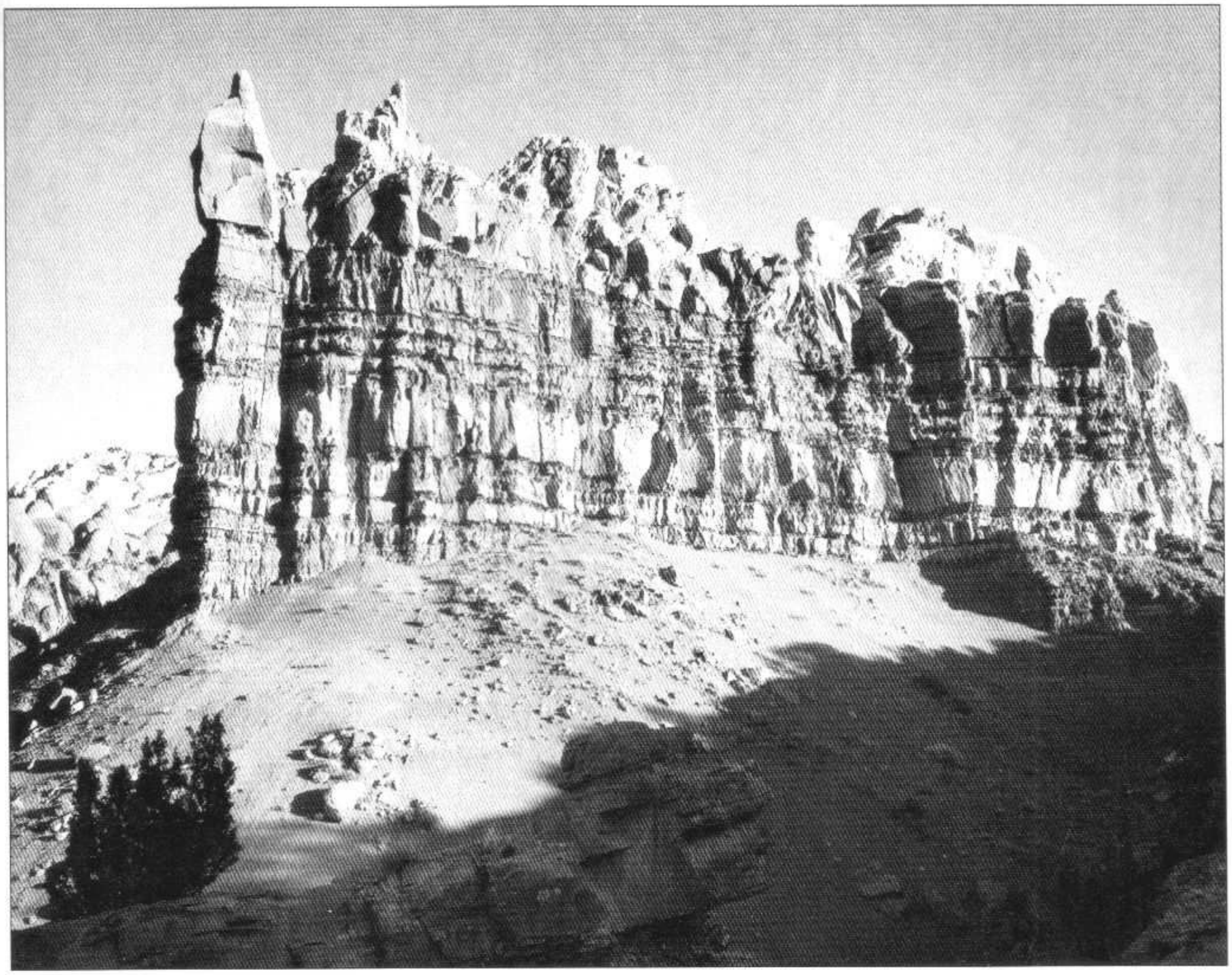


NEAR GHOST RANCH, NEW MEXICO 1990 was made using a Fuji GSW690II camera and 120-format T-Max 100 film. The print was made with Ilford Multigrade FB paper.

Film Developer Dilution

Exciting Local Contrast Differences

By Paul R. Schranz

With respect to controlling negative contrast, two of the most discussed film processing variables are development time and developer dilution. Along with agitation and developer temperature, time and dilution have a powerful effect on film contrast.

