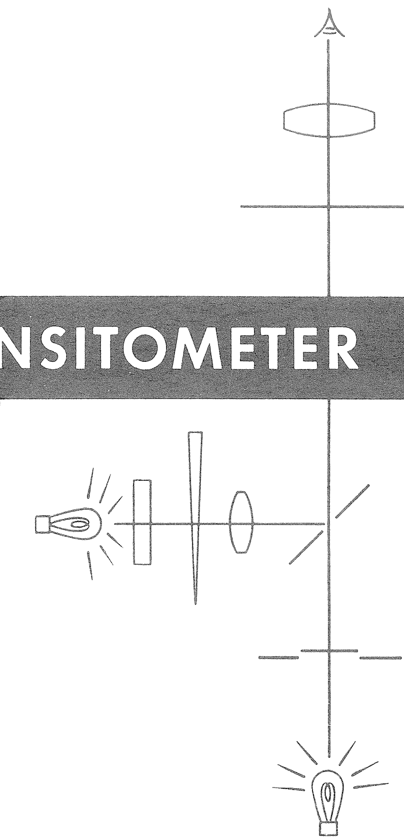
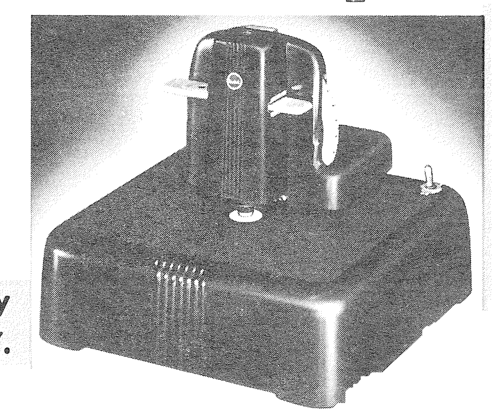
Kodak

Kodak

COLOR DENSITOMETER

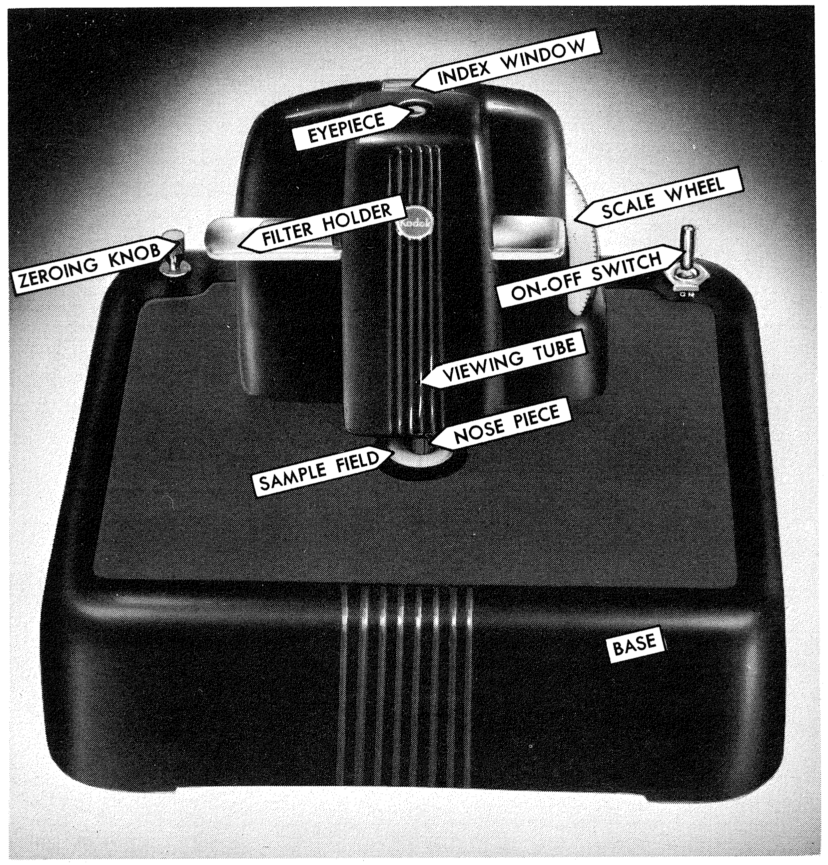




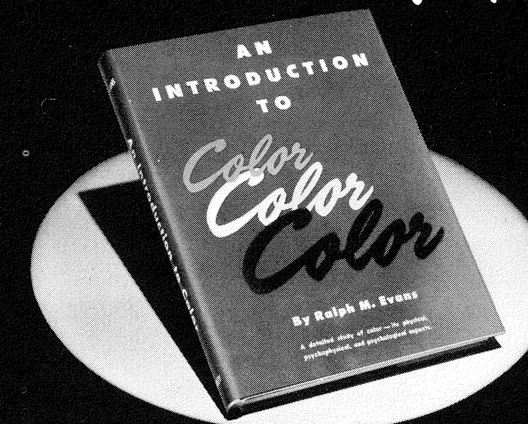
Eastman Kodak Company
Rochester 4, N. Y.

