Customizing Film Speed and Development

Take control and make the Zone System work for you

Film manufacturers have spent a lot of time and resources establishing the film speed and the development time suggestions for their products. Not knowing the exact combination of products we use for our photographic intent, they have had to make a few assumptions. These assumptions have led to an agreement among film manufacturers, which were published as a standard in ASA PH2.5-1960. It was the first standard to gain worldwide acceptance, but it went through several revisions and was eventually replaced by the current standard ISO 6:1993, which combines the old ASA geometric sequence (50, 64, 80, 100, 125, 160, 200, ...) with the old DIN log sequence (18, 19, 20, 21, 22, 23, 24, ...). As an example, an ISO speed is written as ISO 100/21°.

Fig.2 shows a brief overview of the ISO standard. According to the standard, the film is exposed and processed so that a given log exposure of 1.30 has developed to a transmission density of 0.80, resulting in an average negative gradient of about 0.615. Then, the film speed is determined by the exposure, which is developed to a shadow density of 0.10. This makes it an acceptable standard for general photography. However, the standard's assumptions may not be valid for every photographic subject matter, and advertised film speeds and development times can only be used as starting points.

A fine-art photographer appreciates fine shadow detail and often has to deal with subject brightness ranges that are significantly smaller or greater than the normal 7 stops from the beginning of Zone II to the end of Zone VIII. In addition, the use of certain equipment, like the type of enlarger or the amount of lens flare, influences the appropriate average gradient and final film speed. The nomograph in fig.14 gives an overview of these variables and their influence. The Zone System is designed to control all these variables through the proper exposure and development of the film. This requires adjustment of the manufacturer's film speed (or 'box speed') and development suggestions.

In general, advertised ISO film speeds are too optimistic and suggested development times are too long. It is more appropriate to establish an 'effective film speed' and a customized development time, which are personalized to the photographer's materials and technique. In most literature, the effective film speed is referred to as the exposure index (EI). Exposure index was a term used in older versions of the standard to describe a safety factor, but it was dropped with the standard update of 1960. Nevertheless, the term 'EI' is widely used when referring to the effective film speed, and we will accept the convention.

Still, we ask ourselves: How does one establish the effective film speed and development time to compensate for different subject brightness ranges? An organized test sequence can give you very accurate results, but even a few basic guidelines can make a big difference in picture quality. I would like to show you three different ways, with increasing amount of effort, to keep you from wasting your time on too many 'trial and error' methods.

1. Quick and Easy

Here is a simple technique, which will improve picture quality significantly and does not require any testing at all. Use it if you dislike testing with a passion, or if you just don't have the time for a test at the moment. This method can also be used to give a new film a test drive and compare it to the one you are using now.

For a normal contrast, bright but cloudy day, cut the manufacturer's recommended film speed by 2/3 stop (i.e. ISO 400/27° becomes ISO 250/25°) and the recommended development time by 15%. The increased exposure will boost the shadow detail, and the reduced development time will prevent the highlights from becoming too dense. For a high-contrast, bright and sunny day, increase the exposure by an additional 2/3 stop (i.e., ISO 400/27° now becomes ISO 160/23°) and reduce the development time by a total of 30%. Stick to the 'box speed' and suggested development time for images taken on a low-contrast, rainy or foggy day.

A negative processed this way will easily print with a diffusion enlarger on grade-2 or 2.5 papers. Just give it a try (fig.1). It is really that simple to make a significant improvement to negative and image quality.

2. Fast and Practical

Here is another way to arrive at your effective film speed and customized development time. It is a very practical approach, which considers the entire image producing process from film exposure to the final print. The results are more accurate than from the previous method, and it requires three simple tests, but no special equipment.

a. Paper-Black Density Test

This test will define the minimum print exposure required to produce a near-maximum paper density. Make sure to use a blank negative from a fully processed film of the same brand as to be tested. Add a scratch or a mark to it, and use it later as a focus aid.

1. Insert the blank negative into the negative carrier.
2. Set the enlarger height to project a full-frame 8x10 inch print and insert contrast filter 2 or equivalent.
3. Focus accurately, then measure and record the distance from the easel to the film.
4. Stop the lens down by 3 stops and record the f/stop.
5. Prepare a test strip with 8, 10, 13, 16, 20, 25 and 32-second exposures.
6. Process and dry normally.
7. In normal room light, make sure that you have at least two but not more than five exposures, which

scene contrast	adjustments: film speed [ASA]	adjustments: development time	typical subject brightness range
low	-	-	rainy or foggy day
normal	-2/3	- 15%	bright but cloudy day
high	-1 1/3	- 30%	bright sunny day

fig.1 It is possible to make significant improvements to negative and image quality without any testing. Use this table to deviate from the manufacture's recommendations for film exposure and development according to overall scene contrast.

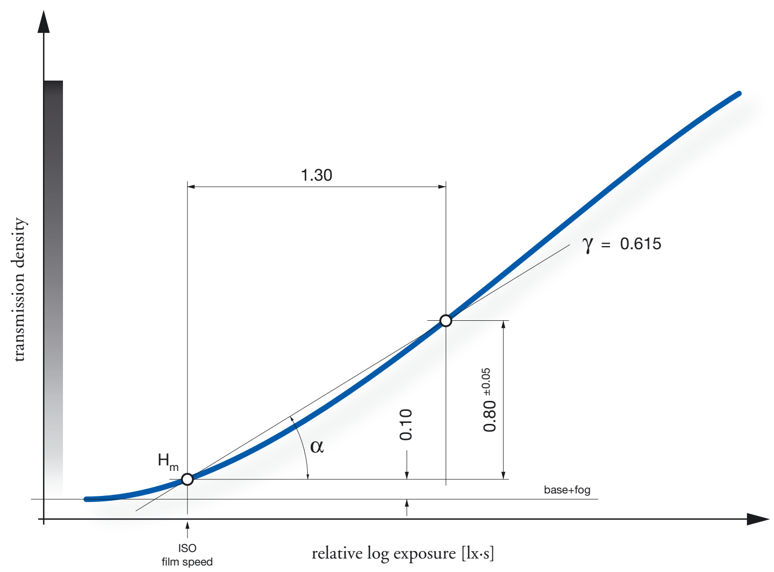


fig.2 Film exposure and development in accordance with the current ISO standard.

are so dark that they barely differ from one another. Otherwise, go back to step (5) and make the necessary exposure corrections.

