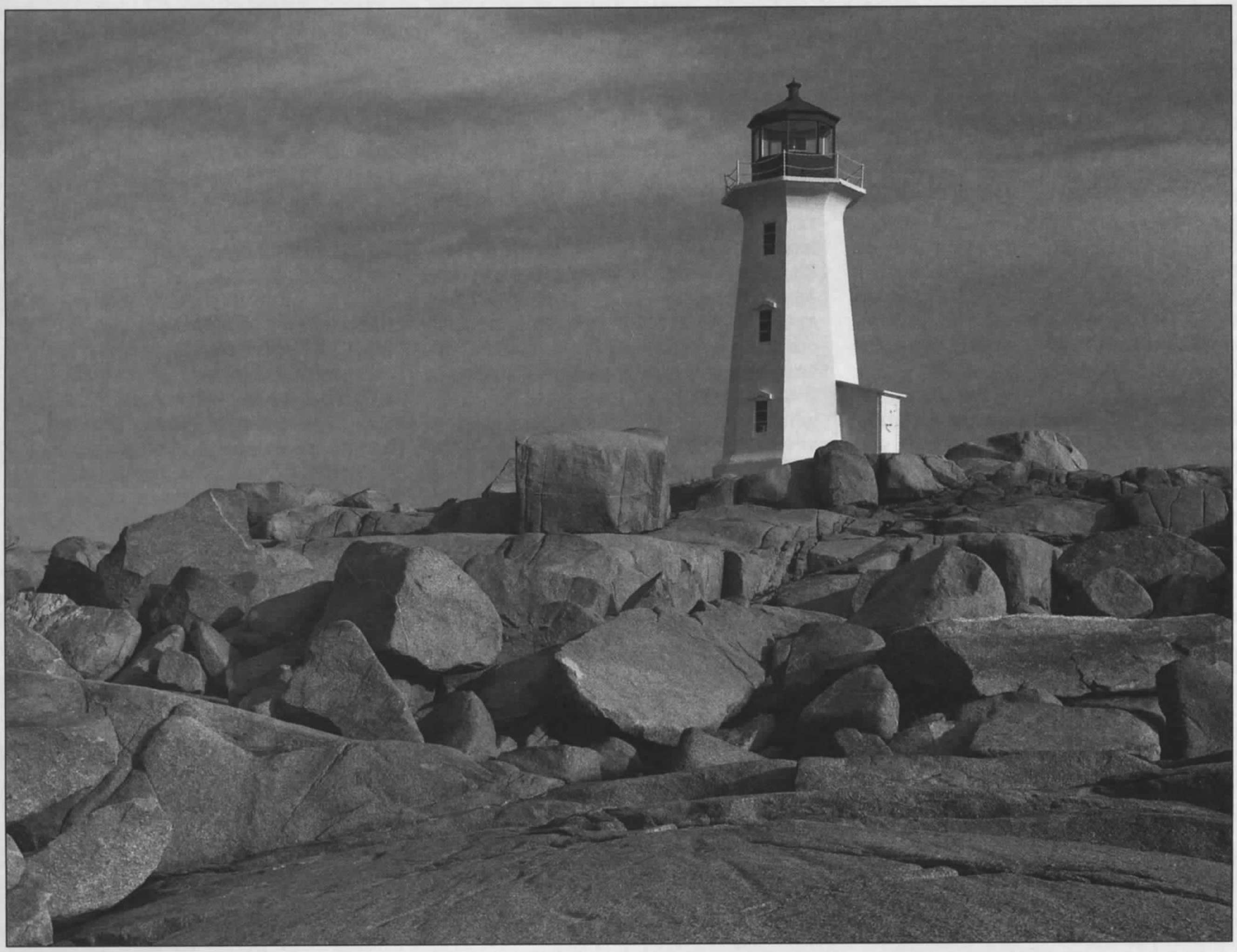


*PEGGY'S COVE LIGHTHOUSE was made using a Sinar 4 × 5 camera with a 135mm Schneider Symmar lens at f/32 on T-Max 400 sheet film. A Pentax spotmeter was used and the meter readings and zone placements were plugged into a Radio Shack PC-5 pocket computer for exposure/development calculation.*

