, the curve family contains information not only about the five tested developing times but about any developing time within the tested range. But that's not all. In addition to the fact that the vertical separation between Dmin and Dmax on each curve identified your "ideal" DR for all possible negatives made with these materials within the test limits, the horizontal distance between Dmin and Dmax on each curve identifies the range of subject tones that will be included in the negative image. In short, your curve family can tell you what you can photograph with these materials, how you should expose and develop the film, and what tones the negative will contain.

In the next article I'll explain how to complete the curve analysis and how to extract actual working data for field use with a slightly unconventional version of the Zone System.

References

- Beyond the Zone System*, by Phil Davis (Curtis and London, 1981).
Sensitometry for Photographers, by Jack Eggleston (Focal Press, 1984).
"Simple Methods for Approximating the Fractional Gradient Speeds of Photographic Materials," C.N. Nelson and J.L. Simonds, *Journal of the Optical Society of America* (J.O.C.A.) Vol. 46, No. 5, May 1956. □

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