HOW TO USE THE

Kodak Color Densitometer



An Important book *for the color photographer...*

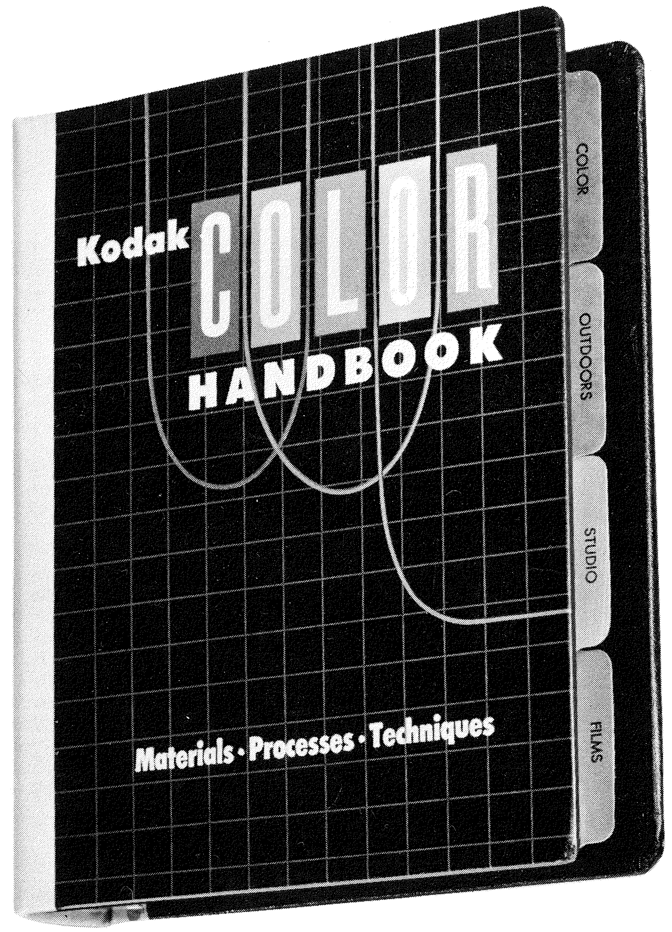


THIS is a truly definitive study of color. It covers the subject in detail, from the physical nature of light to the nature of the color sensations perceived by the mind. Almost no background of previous knowledge is assumed—any interested reader will understand the discussion and find it particularly helpful in clarifying the relationships between physical and mental processes.

Although only one chapter of the book is devoted to color photography as such, each of the twenty-one chapters contains significant information for the serious color photographer. Actually, the comprehensive scope of the book makes it an important one in any field where color is applied.

The author, Ralph M. Evans, is widely known both as a writer and as a lecturer. He heads Kodak's Color Control Department, which has broad responsibilities for maintenance of quality, product improvement, and development of new color processes.

An Introduction to Color *contains 340 pages and more than 300 illustrations, including 15 full-page color plates. It is sold by Kodak dealers.*



Your Kodak Color Densitometer Model 1 is an instrument that will let you measure the density of any transparent or translucent materials, especially photographic negatives and transparencies.

You, as a serious photographic worker, will find many uses for it. If you do color printing, your densitometer will be invaluable: You'll be using it to find exposures for separation negatives when you print your Kodachrome or Kodak Ektachrome transparencies; or for separation positives, if you work from Kodak Ektacolor negatives. Checking the balance of separation negatives is an easy procedure, and you can find out what to do about it if the balance is off. You can figure exposures directly for the three printing matrices you make from your separation negatives; much of the trial-and-error will be eliminated, and densitometry will be a tremendous help in your color-correction masking.

The Kodak Color Densitometer will be just as handy in your black-and-white work. Test strips will be a thing of the past; once you find the correct exposure for a print from one negative, you can make good prints from a hundred different negatives, with very little further experimentation. You can make the same kind of characteristic curves that are in the technical books—such curves will show exactly what you are getting out of your films, developers, etc., under your own working conditions, and with your own equipment.

This is not a textbook on densitometry and/or sensitometry. Therefore, it will be impossible for us to cover all of the uses of your densitometer. We'll try to acquaint you with a few basic principles here. The rest is up to you.

THE LANGUAGE OF DENSITOMETRY

Even if you are already familiar with elementary sensitometry—densitometry, you'd better read this part. And if you are not, it will help a lot to take a quick look at some of the terms—words and phrases—that you will be using regularly.

We have headed this section "The Language of *Densitometry*," and then in the first paragraph, we refer to *sensitometry*. We'd better explain that before going any further.

Sensi-tometry means "measuring sensitivity." We're not talking Greek, so we'll use it to mean determination of the photographic characteristics of a light-sensitive emulsion. *Densi*-tometry means "measuring density." Or, very broadly, using a densitometer to get the data that will *let* us determine the photographic characteristics of a film—or paper. (A densitometer can be used just as well on papers, all right, but it needs to be specially designed to read reflection densities.)

Since we are actually telling you how to use your Kodak Color Densitometer, we'll use the term "densitometry" from here on. Really, the use of one word implies the other. Think about it like this: Densitometry is the practical application of sensitometry. It's a way you can use some photographic theory to improve your own photographs, and save yourself some work. Now, as to some of these terms:

Density, the way we'll be using it, relates to the amount of developed silver (or dye) in any area of a negative, color transparency, or color negative. It's a measure of the "light-stopping power" of that area. The figures we use to express density—that are on the scale of your densitometer—are derived like this:

$$\text{Transmission} = \frac{\text{Amount of light that gets through any area}}{\text{Total amount of light that hits that area}}$$

It's usually called "T" and is expressed as a percent, so you have to multiply the above fraction by 100. A transmission of 85 percent (T = 85%) means that 85 percent of the light that hits any specific part of a negative or transparency gets through it.

$$\text{Opacity} = \frac{\text{Total amount of light that hits any area}}{\text{Amount of light that gets through that area}}$$

As you can see, it's the transmission turned upside down. So "O" = 1/T. We don't use percent here, so for our above example (T = 85%) the opacity ("O") is 1/0.85 or 1.175. We'll be talking about opacities quite a bit, and you'll be using them later. Remember: the higher the opacity, the less light gets through.

Now, density (D) relates directly to the opacity; it's the logarithm of the opacity (to the base 10).

D = log O (or D = log 1/T)

If you don't remember much about logs, don't let that equation scare you. We've included a density-opacity table on page 30 for your reference, when you do any figuring. Keep in mind that density and opacity actually mean about the same thing. They are written in different ways, that's all.