# Sensitometry Primer Part IV

## *Analyzing the Curves for Zone System Data*

By Phil Davis

In the previous article in this series (May/June 1988) I described a procedure for locating the useful Dmin and Dmax limits in a film curve family. As you may recall, the Dmin point can be established in any of several ways, including "eyeballing" it arbitrarily. I fully described the following four approaches: the traditional *fractional gradient* method promoted by Nelson and Simonds; the *fixed density* (usually 0.1 over B+F) method; the Kodak Contrast Index (CI) method; and my own *fractional density* method.

If you apply the traditional fractional gradient procedure you'll find the Dmin points falling relatively far down the toe of the curve. Working data based on these Dmin points will include no *safety factor* at all, and will produce negatives of minimum useful density. On the other extreme, if you locate the Dmin points at the 0.1 over B+F level of each of the curves, your working data will include an exposure safety factor that varies from adequate (for the steeper curves) to excessive (for the curves of lower slope). Although these data will produce negatives of generally fine quality when the subject range is near-normal, longer-range subjects will be progressively overexposed. This is likely to degrade shadow contrast (by exaggerating flare), extend printing times unnecessarily, and diminish image sharpness.

The popular Contrast Index (CI) method relates Dmin location to curve slope producing negatives of relatively uniform characteristics regardless of subject range. Unlike the vintage fractional gradient procedure, the CI method includes a satisfactory degree of exposure safety factor and it's very simple to implement if the toe contours of the curves are accurate and carefully drawn. It is practical and reliable, and has become a sort of industry standard.

The fourth method (fractional density) that I proposed involves more busy-work but is easier to apply to lumpy, inexpertly-drawn curves. You may remember that it finds the Dmin density value by dividing the curve's average gradient number by some constant—I recommended 9 in the last article. Working data derived from the use of this constant (9) include a little less safety factor than the CI method does, but adjustment is simple: use a higher constant value to get thinner negatives. In the illustrations provided for this article, I've used 9 as the constant.

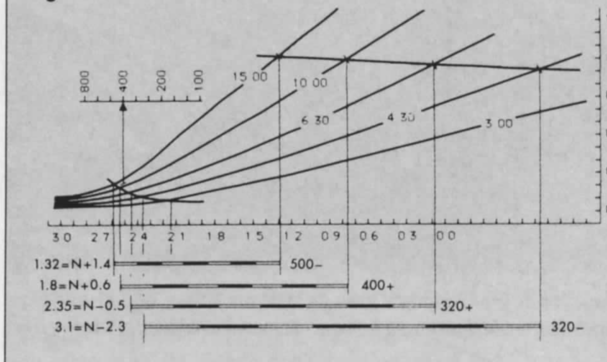
If you completed your own film tests and constructed the basic curve family, as described in the previous article, you have already found the Dmin locations and located the useful Dmax points by adding your personal value of paper ES to the individual Dmin densities. Reviewing briefly, if your paper ES is 1.0 (for example) and the density of the Dmin point on the film curve is 0.06, the Dmax point should be located at a density level of 1.06 on that curve.

Locating these points is usually a simple matter but if your ES value is large and/or the film curve's slope is low, you may have to extend the curve (with a straight line) far enough to reach the necessary density level. This is a little risky of course, but if the necessary extension is no greater than a stop or two, it's worth doing. As you'll see in the example shown in Figure 1, the first curve in the family of five has been extended considerably but is still unusable. The second curve has been extended about 2⅓ stops and its Dmax point is somewhat suspect because we're not sure where the curve shoulder should begin. The error is unlikely to be more than a small fraction of a stop, though, so for now we'll assume that it's satisfactory. If you've completed your curve family to this extent we're ready to proceed.

Analyzing a family of curves for Zone System data involves a lot of drawing and a confusion of lines. To simplify things I suggest that you trace each curve in the family (along with its calibrated X- and Y-axes, of course) to a separate sheet of graph paper so that you can work on it individually. Some of the construction lines may extend several inches below the X-axis, so when you trace the curves allow some extra space below them.

