Sensitometry Primer

Part II: Paper Testing and Calibration

By Phil Davis

As I mentioned in the first article of this series, you can't do any sort of sensitometric analysis of your materials unless you have access to a densitometer. In fact, you really need two of them—one for measurements of negative (transmission) densities and one for print (reflection) densities—a combination of functions that can cost $2,000, more or less. If that's an unrealistic expense (as it will be for many of us) there are at least two alternatives: you can use someone else's equipment, or you can build your own.

Most photofinishing labs have fine densitometers. If there's a lab in your vicinity you may be able to persuade the owners to let you use their equipment occasionally, or they may offer to have a technician read your test samples for you. If your local community college offers a professional program in photography, their lab people may agree to let you make a few readings from time to time. If neither of these sources is available, try the local professional photographers. If you can find one who owns a densitometer he or she might be willing to help.

Whether the local sources are cooperative or not, you may prefer to work with homemade equipment and avoid the hassles of borrowing. Although some *real* densitometers are more accurate and easier to use than anything you can build, it is possible to convert almost any spotmeter into a densitometer that's both inexpensive and practical. The conversion unit is simple to build and the resulting instrument can be adapted easily for either transmission or reflection density readings. See Photo 1. Best of all, it doesn't require any modification of the spotmeter itself; simply slip the meter out of its support stand and it's ready for field use.

The design of the spotmeter adapter unit is quite flexible. You'll have to devise some sort of support stand to hold the meter firmly in position. Also, the meter will have to be equipped with a supplementary closeup lens so that it can focus on the test samples, and you must arrange a suitable light source. Plans and construction details for typical adapter units appear in my book, *Beyond The Zone System Workbook* (Focal Press, 80 Montvale Ave., Stoneham, MA 02180, 617-438-8464). With a little ingenuity you should be able to design and construct a similar adapter for your own meter. In this article and following ones, I'll assume you're using this spotmeter densitometer, but the discussion will not be limited to it.

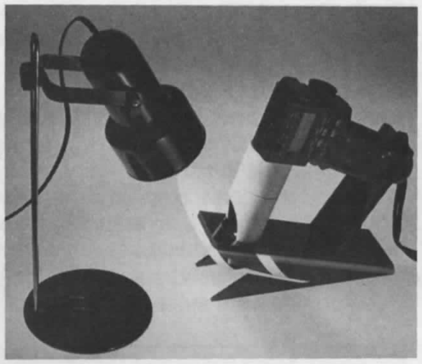

Photo 1

Image density measurements are useless unless you know what exposure values they represent. In laboratory sensitometry, the test materials are subjected to a range of accurately controlled exposures in an instrument called a *sensitometer.* You can provide a similar range of suitable exposure values by simply printing a photographic step tablet on your test material.

A typical step tablet is just a strip of film about 1 inch wide by 5½ inches long, bearing 21 transverse stripes (or steps) of increasing density from about 0.05 to about 3.05. The step densities increase more or less uniformly in increments of 0.15. Because the individual step densities can be measured accurately, and because the exposing light they transmit is inversely proportional to their opacity, the step tablet is, in effect, a calibrated light source. Printing it on your test material—either film or paper—will produce a 21-step *test strip* that represents an exposure range of about 10 stops. This range is much greater than necessary to test ordinary papers, and is also adequate for general-purpose films.

The best-known step tablet is probably the Kodak Photographic Step Tablet No. 2. You may have trouble finding one at an amateur camera store, but professional suppliers in large markets usually stock them. An uncalibrated Step Tablet No. 2 costs about $35. A calibrated step tablet, unnecessary using my technique, costs about twice as much. Functionally similar but less costly step tablets by other manufacturers (such as Stouffer) can be obtained from graphic arts supply houses.

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If you have a Kodak step tablet, number it along one edge, using carbon (India) drawing ink. Step No. 1 should be the least dense step and Step No. 21 the most dense. This won't be necessary if you have a Stouffer step tablet, because they're numbered during manufacture. Next, use your densitometer to read the transmission densities of the individual steps. Record the step numbers and their corresponding density values, and you're ready to begin testing.

Conventional Zone System procedures place a great deal of emphasis on film tests but it's a good idea to consider the printing paper first. That's because papers are relatively inflexible in use and the paper you choose to print on (and your printing method) will dictate the characteristics of the negatives you must make.