It makes sense that a photographer settles on a time and dilution required to produce a desired effect. Photographers usually vary development time to produce negative contrast that will print comfortably on a given grade of paper. Photographers usually devote considerable thought and effort to selecting a development time in an effort to produce a negative that matches the subject, selected paper, enlarger light source, etc. The guiding rule is that a longer development time produces more contrast and a shorter one produces less contrast. This approach works extremely well. It is absolutely clear why a photographer uses a particular development *time*.

However, there are plenty of gray areas about why people select different dilutions, and how dilution differences affect film characteristics. Typically, photographers only change developer dilution when they have a problem—i.e. development times that are too long or short to provide the required control. I think that many of us use dilutions that were recommended by another photographer. We stick with the dilutions and modify development time to alter film contrast. Everyone seems to know that dilution affects film contrast, and many automatically assume the two variables have exactly the same effect.

My students often ask me questions about the effect of dilution. If you re-

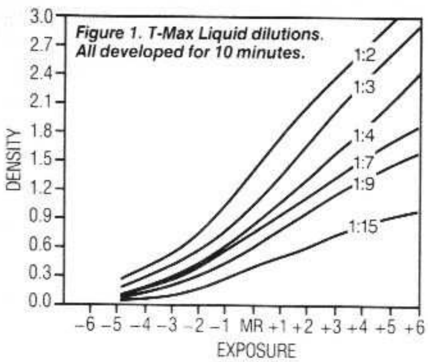


Figure 1. T-Max Liquid dilutions. All developed for 10 minutes.

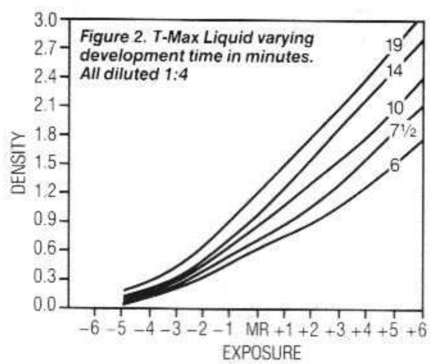


Figure 2. T-Max Liquid varying development time in minutes. All diluted 1:4

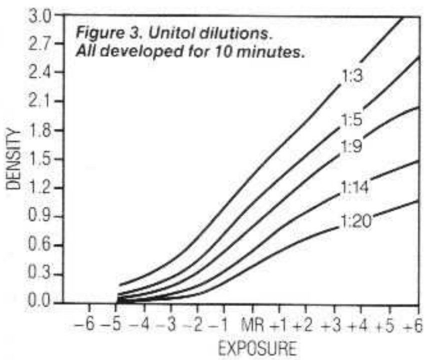


Figure 3. Unitol dilutions. All developed for 10 minutes.

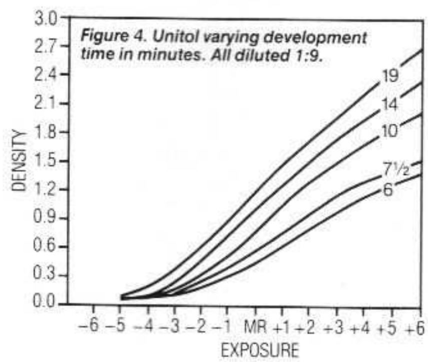


Figure 4. Unitol varying development time in minutes. All diluted 1:9.

Table I. T-Max Liquid Data

Dilution	Time	EI	Contrast Range
1:4	6 min	64	0.82
1:4	7½ min	100	1.02
1:4	10 min	100	1.26
1:4	14 min	100	1.57
1:4	19 min	200	1.58
1:15	10 min	64	0.62
1:9	10 min	100	0.82
1:7	10 min	100	1.04
1:4	10 min	100	1.26
1:3	10 min	160	1.40
1:2	10 min	250	1.72

Altering dilution produces significant highlight contrast changes, while a simple change in development time has little effect on the shape of the shoulder.

search this subject, you'll be surprised at how little careful work has been reported. As a result, I gave myself a series of questions and proceeded to test objectively for answers. The questions were as follows:

1. What happens to film contrast if you lower the dilution (make it stronger) and reduce development time as compared to increasing the dilution (weaker developer) and increasing development time?
2. At what point does decreased and increased dilution fail to be effective?
3. I use rotary processing and know that short development times cause uneven development. Instead of a short (risky) time, can increasing dilution be a viable alternative to minus development time?
4. Other than economics, if a manufacturer gives two recommended dilutions, why is one better than the other?
5. Can any general conclusions come from applying the same testing criteria to two different developers?