As you recall from the previous article, each curve in the family represents a specific development time and, after its Dmin and Dmax points have been placed, the horizontal distance between them will define a particular subject luminance (brightness) range (SBR). The subject luminance values provide the exposure for the film, and the range of these values (SBR) can be measured conveniently along the graph exposure axis (X-axis), in either logs or stops. Our first task is to divide this SBR into *zones;* but before we begin we should probably define zones as they apply to this procedure.

**Figure 1**



***For the curve family the Dmin and Dmax values have been established; the curves are labeled with their individual development times; each of the subject ranges has been divided into its 7 zones; and each range is labeled with its length in log units, its N-number, and its EFS value.***

**Figure 2**

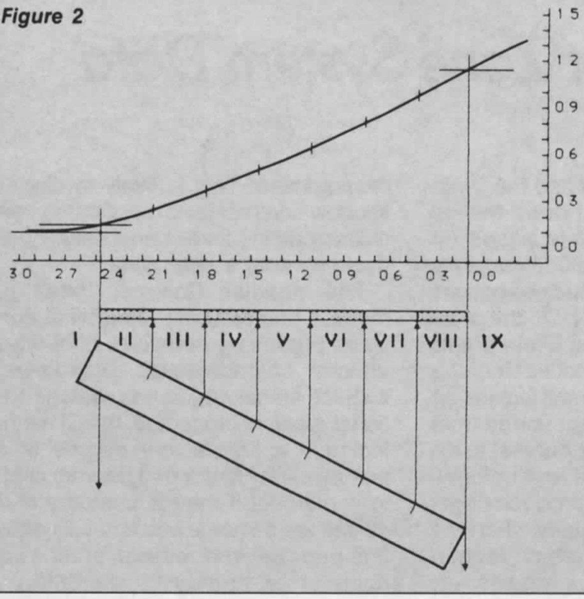
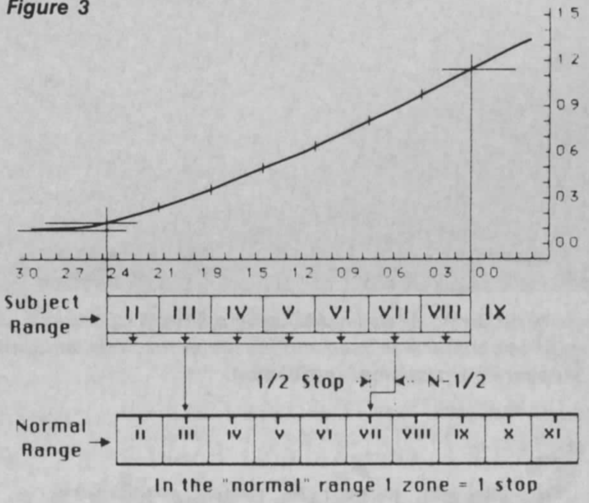
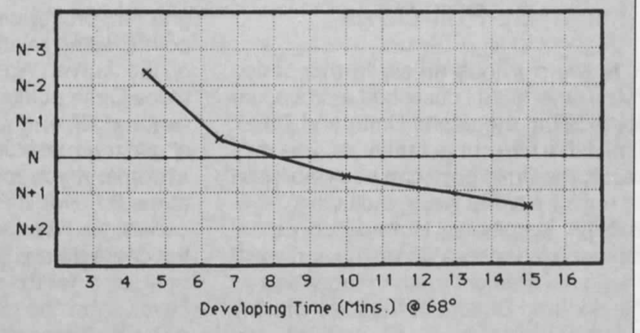


**Figure 3**



***N-numbers are found by subtracting the measured zone range from a similar range of stops. Here 4 zones subtracted from 4 stops results in "minus one-half," so the N-number is N – ½.***

**Figure 4**



It's often stated that zones and stops are equivalent, and I think most photographers will agree that the gray tones that we associate with the various zones are actually print tones. The process of visualization (or *pre*visualization, if you prefer) really involves mentally assigning two or more of those zone (print) grays to appropriate areas of the subject. When we visualize effectively, meter the subject luminances accurately, calculate the subject range (as indicated by an N-number) correctly, and develop the film appropriately, we get good, easy-to-print negatives. The System is designed to adjust exposure and development automatically to provide negatives of consistent quality, regardless of subject range —within reason.