You can, of course, use variable contrast papers, or stock a variety of paper grades to accommodate negatives of any reasonable density range (contrast). This is normal procedure for rollfilm users but if you use sheet film you can standardize on a particular type and grade of paper and modify your negative-making procedures to fit it. This gives you somewhat more control over image characteristics and can make printing considerably easier.

In addition to their visual qualities—base tint, image color, surface texture, etc.—papers have several characteristics that affect their use or influence print quality. Maximum density (Dmax) is one of these. A high value implies that the paper can produce the deep black tones that are necessary to provide richness and emphasis in the print image. Dmax depends to a large extent on the characteristics of the paper emulsion itself but is also affected dramatically by the surface characteristics as shown in Figure 1. Most of the general-purpose papers commonly available can produce Dmax values of about 2.0 in semi-gloss or high-luster surfaces and some exhibition papers can exceed that value. The Dmax value of most papers is also affected noticeably by toning.

Another important characteristic is the exposure scale (ES). The ES value identifies the range of exposure values required to produce a full range of useful image tones, from accent white to accent black (Figure 2). Manufacturers have also used the ES measurement as the basis for assigning the familiar contrast grade numbers (Figure 3) although this relationship has been only a sort of *de facto* standard and not an official one.

The 1983 International Organization for Standardization (ISO) standard for black-and-white printing paper calibration, which was approved by ANSI (American National Standards Institute) in 1984, established a more useful method for indicating effective paper contrast. This new ISO Range value can be determined by multiplying the paper's ES value by 100, then rounding up or down to the nearest multiple of 10. For example, an ES value of 1.05 is expressed, after translation, as *ISO Range 110* or *ISO R110* (1.05×100=105, rounded up to 110). This method of expressing paper contrast is much more informative than conventional grade numbers and we can hope that it will supplement or replace them eventually.

Both DR and ES values are found by constructing and measuring the paper's characteristic curve. There is also, of course, a standard method for doing this, as shown in Figure 4. Use this general procedure as a guide in calibrating the characteristic curves you derive from your personal paper tests.

Your step tablet will fit comfortably in a 4×5 negative carrier but it won't fill the entire area. If you plan to test your paper for projection printing you should mask the step tablet with heavy paper so that no light can spill past it to cause flare (Photo 2). This mask is not necessary if you print by contact. If you have to cut the step tablet in half to fit it into a smaller negative carrier, cut it *through* a central step, not *between* steps. You'll lose only one step instead of two this way.

Place your masked step tablet in the enlarger, focus and adjust it so that the projected image is enlarged slightly. You'll probably have to make a preliminary test exposure to be sure the step tablet is recorded properly. Use an exposure time that's typical for your normal work and control the exposure by adjusting the aperture. This will avoid reciprocity effects that can skew the test results if the exposure time is excessively long or short.

The test exposure is usable when the visible steps in the developed image fall somewhere in the center of the total range. In other words, the image should include several steps of blank white (unexposed steps) and several of total black (overexposed). This will guarantee that you are indeed sampling the maximum range of the paper. You will probably need to make only a single test exposure because any necessary correction can usually be estimated quite accurately. Remember, each step interval is 0.15, which is equivalent to ½ stop. Therefore, if you want to shift the recorded image three steps farther toward the white end of the strip you'll have to increase the exposure by 1½ stops. When you have calculated a useful exposure (it's usually not very critical) expose, process and finish the test sample in your normal manner.

When the strip is dry, read its step densities and plot them against their corresponding step tablet steps, Figure 5. Notice that the x-axis (exposure axis) of the graph is calibrated in step tablet *density* values instead of the more usual increments of exposure. Again, that's because the step tablet steps, when transilluminated by the enlarger light, become *lights* of individual intensity that provide the test exposure values. We don't know the actual intensity of any of these luminous steps but we do know that each of them transmits a fraction of the light that is inversely proportional to the measurable opacity of the step itself. Therefore, we can safely assume that once the general exposure has been arrived at empirically, the individual step exposures can be calculated as *relative values*. That's really all we need to know