8. Pick out the first two steps that barely differ from one another and select the lighter of the two.
9. Record the exposure time for this step.

This is the exposure time required to reach a near-maximum paper density (Zone 0) for this aperture and magnification. If you can, leave the setup in place as it is, but record the f/stop, enlarger height and exposure time for future reference.

b. Effective Film Speed Test

This test will define your normal effective film speed, based on proper shadow exposure.

1. Select a subject, which is rich in detailed shadows (Zone III) and has some shadow tonality (Zone II).
2. Set your lightmeter to the advertised film speed.
3. Stop the lens down 4 stops from wide open, and determine the exposure time for this aperture, either with an incident meter pointing to the camera, or place a 'Kodak Gray Card' into the scene, and take the reading with a spotmeter. Keep the exposure time within 1/8 and 1/250 of a second or modify the aperture.
4. Make the first exposure.
5. Open the lens aperture or change the ISO setting of your lightmeter to increase the exposure by 1/3 stop (i.e., ISO 400/27° becomes ISO 320/26°) and make another exposure. Record the exposure setting.
6. Repeat step (5) four times, and then, fill the roll with the setting from step (4).
7. Develop the film for 15% less time than recommended by the manufacturer. Otherwise, process and dry the film normally.
8. Set your enlarger and timer to the recorded settings for the already determined Zone-0 exposure from the previous test.
9. Print the first five frames, process and dry normally.

An evaluation of the prints will reveal how the shadow detail is improving rapidly with increased film exposure. However, there will come a point where increased exposure offers little further benefit. Select the first print with good shadow detail. The film speed used to expose the related negative is your normal effective film speed for this film. Based on my experience, it is normal for the effective film speed to be up to a stop slower than the rated film speed.

Fig.3a-c show just how much difference the effective film speed can make. Fig.3a is the result of a negative exposed at ISO 125/22° and then printed with the minimum exposure time required to get a Zone-0 film rebate with a grade-2 paper. The highlights are 'dirty', the midtones are too dark and 'muddy', and the shadows are 'dead' with little or no detail. In fig.3b, an attempt was made to produce a 'best print' from the same negative. The film rebate was ignored, the exposure was corrected for the highlights, and contrast was raised to optimize shadow appearance. The highlights and midtones are much improved, but the gray card is still a bit dark. The shadows are solid black, still without any detail, and the picture has an overall harsh look to it. Fig.3c is the result of a negative exposed at an effective film speed of EI 80, and then printed in the same way as fig.3a. The highlights are bright, but not as harsh as in fig.3b, the gray card is on Zone V as intended, and the shadows are deep black with detail. A big improvement, solely due to selecting the effective film speed.

c. Film Developing Time Test

This test will define your normal film development time. A rule of thumb will be used to adjust the normal development time to actual lighting condition, where needed.

1. Take two rolls of film. Load one into the camera. On a cloudy but bright day, find a scene that has both significant shadow and highlight detail. A house with dark shrubs in the front yard and a white garage door is ideal.
2. Secure your camera on a tripod, and set your lightmeter to your effective film speed, determined by the previous test. Meter the shadow detail, and place it on Zone III by reducing the measured exposure by 2 stops.
3. At that setting, shoot the scene repeatedly until you have finished both rolls of film.
4. In the darkroom cut both rolls in half. Develop one half roll at the manufacturer's recommended time. Develop another half roll at the above time minus 15% and another half roll at minus 30%. Save the final half roll for fine-tuning.

5. When the film is dry, make an 8x10-inch print from one negative of each piece of film at the Zone-0 exposure setting, determined during the first test. The developing time used to create the negative, producing the best highlight detail, is your normal film developing time. You may need the fourth half roll to fine-tune the development.

Considering your entire image-making equipment, you have now determined your effective film speed, producing optimum shadow detail, and your customized film developing time, producing the best printable highlight detail for normal lighting conditions.

However, film exposure and development have to be modified if lighting conditions deviate from 'normal'. The rule of thumb is to increase the exposure by 1/3 stop whenever the subject brightness range is increased by one zone (N-1), while also decreasing development time by 15%. On the other hand, decrease the exposure by 1/3 stop whenever the subject brightness range is decreased by one zone (N+1), while increasing development time by 25%.

These tests must be conducted for every combination of film and developer you intend to use. Fortunately, this is not a lot of work and will make a world of difference in your photography.

fig.3a The negative was exposed at ISO 125/22° and then printed with the minimum exposure time required to get a Zone-0 film rebate with a grade-2 paper. This results in 'dirty' highlights, 'muddy' midtones and 'dead' shadows.

fig.3b ISO 125/22°. Print exposure and contrast were changed to make 'best print'. Highlights and midtones are improved, but there is still no shadow detail.

fig.3c EI 80/18°. A film exposure increase but a print exposure as in fig.3a results in bright highlights similar to fig.3b, with improved mid-tone and shadow detail.
(test & images by Bernard Turnbull)

3. Elaborate and Precise

The following method of determining the effective film speed and development time is more involved than the previous two, and it requires the help of a densitometer to read negative transmission densities accurately. The benefit, however, is that it supplies us will all the information we need within one test. It gives enough data to get the effective film speed and how it changes with different development times. We will also get an accurate development time for every possible subject brightness range. Negatives exposed and developed with this information should have a constant and predictable negative density range for any lighting situation. This method is ideally suited for use with the Zone System. The final results are well worth the time commitment of about 8 hours to perform the test and to evaluate the data.