But there's a paradox here. Full-scale prints contain all 7 zone grays (II through VIII) plus the accent extremes (I and IX), and each print tone is directly traceable to some subject luminance value. Therefore, the original subject of every negative that can be printed *full-scale* must have represented a range of 7 zones (plus accents), *regardless of its measured range* of luminances. Obviously, zones and stops are equal when the subject range is normal, but if the subject range is less than the normal 7 stops, each of the 7 zones must be less than one stop; and if the range is greater than 7 stops, each zone is greater than one stop. In other words, each zone (of any subject) must represent 1/7 of the total stop range, whatever it is.

Armed with that knowledge, we can assign zones to the various film curves by simply dividing each subject range into 7 equal segments. It's possible to do this by measuring the subject ranges in log or stop units and calculating the actual length of each range segment, but there's a simple geometric trick that makes it much easier. First, extend vertical lines from the Dmin and Dmax points downward through the X-axis to define the boundaries of the subject range, as shown in Figure 2. Then find a ruler that provides 7 equal divisions (inches, half-inches, centimeters, or whatever) that spans a distance somewhat greater than the subject range, and angle it so the 7 unit spaces fit precisely between the boundary lines. Draw a horizontal line representing the subject range just below the X-axis of the graph, then project each of the ruler divisions vertically to define the zone limits on the range line. Label those 7 zones with the conventional Roman numerals from II through VIII, as shown. Notice that the 7 zones now *fill* the entire useful length of the curve and that the accent zones (I and IX that represent black and white, respectively) lie outside the range limits as they should.

Now we can find out whether this subject range is *normal* or not by comparing the range of zones with a similar range of stops. You can make a suitable ruler for this purpose by marking a strip of paper with stop divisions, as measured along the X-axis of the graph. Remember that each stop is equivalent to 0.3 in log terms. Make this *stop ruler* about 10 stops (3.0) long and label its divisions, from left to right, with the zone numbers II through XI.

Assume that you'll always base your Zone System calculations on measurements of Zones III and VII so that we can use these zones for determining the various N-numbers. We'll call the difference between the measured zones the *zone spread*. In this instance, using Zone III and VII, the *spread* is 4.

Now we can compare this 4-zone spread with 4 stops, but first we must assign reference points because a zone isn't a point itself. Despite the fact that we think of each zone as being a specific tone, it's actually a *range* of tones. The location of the zone reference point that we use is not particularly important; we can measure from the lower boundaries of the zones, or from their upper boundaries, or from any other point within the zone range, as long as we're consistent. To keep things simple and orderly, though, we'll use the centers as reference points because they're easy to locate, and because they really do represent the gray tones that we associate mentally with the zone numbers.

Mark the centers of all the zones on both the subject range line and the stop ruler, then position the *stop ruler* parallel to the subject zone range line and align the centers of their Zone III segments, as shown in Figure 3. You can see in this illustration that the subject zone divisions are longer than the stop divisions so this is not a *normal* subject range. Because the purpose of the Zone System (or any other exposure/development control system) is to produce *normal* negatives, it's apparent that this subject range must be compressed or *compacted* to restore it to *normal* length. To discover the necessary degree of compaction we'll measure the distance that's required to shift the center of subject Zone VII into alignment with the center of *stop VII*. As is indicated by the zig-zag arrow in the illustration, that requires a lateral shift of approximately ½ stop to the *left* (indicating *compaction* of the subject range). Since compaction development is traditionally referred to as *minus* development, we'll identify this subject range as "N–½" or "N minus one-half."