Figure 1

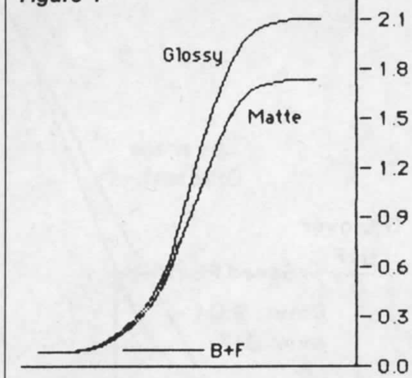


Figure 2

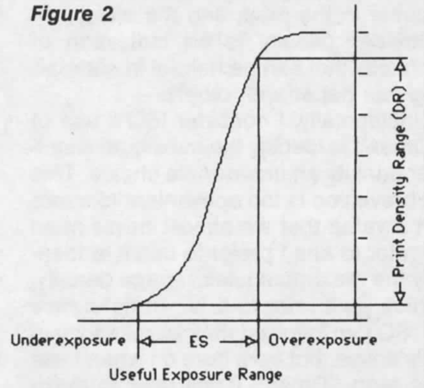
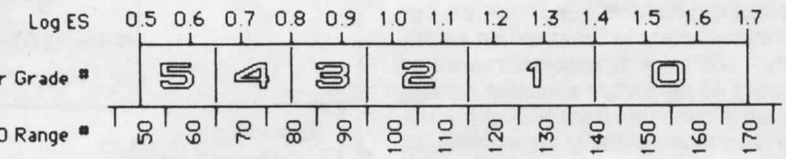


Figure 3



to determine the essential characteristics of the paper.

Notice also that the density axis is calibrated in both conventional density values and spotmeter scale numbers. In this example the spotmeter densitometer was *zeroed* by adjusting the light until the meter read 11 with no sample in place, so that 11 represents zero density. Then, for example, 10 on the meter scale, indicating a one-stop decrease in light intensity, represents 0.3 density; and 6⅓, which indicates 4⅔ stops less light than 11, represents an image density of 1.4. This is a convenient method for calibrating the y-axis because it eliminates the need to translate meter readings to density values while you're reading the steps. If you're using an analog meter (such as the Pentax Spotmeter V) you'll find it quite easy to estimate with useful accuracy even those density values that fall between the meter scale marks. You can also simplify the calibration by using only the step densities on the exposure axis. The extra scales are shown here only for illustration.

The paper curve's characteristics are determined by locating its Dmin and *useful* Dmax points as specified by the ISO standard. Dmin is located on the curve toe at an image density level of

0.04 over base-plus-fog. The upper limit of the image range is located at an image density level that's found by taking 90-percent of the maximum shoulder density (labeled Dmax in Figure 4), measured from the B+F line.

Vertical lines projected down from the curve points representing Dmin and the maximum image density define the useful exposure range, or ES. The ES value also defines the density range (DR) of a negative that will print easily and well on this paper. The paper's DR value indicates the range of useful grays that will appear in the print, and the maximum shoulder density is an indication of *richness* that can be helpful in comparing this paper with others.

Incidentally, I consider ISO's use of "Dmax" to identify the maximum shoulder density an unfortunate choice. This abbreviation is too convenient to waste on a value that we almost never need to refer to and I prefer to use it to identify the maximum *useful image* density, which we'll refer to a lot. In deference to ISO I've followed their terminology in this article, but from here on when I use the term "Dmax" it will refer to maximum *image* density, not the maximum density that the material is capable of producing. Used this way, Dmax is a logical complement to Dmin. When necessary, I will refer to *absolute* maximum density as maximum *shoulder* density. *Absolute* minimum density is, of course, the base+fog density of the material. Be advised that some photographers and writers may prefer different terminology.

Since you have no way of identifying the actual values of the test exposures you can't relate the test curve's speed point directly to any published value. You can, however, compare it with the speed points of other papers that you might test. In general, the lateral location of a curve in the graph space is an indication of its speed. If you plot several paper curves in the same graph space (assuming all received the same test exposure), the faster materials' curves will appear toward the left and the slower curves will be positioned toward the right along the exposure axis. The relative speeds are easy to determine from the exposure axis calibration. For example, if one curve's speed point is positioned 2 units (0.2) to the right of another, it must be ⅔ stop slower.

In practice, paper speeds are of fairly trivial importance for two reasons: in the first place, it's almost always easier and more effective to determine print exposure by making a quick test strip than it is to rely on some calculated exposure time based on the published paper speed. Second, although the manufacturers provide these speed numbers as a general indication of a material's sensitivity, they simply tell you how much relative exposure was required to produce a print gray density of 0.6 over B+F on the average of several samples of that particular emulsion batch. If you are basing your print exposure on the appraisal of some image detail that has a density of other than 0.6, the published paper speed may or may not (probably doesn't) apply.