The use of a densitometer is essential for this test. A densitometer is costly and, therefore, typically a rare piece of equipment in regular darkrooms. A quality densitometer costs as much as a 35mm SLR, if purchased new, but they are often available for a fraction of that on the used market. This test only requires us to read transmission densities, but a densitometer which is able to read both transmission and reflection is a much more versatile piece of equipment. Some darkroom analyzers have a built-in densitometer function, and they can be used to read projected negative densities. Alternatively, you may ask a friend or the local photo lab to read the densities for you. Once you have a densitometer, you will find many uses for it around your darkroom.

Exposure

Many different methods of generating the necessary negative test exposures have been published. Most require changes to lens aperture or camera shutter settings for exposure control. If conducted with care, this is a very practical method providing acceptable accuracy. However, years of testing have made me aware of some equipment limitations, which we need to take into consideration to get reliable results.

Mechanical shutters are rarely within 1/3-stop accuracy, and their performance is very temperature sensitive, acting slower when cold. They also become sluggish after long periods of non-use. In these cases, it helps to work the shutter by triggering the mechanism a few times. In any event, they cannot be set in fine increments, and exposure deviations should be recorded down to 1/3 stop. This is not possible with mechanical shutters. Electronic shutters, on the other hand, are very precise, and sometimes provide 1/3-stop increments, although they are uncommon in large-format equipment. Lens aperture accuracy is usually very good, being within 1/10 stop, but apertures are notorious for being off at the largest and smallest setting. Medium aperture settings are far more trustworthy, but only if worked in one direction. Switching from f/8 to f/11 may not result in the same aperture as switching from f/16 to f/11, due to what is known as mechanical hysteresis. Consequently, we can use shutters and lens apertures to control test exposures, but must avoid mechanical shutters and change f/stops only in one direction.

As an alternative, consider the use of a step tablet wherever possible. A step tablet is a very accurate and repeatable way to expose a piece of film. Fig.4 shows one supplied by Stouffer in Indiana, but they are available from different manufactures and in different sizes. The process is most simple if you purchase one in the same size as the negative format to be tested, and photograph it with the aid of a slide duplicator. If such a device is not available, then a similar setup can easily be rigged up. It can be as simple as placing the step tablet onto a light table, and taking a close-up copy.

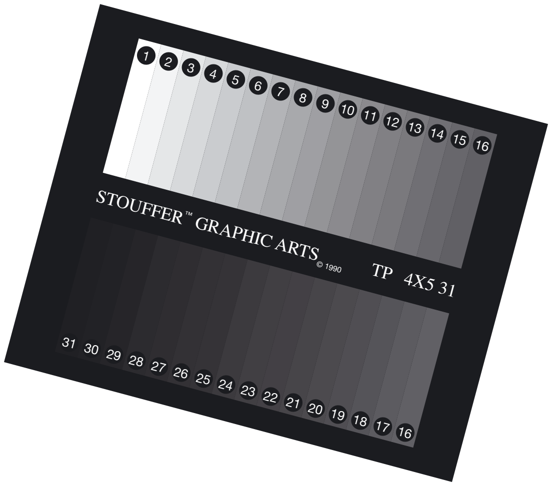


fig.4 The Stouffer 31-step tablet

I prefer the 31-step tablet to the 21-step version, due to the higher quantity of data points available. However, in the process of copying the step tablet, be certain that the steps on the final negative are wider than the measuring cell of the densitometer, otherwise you will not be able to read the density values properly. This may necessitate opting for the 21-step version with its wider bars or adjusting the scaling when you photograph the step tablet. This will be most likely the case only with 35mm negatives. You should be able to fit the 31-step version with most medium format and 4x5-inch film.

Film has a different sensitivity to different wavelengths of light. Therefore, select a light source with a color temperature representative of your typical subject matter and setup. In other words, use daylight or daylight bulbs if you are a landscape photographer, and use photofloods or flashlight if you mainly work in the studio. However, always keep exposure times between 1/500 s and 1/2 s to avoid reciprocity failure.

Assume the box speed to be correct and determine the right exposure with an average reading, or use a spotmeter for the medium gray bars. You can use the manufacturer's recommended film speed, since the actual exposure is not critical as long as it is within 1 stop. The worst that can happen is that a few bars are lost on either end. Once the step tablet is photographed and developed, you will have 21 or 31 accurately spaced exposures on every frame. They are accurate, because their relative exposure is fixed through the densities of the step tablet, and are not affected by any shutter speed or lens aperture inaccuracies. If you are testing sheet film, expose five sheets with the same exposure. If you are testing roll film, fill five rolls of film with the same exposure on every frame.

Development

Select the developer, its dilution and temperature you intend to use for this film. Develop the film in the same manner as you would normally, but for fixed and closely controlled development times. Develop the first roll or sheet for 4 minutes, the next for 5.5 minutes and the following for 8, 11 and 16 minutes, respectively.

Start timing after the developer has been poured into the developing tank, and stop timing after it has been poured out again. Process and dry all film normally.

Make sure that all processing variables are constant and the only difference between these films is the development time. The temperature of the developer is critical, but it is more important to have a consistent temperature than an accurate one. Try to maintain an almost constant developer temperature throughout the process. Keeping the developing tank in a tempered water bath will help to do so. It does not matter if your thermometer is off by a degree or two as long as it reads the same temperature for the same amount of heat all the time. Do not switch thermometers. Pick one, and stick to it for all of your darkroom calibrations. For this test, all chemicals should be used as one-shot, but most importantly, do not reuse any developer solution. It does exhaust with use, and these five films must be developed consistently. The other chemicals are not as critical, but I still suggest using fresh chemicals for film development.

In addition, watch the film/developer ratio. The active ingredients of the developer are gradually exhausted during development. The rate of exhaustion during the test must be similar to your typical application. For example, do not develop one 4x5 test sheet in 1.5 liters of developer if you normally process six at a time in the same volume. Six sheets of film will exhaust the developer more quickly than just one, and consequently, negative densities of the test film will be higher than from normal development. In this case, prepare additional test sheets, also exposed with the step tablet, and develop them together with the actual test film.