The density in any part of a negative, with any film-development combination, depends on two things. First, the exposure which that part of the negative received, and, second, the degree of development—

.05	.06	.07	.08	.09
1.12	1.15	1.18	1.20	1.23
1.41	1.45	1.48	1.51	1.55
1.78	1.82	1.86	1.91	1.95
2.24	2.29	2.34	2.40	2.46
2.82	2.88	2.95	3.02	3.09
3.55	3.63	3.72	3.80	3.89
4.47	4.57	4.68	4.79	4.90
5.62	5.75	5.89	6.03	6.17
7.08	7.24	7.41	7.59	7.76
8.91	9.12	9.33	9.55	9.77
11.22	11.48	11.75	12.02	12.30
14.13	14.45	14.79	15.14	15.49
17.78	18.20	18.62	19.05	19.50
22.39	22.91	23.44	23.99	24.55
28.18	28.84	29.51	30.20	30.90
35.48	36.31	37.15	38.02	38.90
44.67	45.71	46.77	47.86	48.98
56.23	57.54	58.88	60.26	61.66
70.80	72.44	74.13	75.86	77.63
89.13	91.20	93.33	95.50	97.72
112.2	114.8	117.5	120.2	123.0
141.3	144.5	147.9	151.4	154.9
177.8	182.0	186.2	190.5	195.0
223.9	229.1	234.4	239.9	245.5
281.8	288.4	295.1	302.0	309.0
354.8	363.1	371.5	380.2	389.0
446.7	457.1	467.7	478.6	489.8
562.3	575.4	588.8	602.6	616.6
708.0	724.4	741.3	758.6	776.3
891.3	912.0	933.3	955.0	977.2
1122.	1148.	1175.	1202.	1230.

EASTMAN KODAK COMPANY

Rochester 4, N.Y.

HE-1137a
12-55-GLP-B

Lithographed in the United States of America

DENSITY - OPACITY TABLE

DENSITY	.00	.01	.02	.03	.04
0.0	1.00	1.02	1.05	1.07	1.10
.1	1.26	1.29	1.32	1.35	1.38
.2	1.59	1.62	1.66	1.70	1.74
.3	2.00	2.04	2.09	2.14	2.19
.4	2.51	2.57	2.63	2.69	2.75
.5	3.16	3.24	3.31	3.39	3.47
.6	3.98	4.07	4.17	4.27	4.37
.7	5.01	5.13	5.25	5.37	5.50
.8	6.31	6.46	6.61	6.76	6.92
.9	7.94	8.13	8.32	8.51	8.71
1.0	10.00	10.23	10.47	10.72	10.96
1.1	12.59	12.88	13.18	13.49	13.80
1.2	15.85	16.22	16.60	16.98	17.38
1.3	19.95	20.42	20.89	21.38	21.88
1.4	25.12	25.70	26.30	26.92	27.54
1.5	31.62	32.36	33.11	33.88	34.67
1.6	39.81	40.74	41.69	42.66	43.65
1.7	50.12	51.29	52.48	53.70	54.95
1.8	63.10	64.57	66.07	67.61	69.18
1.9	79.43	81.28	83.18	85.11	87.10
2.0	100.0	102.3	104.7	107.2	109.6
2.1	125.9	128.8	131.8	134.9	138.0
2.2	158.5	162.2	166.0	169.8	173.8
2.3	199.5	204.2	208.9	213.8	218.8
2.4	251.2	257.0	263.0	269.2	275.4
2.5	316.2	323.6	331.1	338.8	346.7
2.6	398.1	407.4	416.9	426.6	436.5
2.7	501.2	512.9	524.8	537.0	549.5
2.8	631.0	645.7	660.7	676.1	691.8
2.9	794.3	812.8	831.8	851.1	871.0
3.0	1000.	1023.	1047.	1072.	1096.

To find the opacity corresponding to a given density, locate, in the vertical column on the extreme left, the density to the first place of decimals. Then, in the top row, find the correct figure for the second place of decimals. The corresponding opacity is found in the horizontal row to the right of the first part of the density value and in the column directly below the second part of the density value. To find the density corresponding to a given opacity, locate the value, in the body of the table, that is closest to the given opacity. Then, find the density to the first place of decimals at the extreme left of the same row, and find the second place of decimals at the top of the same column.

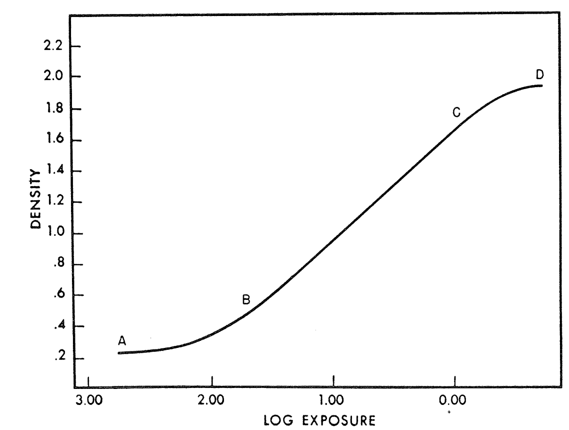
$D = \log O$ (D = density; O = opacity)

$O = \frac{1}{T}$ (T = transmittance)

$T = \frac{I_t}{I_o}$ (I_t = intensity of transmitted light; I_o = intensity of incident light)

or gamma (γ)—of the image. In any normally developed negative, the density differences we see are there because the different areas received different amounts of exposure. We can say that ***with any given degree of development, the density anywhere in the negative depends on the exposure at that point.***

Let's draw a picture of that relationship. To do it, we need to get a piece of film, give it a series of exposures (like a test strip), and develop it. Then we'll make a graph; we'll read the densities in the developed strip, and plot them against the logarithms of the exposures we used to produce them. (We use the logarithms of the exposures because the density is logarithmic.):



That ought to look familiar to you. It is the characteristic curve, or H & D curve (after Hunter and Driffield, the men who devised it), or D-log E curve, or whatever you know it by. We'll call it the characteristic curve.

This curve actually describes a negative. Densities falling on the "toe" portion (A-B) of our curve are *not* directly proportionate to the log exposures. Neither are the "shoulder" (C-D) densities. That doesn't mean that we shouldn't use these two parts of the curve. We do. In a really good negative, we often use the toe. The main thing here is to know what the "toe", "shoulder", and "straight-line" portions of the curve are, and what they mean to us in our picture taking. (We're going to draw our own curves later, so we'll need to be familiar with these terms.)