In the next article I'll suggest some techniques for film testing and discuss film curve construction and analysis. In the meantime, test your favorite paper and determine its ES value. You'll need it to complete the film curve analysis. □

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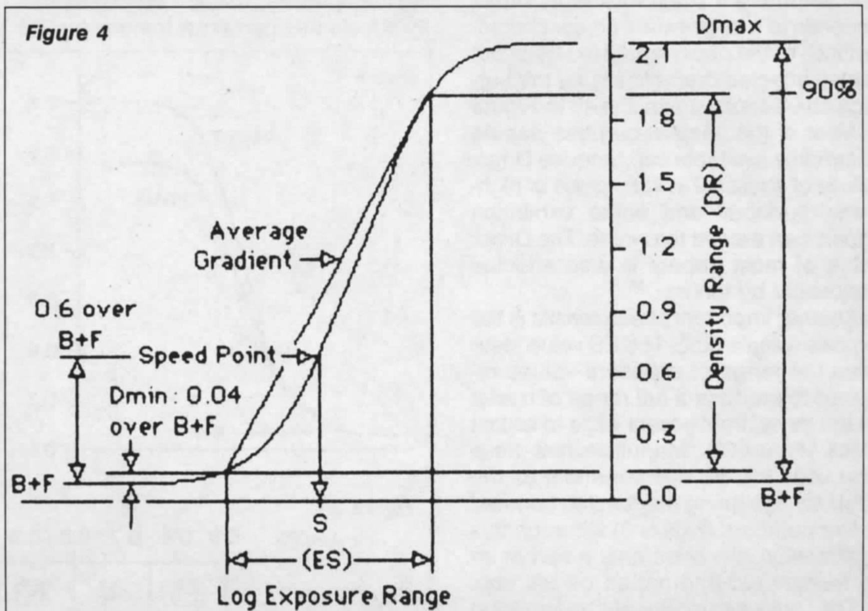

Figure 4

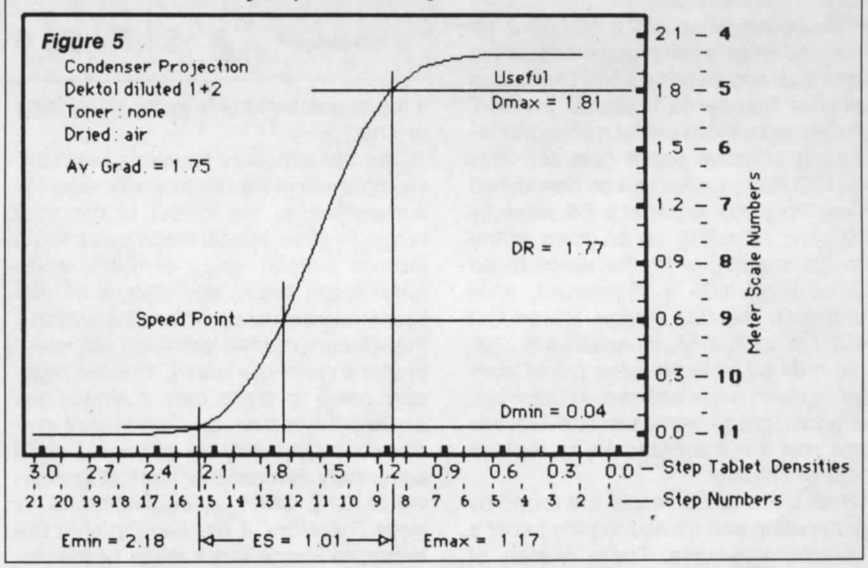

Figure 5

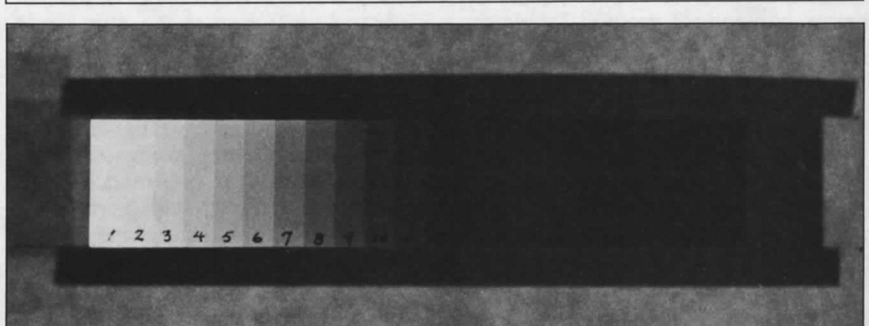
Photo 2

measly seconds make that much difference? I had *visions* of presenting mucky prints to the athletic department, prints made from negatives so thin you have to look at them under a microscope to see detail in the shadows.