Always conduct the test with film in your favored format. Emulsion thicknesses differ between film formats, and consequently, so does the development time. A test based on one film format may not be valid for another.

Collecting and Charting the Data

As previously mentioned, a transmission densitometer is the appropriate tool to measure the test densities. It is best to prepare a spreadsheet with six columns: the first column for the step tablet densities and the others for the negative densities of the five test films. Ideally, the 21-step tablet should have 0.15 step-to-step density increments, and the 31-step tablet should have 0.1-density increments. Be aware that your step tablet will most likely deviate slightly from these anticipated values. This is also true for calibrated step tablets. Therefore, read the densities of the step tablet itself, and list them in the first column. The test results will be more precise when charting the test data against these actual values.

Read the densities of the five tests, and fill them into the spreadsheet. My densitometer has a calibration button to 'zero' out the measurements, because it does not have an internal light source of known intensity for transmission density readings. In other words, it can be used with different light sources and allows for relative and absolute density measurements. If your equipment has a similar feature, then take the first reading with nothing in the light path, push the 'zero' button, and then, continue to take all the measurements. This will enable you to measure the 'base+fog' density of the test negatives. If you 'zero' the measurements to a blank piece of the film before taking any readings, then all base+fog densities are equalized, and you would be unaware of any fog increase due to development time. If your densitometer does not have a 'zero' button, which is most likely the case if it has its own light source, then you can be assured that your readings are absolute values and no correction is required.

The typical measurement accuracy of a standard densitometer is ±0.02 density, with a reading repeatability of ±0.01 at best. This is a more than adequate

Measuring Density

Reliable density measurements are best taken with a densitometer, but the investment is not always justifiable for occasional use. Some darkroom meters have the added capability of measuring transmission densities, but even simple darkroom meters can be calibrated to take density measurements. To do that, use a transmission step wedge, while fixing enlarger magnification and lens aperture, and relate all densities to meter readings. As long as the enlarger settings are repeated, relatively accurate density measurements are possible.

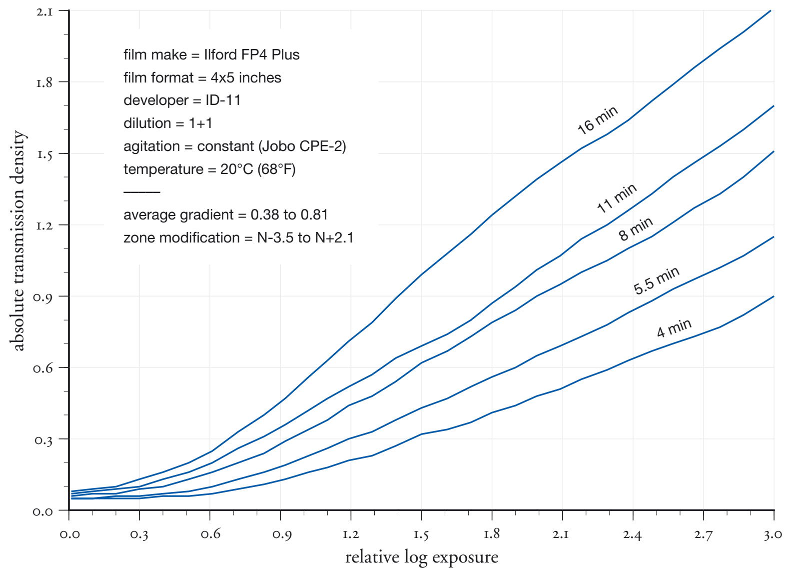


fig.5 A 'family of curves' illustrates how the development time changes the negative transmission density.

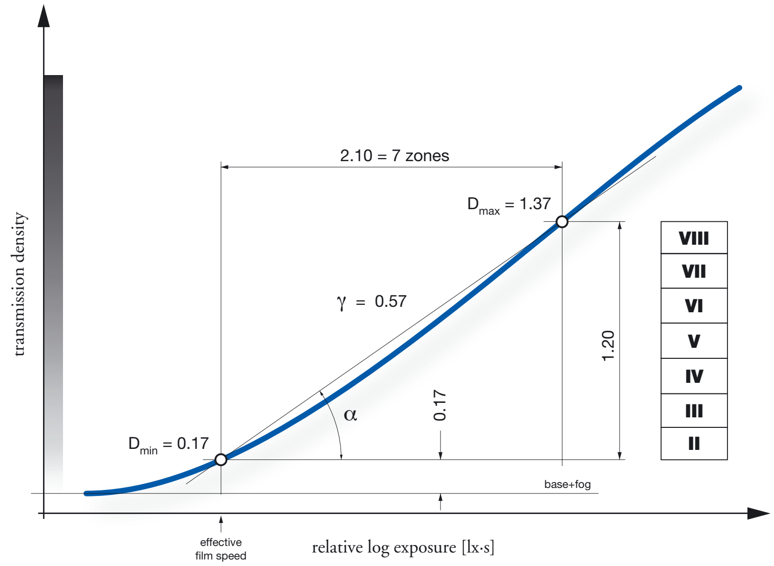


fig.6 Film exposure and development have been adjusted to work in harmony with the Zone System. The speed point has been raised to a density of 0.17 to secure proper shadow exposure. In this example, the development has been adjusted to fit a normal subject brightness range of 7 zones into a fixed negative density range of 1.20, which is a normal range for diffusion enlargers and grade-2 paper. Development modifications will allow other lighting conditions to be accommodated for them to fit the same negative density range.

measurement performance for a film development test. In addition, be aware that the Stouffer step tablet repeats step 16, and so we only need one reading for this density. Feel free to average the two readings if you find them to be slightly different.

A spreadsheet is a good way to collect and view numerical data, but you need to graph individual tests in order to evaluate the results more closely. A blank form, to graph the test data, is included in the 'Tables and Templates' chapter at the end of the book. You may employ a computer for this task, however, it is important that you keep the same axis scales as the supplied graph. Otherwise, you will get false results from the overlays we are about to use. The relative log exposure is traditionally plotted on the horizontal axis and the transmission density is plotted on the vertical axis. The major ticks are in increments of 0.3 unit steps, which correlate conveniently with 1 stop of exposure. The family of curves will look similar to our example in fig.5 once the numerical data has been successfully transferred to the graph.