B-C is the "straight-line" portion of the curve; the density in the film increases proportionately with the log of the exposure. Extend the straight-line part of the curve so that it meets the "log E" axis. The tangent of the angle that line makes with the log E is "γ." Generally, the longer you develop any film in any developer, the higher the gamma will be until it finally reaches a limit. We can say this another way: The higher the γ, the greater the contrast of the negative, *due to development.* That italicized phrase is important. The total—or printing—contrast is due to quite a few factors; subject contrast, development contrast, flare in the optical systems of camera and enlarger, etc. So when we talk about "γ," we are referring to development contrast only.

We said earlier that the characteristic curve can be used to "describe" a negative. How? Let's find out.

Whenever you take a picture of a subject having a long brightness scale—or, of what is commonly called a "contrasty" subject—the whole curve is represented in the developed negative: The *shadow areas* in the negative will correspond to *toe densities* of the curve; the *highlights* in the negative can be said to be *shoulder densities;* and the *tones in between* all the highlights and shadows of the negative will be represented by the densities lying on the *straight-line portion* of our curve.

Remember that in that straight-line portion the density in the film increases an equal amount for each log exposure difference; so we say that we have "good tone separation" in those areas of our pictures that are composed of straight-line densities.

In the toe and shoulder regions of the curve, though, equal log exposure differences don't produce equal density differences, so we can say that the tones in our pictures are *compressed* in the shadows and highlights. *The tone separation is never as good in the toe and shoulder region as it is over the straight-line portion.*

So when we talk about "good exposure," we actually mean that we'd like to expose our pictures so that as much of our subject as possible will be represented in the negative by straight-line densities. The only thing is, we can't get *all* the areas of the subject to record on that straight line—unless we pick our subject very carefully and then we'd have to be pretty lucky. (We don't want to be misunderstood; it's possible to *arrange* such a subject, but we're talking about the things you see and photograph every day.) Let's just say that the "brightness range" of most everyday subjects is too great to let us make negatives of them without using any of the toe or shoulder densities of our curve.

of the bulb for use in the base, to avoid shadow patterns in the ground glass; the other bulb may be used in the head.

To replace the lamp in the base, turn the densitometer on its side and remove the four screws holding the metal cover plate in place. Lower the cover plate.

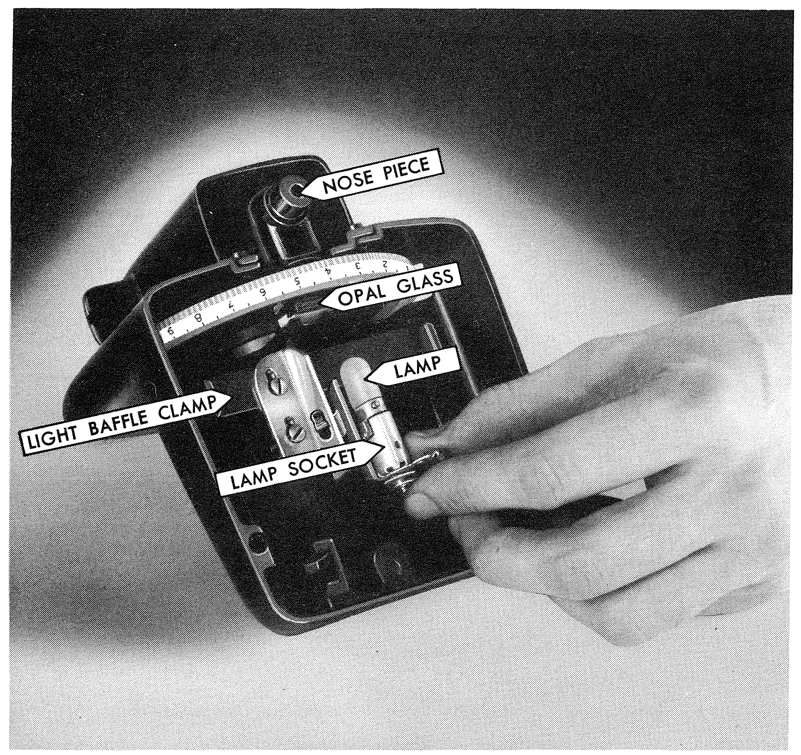
> **CAUTION:** Be sure to unplug the line cord before replacing or adjusting any lamps.

Remove the lamp and socket by drawing straight down on the socket. Press in on the lamp and turn it counterclockwise. Take it out of the socket. Place the new lamp in the socket, and press it in, giving it a clockwise turn to lock it. Replace the socket on the zeroing arm and fasten the cover plate back in place. Note: When you replace the screws, don't try to screw them in any more than is necessary to hold the cover snugly in place, or you'll strip the threads.

To replace the lamp in the head, raise the head as far as it will go, but don't force it back any further. Now remove the spring light baffle by unhooking the ear on one side and drawing the baffle out. The lamp and socket are held in place with a spring clamp like the one in the base. Slide off the socket, and replace the old lamp with a new one. Slide the lamp and socket back into position—the end of the lamp bulb should just clear the glass plate. Replace the light baffle.

Always check the zero setting after changing lamps.

One of the lamps illuminates the sample field; it's located in the base. The other lamp is in the head—to provide light for the comparison field. These lamps have long useful lives, provided the switch is turned off when the densitometer is not in use. Even so, check them occasionally to be sure one lamp hasn't changed in characteristics more than the other. With no sample under the nose-piece, check the zero setting through the three color-filters. You'll probably always get very slightly different readings; but if there is a difference of more than 0.05, change the lamps. Always change both lamps, never just one of them. That insures that they'll stay as closely matched as possible for as long a time as possible; the two fields will then stay visually matched in color balance. Since these lamps are standard commercial lamps, there may be evidence of striae or bubbles in the end of the bulb. Before replacing the lamps choose the lamp with the lesser amount of striae on the end



That's the reason that most expert photographers are so careful in determining their exposures. They realize that the shadow tones in their pictures will be compressed, and so will the tones in the highlights. But if they're reasonably careful in using exposure guides—or meters—*most* of the densities in their negatives will correspond to the straight-line densities of the curve. They'll get "good" negatives. If we keep this in mind, we won't go far wrong in evaluating our own negatives.