Testing Procedures

My film testing procedures were similar to those I outlined in my articles *B&W Calibration and System Testing, Part I* and *Part II* (January/February and March/April 1990). Since I'll only briefly describe my testing procedures, you may wish to see these two articles for more complete information.

I use a large untextured white board as a test target and make a series of progressive exposures from 5 stops under the meter reading to 6 stops over on two sheets of 4×5 T-Max 100 film. As a result, each 4×5 pair has a full range of exposures and can be used to produce a characteristic curve for the test. These tests were made using a Schneider 150mm Apo-Symmar lens on a Wisner Technical Field camera. I used a Minolta Spotmeter F for metering. I processed all the film using a Jobo CPP-2 processor and Jobo 3006 Expert Drums.

The developers I tested were Kodak T-Max Liquid and Monocolor Unitol (imported and distributed by Jobo Fototechnic). Both developers are recommended by the manufacturer for T-Max films.

I made a large number of identical exposure test sets to determine the differences (if any) between development time and dilution. For T-Max Liquid developer, I processed a two sheet film test (70°F for 10 minutes) at dilutions of 1:2, 1:3, 1:4, 1:7, 1:9, 1:15, 1:25, and 1:30. For comparison, I processed additional T-Max Liquid tests in the Kodak-recommended 1:4 dilution for 6, 7½, 10 (from above), 15, and 19 minutes.

For Unitol, I processed film tests (10 minutes at 70°F) for dilutions of 1:3, 1:5, 1:9, 1:14, 1:20, and 1:30. Additional tests were processed at the recommended 1:9 dilution for 6, 7½, 10, 14, and 19 minutes.

For each test pair, I read all the transmission densities and drew a characteristic curve (See Figures 1 to 4). Finally, I calculated an exposure index and determined film contrast.

Initial Observations

Comparing the four sets of characteristic curves for T-Max Liquid (Figures 1 and 2) and Unitol (Figures 3 and 4), it is easy to see the compensating effects of increased dilution on the highlight section of the curve. As you'll recall, compensation results from localized developing agent exhaustion and reduces highlight contrast. Compensation is most closely associated with "waterbath" and "two-bath" development, but it's also produced by highly diluted developers.

Compensation produces some pretty interesting effects in these tests. I found that varying development time produces contrast increases and decreases that don't produce much of a difference in curve shape. However, the more I diluted the developer, the more S-shaped its curves became. I also found that greater dilution produced a more pronounced curve shoulder. Even though I recognized what was happening immediately upon looking at the curves, I was excited by what I saw. I knew the tests had produced significant local contrast differences. Such differences produce novel subject renderings, and that's the stuff of creative variability. I'll have more to say about local contrast later in this article.

In determining EIs, I used 0.10 over film-base-plus-fog as a speed point. You can find my film speeds and contrast data in Tables I and II. Please note that my film "Contrast Range" is roughly equivalent to another photographer's "Density Range," or "Zone VIII—Zone II Density."

Not surprisingly, T-Max Liquid 1:25 and 1:30 dilutions were not strong enough to ensure full development. Both were inconsistent and yielded a contrast range lower than practical for use. I eliminated both from the tests.

I found another anomoly with T-Max Liquid diluted 1:4 for 19 minutes. While speed increased by one full stop, the increased fog level and threshold point negated any significant increase in highlight value, so contrast index remained the same from 14 minute to 19 minute development times. Only the speed increased.

My Unitol tests at 1:25 and 1:30 also proved to be uneven and inconsistent, yielding less than practical contrast ranges. Both were eliminated.

Note from Table I and II that EI and fog base changed progessively for both a time increase and a dilution decrease. Overall, Unitol produced the least fog. Also, I noticed that T-Max Liquid maintained more consistent film speed through the middle dilutions and middle development times.

Curve Comparisons

At this point, I was ready to learn more about the local contrast differences I had spotted in scanning the curve families. This involved picking two curves that produced roughly the same overall contrast but may have shown some local differences. I replotted the curves I wanted to compare, paying special attention to any opportunities I saw to compare development time with developer dilution. I've reproduced the four best contrast matches produced by the tests.

I compared T-Max Liquid 1:3 for 10 minutes (CR=1.4) with the same developer diluted 1:4 for 14 minutes (CR=1.57). See Figure 5.

Figure 6 shows T-Max Liquid diluted 1:7 for 10 minutes (CR=1.04) plotted with the same developer diluted 1:4 for 7½ minutes (CR=1.02).

For Unitol I first compared 1:5 for 10 minutes (CR=1.50) with a 1:9 dilution for 14 minutes (CR=1.49). See Figure 7.