It's apparent, now, that if the subject range were equivalent to 7 stops, the zone divisions would match the stop ruler's divisions exactly; no shift would be necessary, and the N-number would be simply N or Normal. If the subject range were less than 7 stops, the center of subject Zone VII would have to be shifted to the right to align with the center of stop VII, indicating the necessity for "expansion" (greater than normal) development, and a corresponding "N plus" development. The actual value of the N+ number is found in the same way, by measuring the length of the shift required to align the Zone VII centers.

When you have repeated this procedure for each of the usable curves in the family and labeled each curve with its N-number, you'll have enough information to construct a useful working chart. You know the development time represented by each curve and you know the N-number for each curve; plot them against each other as shown in Figure 4 and you'll be able to find appropriate developing times for subjects of any range within the test limits.

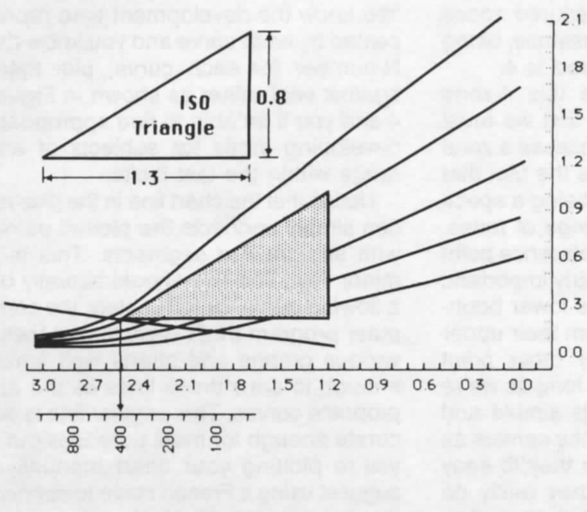
Notice that the chart line in the illustration simply connects the plotted points with straight line segments. This is a minor flaw. The line should actually be a flowing curve. Unfortunately, the computer program that I used to plot these various graphs and charts isn't smart enough to draw these lines as the appropriate curves. This angular line is accurate enough for most purposes but if you're plotting your chart manually I suggest using a French curve to connect the points more elegantly.

The development time information that's indicated by this chart line will allow you to produce negatives of quite uniform density range (DR) regardless of subject range but, as you probably know, variations in film development will also influence exposure to some extent. To find out how serious a problem that is, and to discover the appropriate compensation, we'll return to the curve family for effective film speed (EFS) analysis.

The manufacturer's rated film speeds are determined from analysis of a standard characteristic curve and actually calculated from the value of exposure required to produce a negative density of 0.1 over B+F when the test exposure range (ER) is 1.3 and the DR is 0.8 (see the previous article in this series if your memory needs refreshing). If we knew the location of the *official* speed point in the curve family it would be easy to find the EFS value for any condition of development. Unfortunately, we can't locate the official speed point precisely but we can estimate its position with useful accuracy by constructing, in the curve family, a new curve that satisfies the standard conditions.

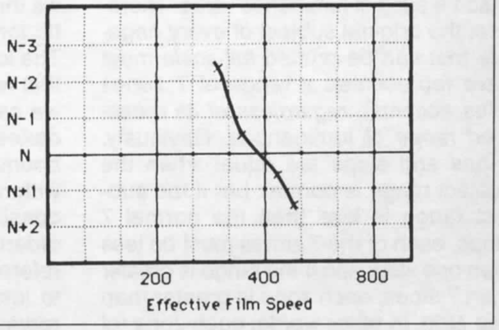
There are several ways to go about this but I think the principle is demonstrated best by actually positioning an "ISO triangle" in the curve family, as illustrated in Figure 5. Using the standard dimensions (measured along the graph axes) draw the triangle on paper as shown and cut it out carefully.