The highlights in our negatives shouldn't fall on the shoulder any more than we can help. If we overexpose very much, more of the densities will be on this shoulder region. We'll then have very poor highlight tone separation in our prints. As we said, part of our shadow densities will normally be on the toe of the curve; if we underexpose quite a bit, we use even more of this toe portion, and our shadow tone separation will be poorer than it should be.

In each case, gross over- or underexposure of the negatives, our prints are apt to be flat, with the important tones in both highlights and shadows showing far too little separation.

If we expose and develop our negatives so that as few densities as possible fall on the toe and shoulder, we're all right—we have "good" negatives.

Let's summarize:

$$T = \text{Transmission} = \frac{\text{Light transmitted by any part of a film or plate}}{\text{Total light falling on that part of the film or plate}}$$

$$O = \text{Opacity} = \frac{\text{Total light falling on the film or plate}}{\text{Light transmitted by any part of the film or plate}}$$

D = Density = Logarithm of Opacity, or log O.

Characteristic curve: The graph you get when you plot density ("D") against the log (logarithm) of the exposure. (Sometimes referred to as the "H & D" or D-log E curve.)

Toe: That part of the characteristic curve representing the shadow portions of the original subject in a photographic negative (or the highlights of the subject in a positive). Equal log exposure differences produce *increasing* density differences.

Straight line: The part of the curve where equal exposure differences produce *equal* (or almost equal) density differences.

Shoulder: That portion of the curve that shows *decreasing* density differences with equal log exposure differences. Some of the highlights in your negatives will probably be shoulder densities.

Gamma: (γ) The tangent of the angle the straight-line portion of the curve makes when extended to cut the log E axis. Gamma varies directly with development time; the longer you develop any film in a given developer, the higher the gamma will be. Gamma (γ) is development contrast. It *does not* specify the printing contrast of a negative. (If you're worrying about that "tangent" term, don't. We're going to determine gamma (γ) later by using a simple proportion.) Before closing this basic theory section, we want to clear up a point that is bound to arise sooner or later:

There are two kinds of density. They're defined alike, but measured differently. The first is *diffuse* density. It is measured by placing a light source behind the film and reading the density right at the film (emulsion) surface—your Kodak Color Densitometer measures diffuse density.

The second kind of density is *specular* density. Here, the light that illuminates the sample is "collimated" (i.e., passed through a condenser system) and the reading is made through a lens system placed at a distance from the emulsion of the film. Specular density is always higher than diffuse density; this accounts for the fact that condenser enlargers produce more contrasty prints with any given negative than enlargers using a diffused light source. The ratio between specular and diffuse density is labeled "Q." It's called Callier's quotient, Callier being the man who discovered the difference.

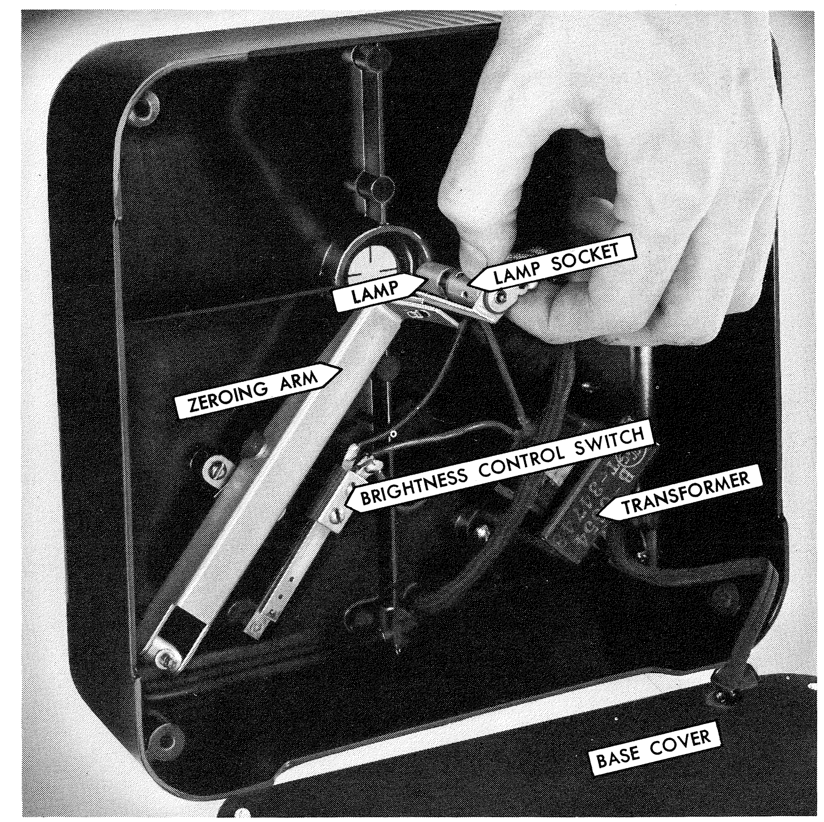
You're going to want more information along these lines, and we haven't space in a booklet such as this to go any deeper into theory. We've had to skip many important parts of what can be a really fascinating study. For more complete information, read any of the texts on photographic theory, such as "This is Photography," by Miller and Brummit, published by the Garden City Publishing Co., Inc., Garden City, N.Y.; "Fundamentals of Photographic Theory," by James and Higgins, published by John Wiley and Sons, Inc., New York City; "The Theory of the Photographic Process," by C.E.K. Mees, published by the MacMillan Co., New York City; "Photographic

of readings to make at any one time. Try yours "on a slant" and see if you like it.

When not in use, your densitometer should be covered to protect it from dirt and dust. You can keep it in its box, or keep the head covered with a dust cover of some type. (One of those plastic covers with the elastic top, designed for covering food dishes in a refrigerator, makes a wonderful dust cover.)

Replacing Lamps

The Kodak Color Densitometer uses two similar lamps—both 6- to 8-volt, .25-amp, T 3 1/4 bulb, miniature bayonet base. The lamps operate at rated voltage—6 volts—obtained by the transformer in the base of the instrument.



red exposure time is opposite the red density of the negative to be printed.