Evaluating the Data

With the aid of an overlay provided in 'Tables and Templates', you will have to take two types of measurement per curve, in order to evaluate the data (see fig.8). One is the average gradient, and the other is the relative log exposure of the speed point.

The average gradient is simply the ratio of the density range over the log exposure range. Film manufacturers and Zone System practitioners agree with the above definition of average gradient, but they differ when it comes to the selection of the boundaries for the calculation.

In fig.2, we saw how the ISO standard defines normal development as a log exposure range of 1.30 and a density range of 0.80, measured at a 0.10 shadow density. We will now replace these values with our Zone System target values as explained in 'Creating a Standard'. Fig.6 illustrates the change, which will better suit the Zone System and fine-art photography. First, we use our minimum shadow and speed-point density of 0.17. This ensures proper shadow exposure, even when development time is reduced to support high-contrast scenes. Second, we use our standard fixed negative density range of 1.20 (pictorial range). This covers the entire paper exposure range, from the beginning of Zone II to the end of Zone VIII, for normal graded papers printed with a diffusion enlarger. This, combined with a minimum shadow density of Dmin = 0.17, fixes the maximum highlight density at Dmax = 1.37. In addition, it also sets the normal log exposure range to 2.10, since we need 7 subject brightness zones to expose the 7 paper zones above, and each zone is equivalent to 0.3 log exposure. The normal average gradient can be calculated as 1.20 / 2.10 = 0.57.

The 'Tables and Templates' chapter also includes an overlay called 'Film Average Gradient Meter', which is a handy evaluation tool based on our Zone System standard. The use of the 'Film Average Gradient Meter' overlay is shown in fig.7, as it is applied to the 8-minute development test. The other curves have been removed for clarity. The overlay is placed on top of the graph in a way that the 'base+fog density' line is parallel to the grid, but tangent to the toe of the curve. The overlay is then moved horizontally until the effective film speed for 'Zone I·5 = 0.17' intersects with the curve at the speed point. Fig.7 shows the overlay in this final position at which the reading can be taken. Take the average gradient reading as close to the 'Zone VIII·5 = 1.37' density as possible. In this example, 0.55 is the average gradient for the 8-minute curve. Before you move or put the template away, you need to measure the relative log exposure at the 'effective film speed' marker. In our example, 0.80 is the log exposure that

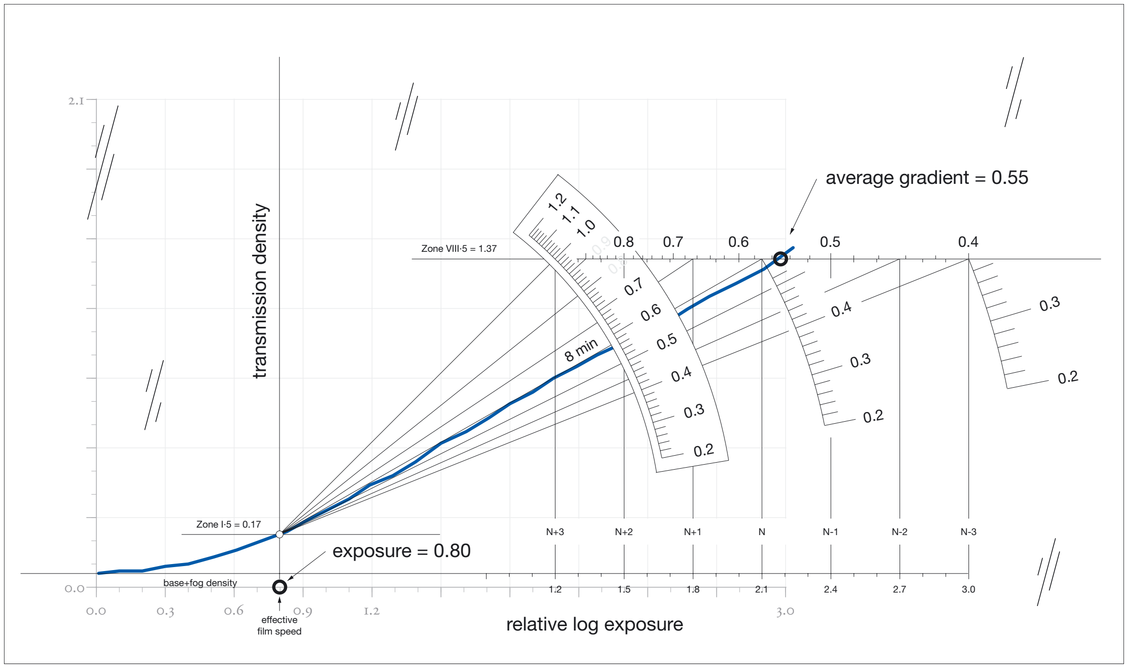


fig.7 As an example, the transparent 'Film Average Gradient Meter' overlay is used to measure the average gradient and the relative log exposure of the effective film speed for the 8-minute characteristic curve. This is done for all characteristic curves in fig.5 and the results are shown in fig.8.

created a minimum shadow density of 0.17. Record the average gradient and the relative log exposure in a table similar to the one shown in fig.8.

Evaluate the rest of the test curves in the same way and record all readings. When finished, you will have a valuable table showing the entire test data.

Predicting Development Times

We are beginning to close the loop, and we are finally getting to chart some of the results, which will guide us to use our film effectively. The ability to precisely predict development times, in order to cope with many lighting scenarios, is a major advantage. We have now collected enough data to start filling out the 'Film Test Summary' template. Again, a blank form is included in 'Tables and Templates'. It has four sections, and we will use them in sequence.