Figure 8 shows Unitol diluted 1:9 for 7½ minutes (CR=1.01) compared with Unitol 1:14 for 10 minutes (CR=1.02). See Figure 8.

Observations

A greater dilution combined with a very long development time, produced a definite compensating effect with a noticeable loss of highlight contrast. Surprisingly, higher dilutions also affected the local contrast in curve toes, and, as a result, shadow reproduction. I must admit I can't find anything in the literature to attribute this effect, but I've since reproduced the results many times. In its most pronounced form (Unitol) the effect is similar to a long-toed film. See Figure 8 for a head-to-head comparison, but the overall trend is visible in Figures 1 and 3.

I'm quite surprised that dilution alone could impose a significant toe in a fairly short-toed film, like T-Max 100. To accomplish this "S" shape, dilution must be working to reduce local contrast in both the highlights and shadows.

For those photographers who've had difficulty adapting to T-Max, a higher dilution may help you make it behave more like a traditional film. A longer toe typically offers a little forgiveness in over and underexposure, but since it reduces shadow contrast there's likely to be a loss of shadow separation.

The more diluted developers also produced bumpy ("S"-shaped) midtone regions—the straightline middle section is anything but *straight*. The more diluted the developer, the greater the hump. Don't let this bumpiness frighten you away. Remember that Tri-X Professional is one of the bumpiest long-toed films you'll ever find, but it remains one of the most popular among fine art photographers. This humping effect typically produces a little more midtone contrast and gives slightly greater middle value separation.

I was very surprised to find such a high degree of contrast control available using dilution. It appears to be very different from simply changing development time. Looking at Figures 1 through 4, note that altering dilution produces significant highlight contrast changes, while a simple change in development time has little effect on the shape of the shoulder.

By way of conclusion, it seems there is more here to be considered than simply time and money. For the developers I tested, altering dilution definitely changed T-Max 100's characteristic curve, and subsequent subject rendering. It's very possible that other film-developer combinations would work along similar lines. I've come to the conclusion that dilution is a viable contrast control alternative. Also, for those of us using rotary processing, I've determined that dilution is a superior way of meeting minus (low contrast) film development needs. □

Contributing Editor Paul R. Schranz is a professor of photography at Governors State University in University Park, Illinois. His photographs can be found in many galleries and collections across the United States.

A greater dilution combined with a very long development time, produced a definite compensating effect with a noticeable loss of highlight contrast.

Table II. Unitol Data

Dilution	Time	EI	Contrast Range
1:9	6 min	32	0.94
1:9	7½ min	40	1.02
1:9	10 min	64	1.35
1:9	14 min	80	1.49
1:9	19 min	125	1.60
1:20	10 min	20	0.70
1:14	10 min	25	1.01
1:9	10 min	64	1.35
1:5	10 min	100	1.50
1:3	10 min	250	1.58

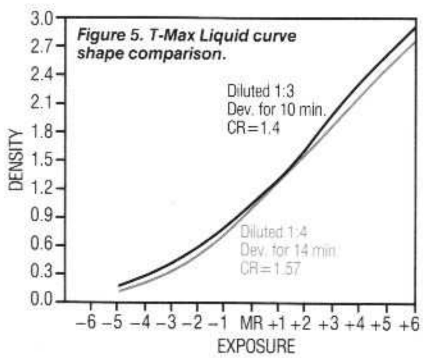


Figure 5. T-Max Liquid curve shape comparison.

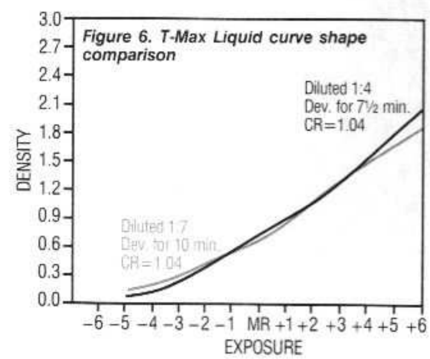


Figure 6. T-Max Liquid curve shape comparison

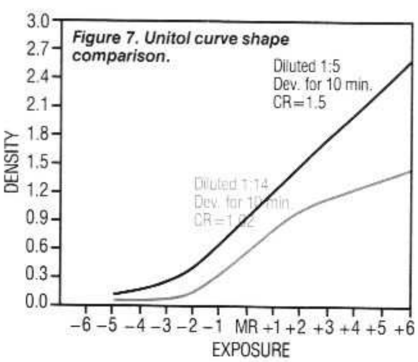


Figure 7. Unitol curve shape comparison.