4) Turn both dials (red and transparent) until the *green* pointer is opposite the *red-filter* exposure time. Now read the green-filter exposure time opposite the green density of your negative.

5) Rotate both dials again so that the *blue* pointer is opposite the *red-filter* exposure time. Read the blue-filter exposure opposite the blue density.

Treat all your negatives that were exposed and processed like the "gray-card" negative this way. We repeat, if you change to a different exposure-processing batch, be sure to include one negative that contains a well-lighted image of the gray side of the Kodak Neutral Test Card. Then, read the three color-densities and tie them in with the "master" negative as we've just done.

Summary

You are aware of the fact that in this booklet we have been telling you how to use your Kodak Color Densitometer. We have therefore eliminated all detailed instructions as to the exposure and processing of color films, the preparation of separation negatives, and the actual color-printing procedure. Complete information along these lines is readily available to you in the *Kodak Color Handbook* and the Kodak Color Data Books "Color Separation and Masking" and "Kodak Dye Transfer Process." These publications are all available from your Kodak dealer.

Good luck in your densitometry.

APPENDIX

Care and Maintenance

Your Kodak Color Densitometer Model 1 is a laboratory instrument, so you need to use some care when you handle it. Ordinary handling won't hurt it, and it can be expected to give satisfactory service for a long time with normal care. The main thing is: don't drop it, and/or don't drop anything heavy on it!

Some densitometer operators find their instruments more convenient to use if a stand is built so that the base is tilted 20° or 30° toward them. Then, they don't have to lean over so far when they make density readings. This can be a very important point; your shoulder and neck muscles can get very tired if you have a lot

Sensitometry," by Lloyd A. Jones (now out of print, but available in some libraries); or "Photography Principles and Practice," by C.B. Neblette, published by D. Van Nostrand Co., New York City.

OPERATING YOUR DENSITOMETER

Power Supply

The Kodak Color Densitometer Model 1 is designed to operate on 110- to 125-volt, 50- to 60-cycle alternating current (AC). (A 220-volt, 50- to 60-cycle AC model is available on special order.)

Setting the Zero

Before you can measure anything accurately with your densitometer, it must be "zeroed." That is, it has to be adjusted to read "0" on the scale when no sample is under the nosepiece.

To zero the Kodak Color Densitometer, plug it into a suitable electric outlet and turn it on, then: 1) Set the 0 on the density scale at the index mark inside the window atop the head. 2) Move the filter holder so that the clear aperture is in the viewing beam. 3) Hold the head down in contact with the opal glass disk in the base. 4) Look through the eyepiece, and turn the *zeroing knob* until the two fields you see are the same brightness. *Do not move the density scale from 0.* 5) Now, leave the zeroing knob alone, and move the density scale so that it reads above zero. Then, by moving the density scale, rebalance the field. With the two fields adjusted to the same brightness (balanced), see if the scale reads 0 again. If it doesn't, repeat the procedure until the proper setting of the zeroing knob is confirmed.

Once you have zeroed your densitometer, you don't need to check it again until the next time you make readings. It's always a good idea to check the zero setting each time you use your densitometer to make sure the zeroing knob hasn't been moved. Since both the fields you see through the eyepiece are illuminated by identical lamps, normal line-voltage variations do not affect the zero setting or the accuracy of your readings. Always take the time to check the zero setting before you make any critical readings.

To Measure Density

To read densities with the densitometer, raise the head and place the sample, emulsion up, on the opal glass disk in the base; then, lower the head until the nosepiece touches the sample. Be sure the clear aperture of the filter holder is in the viewing beam. When you change from one spot to another on the sample, raise the head. so you don't scratch the film or plate.

By the way, when you raise the head, you'll notice two things: First, the light dims when the head is up, brightens when the head is lowered. This saves the lamps and makes centering the sample easier on the eyes. Second, there are four position lines on the opal disk in the base. Use them to center the area to be read. Your densitometer actually "sees" an area 1-1/4mm in diameter.

With your sample in place and the head lowered, look into the eyepiece. Does the central spot look uniform in density? If not, move the sample around very slightly until it does. Your readings will be much more accurate, and a lot easier to make.

When you've smoothed out that center spot, make your reading. While looking through the eyepiece, turn the density scale until the spot matches the surrounding field as closely as you can make it. (The spot ought to practically disappear.) Now read the density on the scale under the index line.

The scale is graduated in equally spaced steps of 0.05 with each 0.10 step marked. If your reading doesn't exactly fall on one of the calibration marks, estimate what you think it is. For example, if the scale indicates that the sample you're measuring has a density a little more than halfway between 1.6 and 1.65, call it 1.63. If it's a little less than halfway, call it 1.62.

Reading Densities Higher than 3.0

Your Kodak Color Densitometer is designed to read densities from 0.0 to 3.0. Sometimes (not very often) you may want to measure densities above 3.0. You can do this by a very simple modification of your densitometer. You just put a small rectangle cut from a Kodak Wratten Neutral Density Filter No. 96 (Gelatin Film, Density 1.0) in the comparison beam; this adjustment makes the usable scale of the densitometer run from densities of 1.0 to 4.0. All you do is make the reading as usual and add 1.0 to whatever value appears on the scale. If the scale says 2.32, the density actually is 3.32.

To insert the filter, raise the head and take out the spring light baffle as described in the section in the back of this booklet, "Replacing Lamps." Then, slip the small square cut from the Neutral

for all the other negatives in that exposure-processing batch by reading the red, green, and blue densities of that Neutral Test Card image, so don't ever forget it. Typical values might be: red, 0.66; green, 0.72; and blue, 0.76. If you find it hard to get the blue density reading, use the Kodak Wratten Filter No. 47 supplied with the Kodak Vacuum Register Board instead of the No. 39A supplied with the densitometer. However, you'll generally get more dependable exposure information by using the No. 39A.