In fig.9a, the average gradient is plotted against the development time. We conducted five development tests, and therefore, we have five data points. Draw a point for every average gradient, which you measured with the 'Film Average Gradient Meter' for 4, 5.5, 8, 11 and 16 minutes of development time. In our example in fig.7, we measured an average gradient of 0.55 and that is where we draw a point on the 8-minute line. Now, draw a smooth curve through the data points. I use a computer to 'curve fit' the line, but there are other options. Feel free to create it freehand, use a bend ruler, or use a set of French Curves, available from any drafting supply store for a small outlay. The point is that you need an averaging line through the data points; how you get there is irrelevant. You see from fig.9b how this can help determine the appropriate development time for any average gradient.

The relationship between development compensations in Zone System 'N' terms and the average gradient was explained in 'Creating a Standard'. Fig.10 shows the relationship in the form of a graph, a table and two equations. I used the values of the small table to mark the smooth curve in fig.9b at development expansion and contractions from N-2 to N+2. We can go a step further by plotting the 'N' values directly against the development times, as illustrated in fig.11. There is little difference to the previous graph, but the five average-gradient values from the test were first converted to 'N' values. To do that, either use the graph in fig.10 to estimate the closest 'N' value for each average gradient, or, if you are more comfortable with math, compute the 'N' value with the equation listed there. If you are comfortable thinking of development

Precise Film Test Procedure Overview

1. **Exposure**
   Using the film's advertised speed, fill five sheets or rolls of film with identical exposures of a transmission step tablet.
2. **Development**
   Develop each film for 4, 5.5, 8, 11 and 16 min, respectively, and process normally.
3. **Collect the Data**
   Measure the average-gradient and relative log-exposure values of each film.
4. **Predict Development Time**
   Chart average-gradient values against their respective development times to estimate the time required to achieve a desired negative contrast.
5. **Predict Effective Film Speed**
   Chart average-gradient values against their respective log exposures, and fill another test film with increasing exposures before developing it normally. Find the speed point and align relative log exposures with the ISO scale to estimate the effective film speed for any subject brightness range.

dev time [min]	average gradient	relative log exp
4	0.38	1.23
5.5	0.45	0.97
8	0.55	0.80
11	0.62	0.63
16	0.81	0.58

fig.8 The results from the development test in fig.5 are recorded in a table.

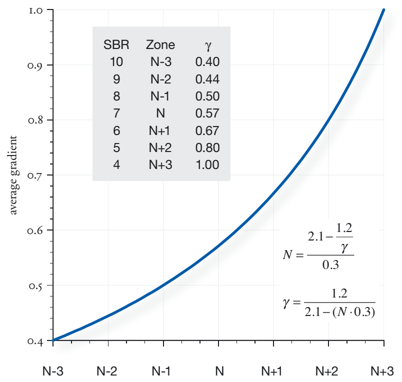


fig.10 Average gradient and Zone System compensations can be estimated or calculated. See 'Creating a Standard' for details.

compensations in terms of N- or N+, you may find the graph in fig.11 more useful than the graph in fig.9b. Some people find this easier than thinking of target contrast in terms of average gradient. The result is the same; it is just presented in a different way.

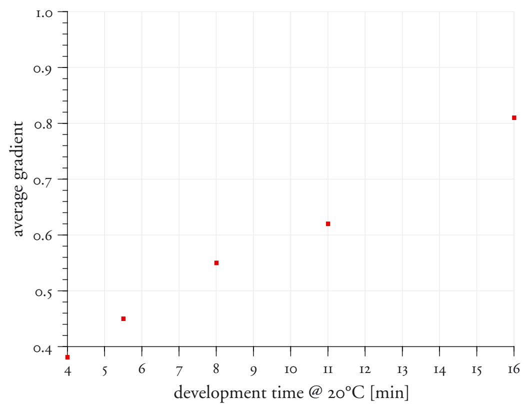
With these graphs at hand, predicting accurate development times has become simple. However, care must be taken not to alter any of the other significant variables. Be sure to keep temperature, chemical dilution, film/developer ratio and agitation as constant as possible.

Predicting Effective Film Speeds

The final task is determining the effective film speeds for all developments. Of course, we would like to have these effective film speeds in ISO units, but doing this directly is a complex task and involves laboratory equipment not available to a fine-art photographer. The only data obtainable at this point are the relative log exposures required to develop the speed point densities as measured with the 'Film Average Gradient Meter' in fig.7. We will convert these relative log exposures to effective film speeds in a moment.

First, plot the test values from fig.8 in terms of average gradient versus relative log exposure of their effective film speeds, as shown in fig.12a, and draw a smooth line through the data points. Then, as shown in fig.12b, find the intersection of the N-development's average gradient (0.57) and the curve. Project it down to the relative log exposure axis. There you will find the relative log exposure for an N-development (0.75), as marked with the gray circle. This log exposure is equivalent to the normal EI, which is the normal effective film speed for this film/developer combination. However, to get the normal EI in terms of ISO units, we must conduct one last test.

1. Use an evenly illuminated Kodak Gray Card as a test target (see fig.12c).
2. Set your lightmeter to twice the advertised film speed and take a reading for the card.
3. Place the reading on Zone I·5 and determine the exposure for a lens aperture closed down by 4 stops from wide open. Keep the exposure time within 1/8 and 1/125 of a second or modify the lighting.
4. Make the first exposure.
5. Open the lens aperture to increase the exposure by 1/3 stop, and make another exposure. If the lens is



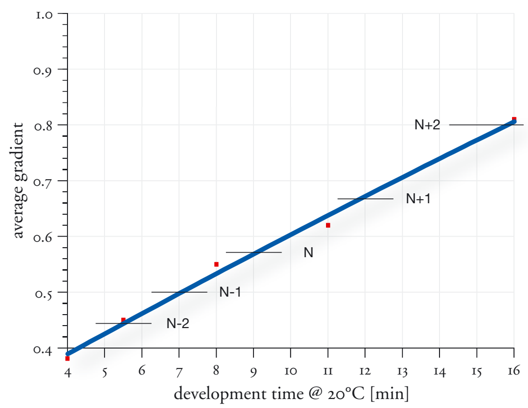


fig.9a-b The average gradient for each test is first plotted, then a smooth curve fit is applied and the typical Zone System development compensations are marked for reference.