I braced myself and went with the recommended development. Before the VR 400 (E.I. 1600) negatives had dried, I knew I was out of the woods. They were fine—not too thin and not too dense. Just right. *Whew!*

Evaulation

None of the pushed films produced perfect negatives. They won't give you prints that look like you exposed and processed them normally. If you want perfection, rent a studio and hire models. This is the real world, and a wet one at that.

The push processing increased the contrast of my flat subjects and resulted in normal negatives.

The prints from the normally processed VR 400 were excellent. This is my standard for outdoor sports, and, of course, that's what standard procedures are for: no surprises.

The VR 400 negatives pushed to 1600 look very much like their unpushed counterparts. The film base is slightly less pink and a bit more grayish. I had half-expected to see an increase in fog, but there was none. The contrast was normal. I was expecting to see a great increase in contrast, but it just didn't happen. This was helped, I'm sure, by the fact that I was photographing low contrast subjects, illuminated by heavy overcast sky. The push processing increased the contrast of my flat subjects and resulted in normal negatives.

The pushed VR 400 produced some of the best looking prints of the day. In my 8×10s, the grain is no more pronounced than the normally developed negatives. The colors are bright and true. I can't wait to try this technique on the new VR-G 400 film.

If anything, the Konica 3200 (processed normally) is slightly *overexposed*. The negatives looked a little dense, but the prints I made were terrific. If anything the ISO is a little conservative. How 'bout 4000 or 5000? You never know. It could be meter error.

I am very pleased with the prints I made from the Konica 3200 negatives. The prints are bright and the colors true. In an 8×10, you can see the grain, but it doesn't jump out at you. I was expecting the prints to be much grainier and would have tolerated even more of a salt-and-pepper look. Konica has a great new film here that's destined to help out a lot of people. Hmmm. I wonder what it'd be like pushed to 16,000.

The Kodak VR 1000 bumped to 4000 produced some fairly strange looking negatives. The film base is sort of pinkish gray. Or, grayish pink. I'm not sure which. These negatives are also a bit underexposed, and the prints look like they were made from underexposed negs. The blacks really aren't black. Overall though, the color is pretty good. I think rating the film at 2000 and using the same 3 ¾ minute development time would have done the trick.

The Agfa 1000 pushed two stops also produced very funny looking negatives. The base was kind of pink-orange gray. They also looked underexposed, but the prints were just fine. I'm very impressed. However, I think it could benefit from slightly more exposure. Rating it at 2000 would do the trick.

Conclusions

What I'm dealing with here are special purpose applications. It's a way out for those times when you can't see any daylight. Pun definitely intended.

When you are backed into a corner—low contrast and low-level illumination—one of these films can give you the results you need. Push processing (or using a very fast film) is a compromise, but need not produce unacceptable results. You can make a print from a negative exposed at 3200 that will please your editor or client. I did.

For me, it's a pretty easy solution, since I'm already using VR 400 processed normally for outdoor sports. When the clouds roll in, I'll reload with a fresh roll of VR 400 and set the meter to 1600. Your solution to the problem is likely to be altogether different.

I hope that in my tests, I've at least given you a jumping off point for conducting your personal tests. At the very least, I've shown there's no reason to turn up your nose at the thought of push-processing color negative film.

NOTE: Just before publication, I learned that Kodak is recommending up to a two-stop push with its new VR-G 400 film. I can't wait to give it a try. I did use the VR 400 (E.I. 1600) to photograph a Purdue basketball game. It allowed me to use my 135mm lens at f/2 for great close-ups of the players. My shutter speed was $1/250$ second. □

Contributing Editor and photographer/writer Robert Mitchell has invented many successful photographic products. He writes frequently on subjects concerning photographic technique.