**Figure 5**



***The base of this "ISO triangle" represents the subject range, the altitude represents the negative density range, and the hypotenuse represents the average slope of the characteristic curve. When the triangle is positioned properly in the curve family, a new curve, drawn through the acute vertices of the triangle defines a development time that's appropriate when the film is exposed at the official ISO film speed.***

**Figure 6**



Next, locate on the first and last curves in the family, a density of 0.1 over B+F, and connect these points with a straight Dmin line. This is just a temporary construction line, so draw it lightly in pencil so it can be erased easily. Now position the triangle so that its lower acute vertex *touches the Dmin line.* Next, while keeping its base *parallel* to the X-axis of the graph, slide the triangle along the Dmin line until its acute vertices fall between the same pair of curves (or precisely on a single curve), and *proportionately spaced* between them. Only one position in the family will satisfy these requirements, and when you've found it, mark the position of the lower tip of the triangle on the Dmin line. This is a reasonable approximation of the official speed point location. Drop a vertical line through the X-axis to see what value of exposure it represents; in the illustration that value is 2.51.

Remove the ISO triangle, erase the temporary Dmin line and refer to the real Dmin line that you constructed using the fractional density method described in the previous article. This line will undoubtedly be lower down on the curve toes than the temporary line you just erased, and it will probably also be curved, as shown in Figure 1. Now you can compare the position of each of these Dmin points with the official speed line (at 2.51). Points that fall to the left of the official line represent a speed gain; to the right they represent a speed loss.

Cut another paper ruler strip a couple of inches long and mark one edge in ⅓ stop increments (log units of 0.1 as measured along the X-axis). Then label the marks with numbers from the standard film speed series (described in the previous article) and position this "film speed ruler" so that the nominal speed of the film (on the ruler) is aligned with the official speed line, as shown in Figures 1 and 5. Project vertical lines from each of the other Dmin points to the ruler and identify their EFS values by modifying the standard speeds with plusses or minuses. For example, if a point falls between 320 and 400, closer to 320, call it "320+" or "320++." If it falls exactly between, say, 200 and 250, call it "200-250." When you've estimated all the EFS values, label each curve with its number.

Now you can relate N-numbers to EFS values in a second chart, as illustrated in Figure 6, estimating the positions of the points between the vertical lines by referring to your plus and minus labels. Again the computer has connected the points with straight lines but it's less of a problem here because you can set only standard ISO speeds into your meter. Intermediate speed values—such as 150 or 425—are meaningless, they must be translated into the closest real speed value for use, so subtle refinements of the chart curve contour are probably a waste of time.

You won't need to modify your usual Zone System visualization or metering methods in any major way to make use of these new data, but to get the best results from these charts you should base your calculations on Zones III and VII if possible. Actually, the spread value is more significant than the zones themselves; any zone pair that has a 4-zone spread (such as II and VI or IV and VIII) is appropriate. Nothing dreadful is likely to happen if you pick other spread values but some variation in negative quality is likely. In general it's best to base your N-number calculations on the spread value you prefer to use.

In using this version of the System take your meter readings, make your zone assignments, and calculate the N-number by subtracting the zone range from the stop range. That number is the N-number. If it's a negative number the N-number is minus and if it's positive the N-number is obviously a plus. Then consult your EFS chart for the appropriate speed value, set it into the meter instead of the film's rated speed, place the low luminance value in your chosen low zone, and shoot. Label the holder (or the film roll) with the N-number. When you return to the darkroom consult the development chart for the proper developing time and process the film accordingly.

In the next installment I'll show you how to analyze the curve for working data that's appropriate for use with incident metering, and describe an Incident System that offers a quite different (but very effective) approach to visualization and the control of image quality.

The standard version of the computer program "Plotter," which was used to do the curve analyses from which these illustrations were derived, is available directly from the author (7373 Webster Church Rd, Whitmore Lake, MI 48189, (313) 426-8631). It is supplied on a 3.5-inch single-sided disk and runs on Macintosh computers up to and including the SE (it may also run on the Mac II but I haven't tried it). Sorry, it's not available for MS-DOS machines. The program is *shareware*: that is, it's free, but if you like it and find it useful, a $10 remittance (to help justify the distribution effort) will be gratefully accepted. ☐

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*Photographer/writer Phil Davis is the author of* Beyond the Zone System *(Curtis and London, 1981) and* Photography *(William C. Brown, 1986). With his partner Bob Routh, he also teaches Beyond the Zone System Workshops.*