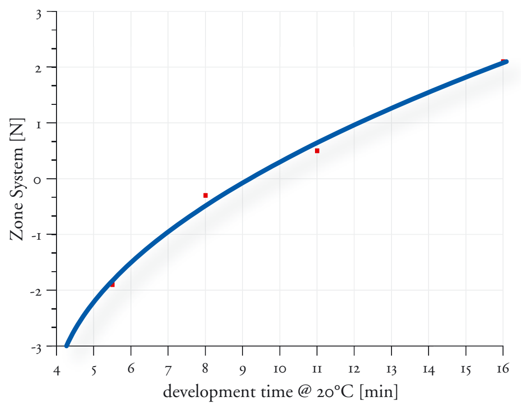


fig.11 A practical development chart is created, when the 'N' values are plotted against the development time.

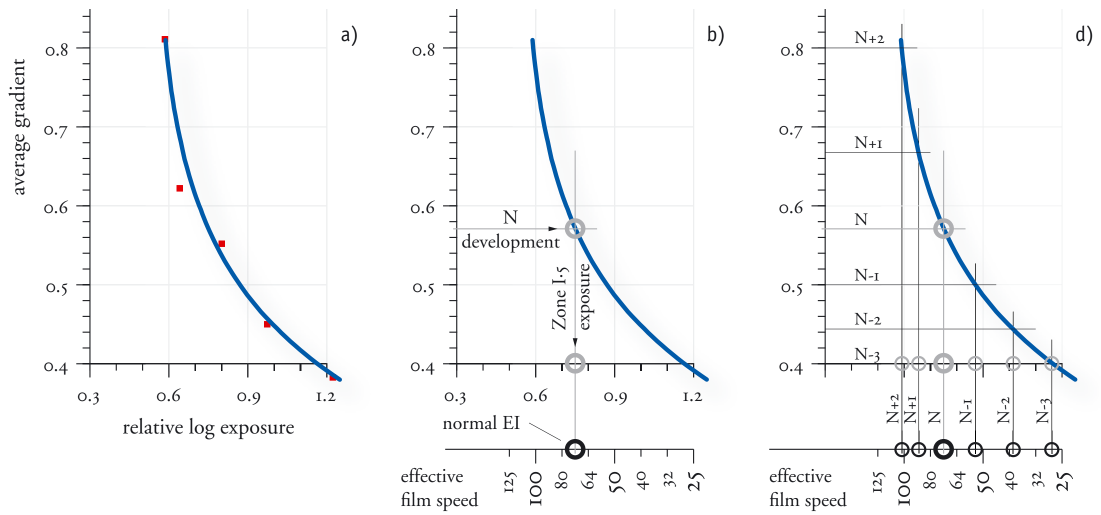


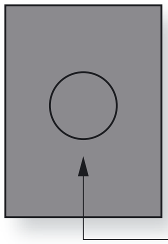
fig.12a (top left) The test values from fig.8 are plotted in terms of average gradient versus relative log exposure, and a smooth curve is drawn through the data points.

fig.12b (top center) Find the intersection of the average gradient for N and the curve. Project it down to the relative log exposure axis to find the relative log exposure for N.

fig.12c (bottom) Zone I·5-exposures in 1/3-stop increments are evaluated to determine the ISO speed for a normal EI. This is aligned with the relative log exposure in fig.12b.

fig.12d (top right) More average-gradients values are projected onto the bottom axis to determine the missing film speeds for other Zone System developments.

c)



exposure	1	2	3	4	5	6	7	8	9	10
1/30s	**f/16**	f/14.3	f/12.7	**f/11**	f/10.1	f/9.0	**f/8**	f/7.1	f/6.3	**f/5.6**
EI	**250**	200	160	**125**	100	80	**64**	50	40	**32**
density	**0.03**	0.04	0.06	**0.09**	0.12	0.15	**0.18**	0.22	0.27	**0.33**

measure and place on Zone I·5

box speed

normal EI

limited to 1/2 stop aperture increases, change the following steps accordingly.

6. Repeat step (5) nine times to simulate different effective film speeds over a range of 3 stops in 1/3-stop increments, but don't change the exposure time.
7. With roll film, set your lightmeter back to the advertised film speed and expose the remaining frames with Zone-V exposures.
8. Develop the film for the time established as a normal N-development in fig.11. Process and dry the film normally.
9. Using a densitometer, start with the first frame and twice the box speed, count down 1/3 stop for every frame until you find the frame with a transmission density closest to a speed-point density of 0.17 (Zone I·5). The film speed used to expose this frame is your customized 'normal EI' (fig.12c).

We can relate the data from the curve in fig.12b to film speeds, because the relationship between log exposures and ISO speeds is known. A 0.1 log exposure difference is equal to a 1/3 stop difference in film speed. The effective film speed scale below the relative log exposure axis illustrates this relationship. It uses the normal EI as a starting point, and we are now ready to specify the effective film speed for any average gradient. In fig.12d, the typical values for N-3 to N+2 were projected on the curve and onto the log exposure axis, where they were marked with gray circles. Extending the projection to the effective film speed scale yields the EI for all development compensations this particular film/developer combination is capable of.

The graph must be cleaned up a bit so the data is readily available in the field. An improved graph is shown in fig.13. The 'N' values are plotted directly against the effective film speed. We can see how the film sensitivity decreases with development contraction. In other words, the film requires significantly more exposure to maintain constant shadow densities, when development time is reduced.