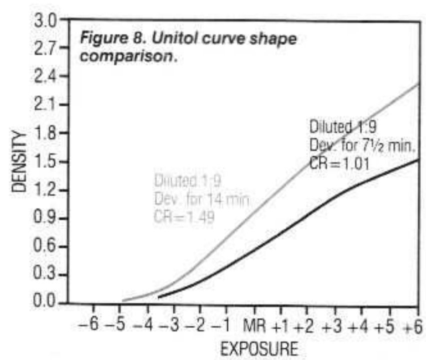


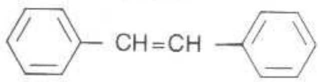
Figure 8. Unitol curve shape comparison.

Photochemistry

Continued from page 14

by giving off blue light fluorescence. The excess blue neutralizes the yellow and makes the object appear neutral, i.e. white. Remember that blue and yellow are color complements: B+Y in equal proportions equals neutral density. If even more brightener is used, the object will actually measure blue-white on a photometric instrument but will seem "whiter" and more appealing to the eye.

I won't give the formula for Tinopal SFP, since it would require about four full lines in this column and wouldn't make sense to anyone. This material is a member of the stilbene chemical family. The structure of stilbene is shown below:



Could you give an order of magnitude figure of the silver halide present in the emulsion of various films and paper?

Anything pertaining to emulsion composition is considered *sancto sanctorum* by emulsion manufacturers. However, silver halide content is fairly easy to determine, even with equipment found in a freshman chem lab.

According to my sources, emulsion coating thicknesses usually range between 3 and 30 microns (25 microns equals 0.001 inch). The silver (metal) to gelatin weight ratio normally ranges from 0.2 to 1.0.

Using a bit of arithmetic I arrive at coating weights of roughly 10-500mg of silver bromide per $100cm^2$ of coated emulsion. Understand that these are order of magnitude calculations only and are not meant to represent a particular film or paper. Most likely, coating weights for modern materials, except specialty items like nuclear or X-ray films, probably hover at the lower end of this scale.

If you have an accurate balance (roughly ± .01mg), try weighing undeveloped film before and after clearing it in fixer. Subtracting the two weights will give a fair approximation of the silver present. Using a larger sheet of film should provide the best accuracy.

The following question was submitted by R. C. Gannett, Wooster, Ohio:

Due to an extended illness I have been out of the darkroom for quite a while. I've had trouble mixing the Kodak F-5 Fixer. I follow Kodak's directions carefully but wind up with a milky solution when I mix in the potassium alum. In fact, there is precipitation.

My chemicals have been stored in tightly sealed bottles since I last used them. Can you tell me what I am doing wrong? Is the potassium alum the culprit?

Potassium alum (sulfate) is the likely source of the milkiness and precipitate in your fixer. The root cause is insufficient acidity.

When alum is dissolved, free aluminum ions (Al^{3+}) are produced. It is these ions that do the actual crosslinking or hardening of the gelatin emulsion. However, Al^{3+} ions also have a strong propensity to react with water to form the gelatinous white precipitate, aluminum hydroxide ($Al(OH)_3$), by the following reaction:

$$Al^{3+} + 3H_2O \leftrightarrow Al(OH)_3 + 3H^+$$

The main way to prevent this reaction from occurring is to maintain a high level of acidic buffer at a pH value around 4.5. This is normally done with a combination of acetic acid and sulfite (or metabisulfite).

Boric acid is often added since it inhibits precipitation at pH levels up to 6.0.

The formula I've provided incorporates both precipitate-inhibiting principles.

Hardening Fixer

Water	700ml
Sodium thiosulfate (penta.)	320g
Sodium sulfite	30g
Boric acid	10g
Acetic acid (99%)	18ml
Potassium alum	25g
Water to make	1 liter

Contributing Editor Robert Chapman holds a Ph.D. in chemistry from Yale University. He has worked in photo research and development departments at DuPont and Unicolor. He is currently engaged in holographic research.

Do you have a question on photochemisty? Send it to Robert Chapman, DARKROOM & CREATIVE CAMERA TECHNIQUES, *P.O. Box 48312, Niles, IL 60648. Look for the answer in an upcoming issue.*

Most installments of Robert Chapman's column from 1985 through 1987 have been reprinted and indexed in the book Photographic Processes: The Chemistry of Photography Volume II. *For ordering information see page 64.*