Now determine, by trial, the exposure times required through the three separation filters to obtain equal densities in the Neutral Test Card area on Pan Matrix Film. Let's say these exposures are: red, 18 seconds; green, 23 seconds; and blue, 29 seconds.

You are now ready to set up the Dataguide for use. Attach the small *red* acetate triangle to the edge of the outer transparent dial with Scotch tape, so that a small point of the triangle is visible beyond the edge of the dial. Then slip the transparent dial in the red "Density" dial so that the red pointer is opposite the red density in the master negative—0.66 in our example.

Now rotate both dials until the *green* density (0.72) is opposite the green-filter exposure time (23 seconds). Fasten the *green* acetate triangle under the transparent dial so that the pointer is opposite the—note carefully—*red* exposure time (18 seconds). The green and red pointers may or may not fall in the same place.

Rotate both dials again, until the blue density of the master negative (0.76) is opposite the blue exposure time (29 seconds). Now fasten the blue acetate triangle under the transparent dial so that—again, watch it!—the point is opposite the *red* exposure time (18 seconds).

The Dataguide is set up and ready to use.

Using the Dye Transfer Dataguide

As long as you use the same equipment and the same emulsion of Pan Matrix Film, you can now get your relative exposure values directly from the Dataguide. Here's your procedure:

1) Read and record the three color densities in the Test Card area of the negative you're going to print.

2) Find—by trial—the exposure required to give a just perceptible density in a diffuse white highlight area of the cyan printer (the red-filter exposure).

3) Slip the transparent dial (with the pointers attached) until the

By the way, the spaces at the ends of the holder are fine for storing extra filters.

Determination of Separation Exposures from Color Negatives

In making Dye Transfer Prints from Kodak Ektacolor negatives, it is not necessary to make color separation negatives. We do, however, make separation exposures through red, green, and blue filters on separate sheets of Kodak Pan Matrix Film. These are then processed, dyed, and the dye images transferred to Kodak Dye Transfer Paper to produce the final color print.

The first step is to determine by trial the exposure required to give a just perceptible density in a diffuse white highlight area of the cyan printer. You can then use your densitometer to simplify greatly the process of determining the other two printing exposures. For this job, you're going to need a Kodak Print Exposure Computer, so have one handy.

When you buy your Kodak Vacuum Register Board, you'll notice that some colored acetate triangles and a 5/8" x 1 1/4" strip of unexposed but processed Ektacolor film are included.

The strip of Ektacolor film is there to let you modify your densitometer so that the over-all orange-red color of the Ektacolor negative won't interfere with your colored density readings by making the sample field a different color from the comparison field. Just cut a piece of the film 5/8" square and slide it into the comparison beam of the densitometer, as you did the Neutral Density Filter when you wanted to read densities higher than 3.0 (see page 8). The densitometer is then zeroed with the green filter in place in the filter holder. The triangles are for use with the Dye Transfer Dataguide.

Pick one of your good Ektacolor negatives that contains the image of the gray side of the Kodak Neutral Test Card—it should be typical of the negatives you're going to print later. We'll call this our "master" Ektacolor negative.

After you put the unexposed, processed Ektacolor film in the comparison beam, read the densities of the image of the Neutral Test Card in your "master" Ektacolor negative. Read the densities through the red, green, and blue filters, and write them down. Each time you expose and/or process any Ektacolor film, include one shot made with the Neutral Test Card—the gray side—held where it receives the same lighting that falls on the important part of the subject. You're going to determine your relative printing exposures

Density Filter (it should be about 5/8" square) between the opal glass and its mount. Replace the light baffle and make your readings. It helps to darken the room when you're reading densities above 3.0.

Filter Holder

In case you're wondering about the Filter Holder that came with your Kodak Color Densitometer, it's to be used when we start measuring colored areas, like Kodachrome or Kodak Ektachrome transparencies, or color negatives, like those made with Kodak Ektacolor Film.

When a number of low density measurements are to be made, it is desirable to install the neutral density filter, packed with the densitometer, in the filter holder and adjust the holder so that the neutral density filter is in the beam to reduce the over-all brightness of the fields.

PUTTING DENSITOMETRY TO WORK

Densitometry in Black and White

We've covered some basic theory and have learned to read the densitometer; now let's take up some practical problems. For a start, we'll take up the question of the exposure, development, and printing of black-and-white pictures.

Your densitometer will let you put your darkroom work on a truly scientific basis. You can tell if your negatives are properly exposed and developed—if you can expect to get really good straight prints from them. If indications are that your negatives aren't all that they should be, you can do something about it. In your printing, you'll find that correct use of your densitometer will save a lot of wasted time and materials.

Judging Negative Exposures

First of all, check up on yourself: You've been making good negatives, but let's see if we can't perhaps improve them a bit. Get a few of your negatives together—some that are representative of your work. You are about to find out if you've been exposing your negatives correctly.

Take a density reading of the clear edge of the film. Write it down. (Always keep a scratch pad and pencil with your densitometer, or, better still, start keeping a notebook. Never trust your memory.)

Next, read the density of the shadow area—the lightest part—of the image in the negative. Now, subtract the first reading from the second. Is the difference at least 0.05? If it's lower than that value, your negative is underexposed so badly that you'll never get a really good print from it.

The first reading you took was to measure the density of the film support *(base density)* and the small amount of fog that is always present due to development. Such a measurement is called a "base-plus-fog" density determination.

We've said that the difference in density between the deepest shadow in a negative and the base-plus-fog should not be *less* than 0.05. For a really good negative, that difference ought to be around 0.15 or 0.2. So, if your shadow densities are consistently low with any film-developer combination, start boosting your exposures. Begin by doubling the exposure you've been using. If that doesn't do it, keep giving more exposure, until your shadow densities are up to where they should be. You'll notice a vast difference in your prints. We haven't mentioned changing your development yet. Don't. ***Shadow density measurements are used to adjust exposures.*** That's a very important point to remember.

Density Scale of Negatives

Later on we'll be talking about "density ranges" in connection with color-separation negatives. Really, the two terms "density scale" and "density range" mean the same thing. However, densitometrists usually say "density *scale*" when they're talking about black-and-white negatives and "density *range*" when discussing color materials.