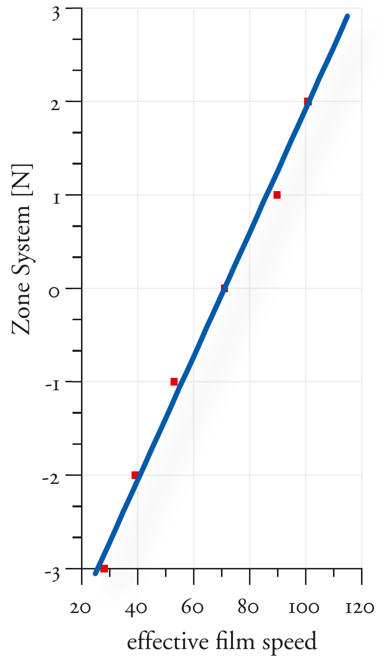


fig.13 This improved graph is a useful guide for Zone System exposures.

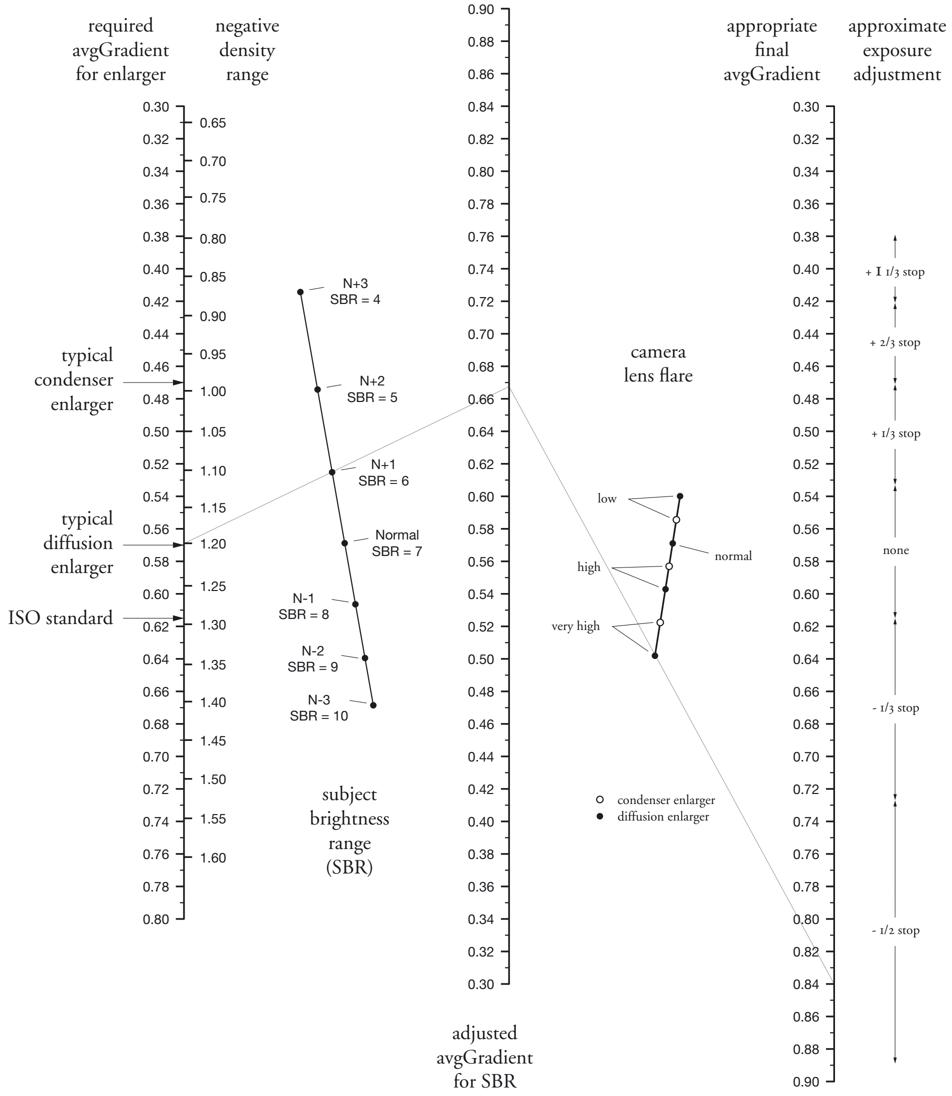


fig.14 This contrast control nomograph, based on a Kodak original, is designed to determine the appropriate average gradient and film exposure adjustment for different enlargers, lighting situations and camera flare. Select the required average gradient for your enlarger that gives a negative density range, fitting well on normal contrast paper. Draw a straight line through the subject brightness range and extend until it intersects with the adjusted average gradient. Draw another straight line through your typical camera flare value and extend it to find the final average gradient and the approximate exposure adjustment. One example is shown for a typical diffusion enlarger, a slightly soft (N+1) lighting condition and the use of an older, uncoated lens with very high flare. The average gradient is raised from 0.57 to 0.67 due to the lighting condition. The lens flare requires a further increase to 0.84, and exposure must be reduced by 1/2 stop.

Equipment Influence

You may want to lower the average gradient if you are working with a condenser enlarger. Their optics make a negative seem to be about a grade harder, but print with the same quality once the negative density range is adjusted. Use a fixed negative density range of 0.90 as a starting point for condenser enlargers. In addition, you may also want to make other adjustments to target average-gradient values if you have severe lens and camera flare, or if you experience extremely low flare. Fig.14 will help to approximate a target average gradient and exposure compensation, but I have not found any need to do so with any of my equipment.

Conclusion

A precise film-speed and development test is not a simple task. It requires some special equipment, some time, patience, practice and several non-photographic related skills. But the rewards are high. Fig.13 contains all information required to properly expose a given film under any lighting condition and then develop it in a given developer with the confidence to get quality negatives. These negatives will print well on a standard ISO grade-2 paper when using a diffusion enlarger. In my view, all the hard work has paid off. There is no need to worry about exposure and development anymore. No need to bracket exposures endlessly or to hope that it will 'work out'. The occasional gremlin aside, it will. Now, all attention can be directed entirely towards the interaction of light and shadows, making and not taking a photograph, and therefore ultimately producing a piece of art.

Nevertheless, if this is all too much technical tinkering and you prefer to spend your time creating images, then remember that even a simplified method, as shown in 'Quick and Easy' or 'Fast and Practical', will improve negative and print quality significantly.