So let's measure the ***density scale*** of a negative. Here we don't need to measure the base-plus-fog density, unless we want to for some special purpose. We're going to compare two densities in the negative, and the base-plus-fog will be part of each; it will cancel itself in any calculations we make.

Read the density of the blackest highlight in the negative in which you expect some detail in your print. Then read the shadow density, or the lightest part of the negative where detail is required. Subtract the shadow density from the highlight density; the difference between them is the density scale of the negative. For example:

Highlight density = 1.62
—Shadow density = 0.32
Density Scale = 1.30

the highlight densities of all three negatives to opacities, and find the other two exposures:

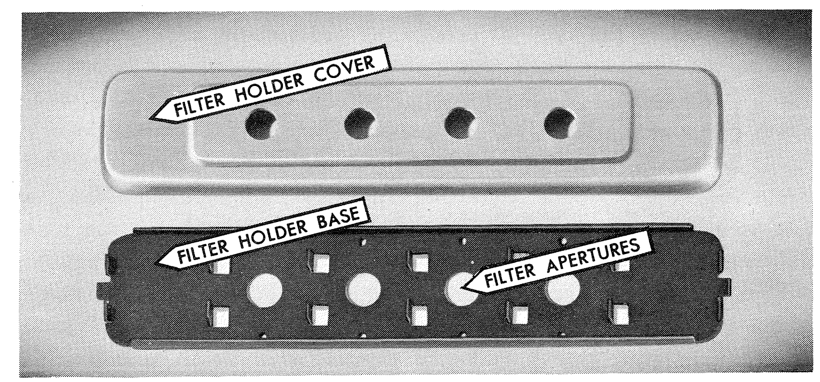
Negative	Highlight Density	Opacity	Exposure
Red	1.70	50.12	10 seconds (by test)
Green	1.65	44.67	9 seconds (calculated)
Blue	1.74	54.95	11 seconds (calculated)

Or you can use the Kodak Dye Transfer Dataguide to get the relative exposures from the densities directly, without having to do any figuring. Instructions for this technique are on the back of the Dataguide.

If you want to print another set of separations at the same time, you don't need to make another test, provided you don't change emulsions of matrix film. Just use the relative highlight densities and base your exposures on the first test. If you change magnification, use the Dataguide to find the new exposures.

Color Prints from Color Negatives

Now we start to measure colored densities. Let's go back to that Filter Holder.



A pressed metal filter holder is supplied with your Kodak Color Densitometer. The holder provides for three filters and a clear space. Slide the filter holder into the viewing tube of the head. You can tell when any filter is correctly positioned—there are click stops to let you know. The filters provided are the Kodak Wratten Filters No. 70 (red), No. 74 (green), and No. 39A (blue).

To change or clean the filters, draw the filter holder from the viewing tube and pry the holder apart. The filters come out easily.

Don't use any of your filters to measure the densities of the transparency. Use white light. There will be some color in the areas you want to measure, but it probably won't bother your density measurements. Just balance the two fields as closely as you can, and let it go at that. Here again, we want to *compare* the density ranges of the separations. The absolute values of the original densities are of no real importance.

Sometimes you can't measure the highlight and shadow densities of the original transparency. In that case, you can get comparative density ranges of the separations as follows:

Pick the important highlight and shadow areas in the red separation negative—the picture area—and read the densities. Next, locate the two steps of the step-tablet image, on the same negative, that most closely match the highlight and shadow densities in the picture area, and record the readings. Now, measure these two steps in the step-tablet images of the other two separation negatives. Subtract the low density from the high density in each case, and you'll have the comparative density ranges again.

Do these "density-range" determinations sound familiar? That's right. We called it finding the density *scale* of a black-and-white negative. There we could read the densities—highlight and shadow—in the picture area, and use them directly. In color-separation work we can't, unless we have a completely neutral highlight and shadow in our original transparency—a very rare situation. Usually, these areas have some color in them, so we can expect that the relative densities will *not* be the same in all three separations, even if the separations are correctly balanced for exposure. That's why we use the step tablet to get comparative density ranges; it's neutral.

Determination of Printing Exposures for Color-Separation Negatives

Use the relative highlight density method—don't try to use shadow densities. Make a test on Kodak Matrix Film with the red separation, using the Kodak Projection Print Scale or make a picture test strip as you would to find the printing time of a black-and-white negative. Process the test strip completely, dye it cyan, and transfer it. Examine the transferred image from a "print-quality" standpoint exactly as you would in black-and-white. To prevent the cyan color from affecting your judgment, look at the image through a red filter (Kodak Wratten No. 25 or No. 29).

After you pick the correct exposure for the red negative, convert

That's all there is to that. One word of caution:

Some things you photograph may contain shiny objects—metal, glass, etc.—that reflect any lights brilliantly. The "highlights" in your negative will not be these very bright reflections. They contain no detail at all and should reproduce in the print as white. The highlight you measure should be the densest part of your negative in which you want to be able to see detail in the print.

We know how to find the density scale of a negative; now let's put it to practical use.

Exposure Scale of Photographic Papers

When we speak of the exposure scale of a paper, we're talking about the difference in light intensities necessary to produce the full range of tones in the paper—from white to the maximum black of which the paper is capable.

If a light intensity of one unit produces an exposure that barely shows, and a light intensity of 30 just produces the maximum black, the *exposure scale* of that paper is said to be 30 to 1. Or, it can be written 30:1.

The main difference between the printing grades of any given paper, such as Kodabromide, is that the higher numbers have progressively shorter exposure scales. For different surfaces of the same grade of any given Kodak paper, the exposure scales are essentially the same. For example, the scale of Kodak Azo E Paper No. 2 is just about the same as the scale of Kodak Azo G Paper No. 2. This relationship doesn't hold, though, for similar contrast grades of different papers. Also, the various grades of Kodak contact printing papers do not generally have the same exposure scales as corresponding grades of Kodak enlarging papers.

The exposure scales of the most commonly used Kodak papers are given in the table below. Exposure scale values for the other Kodak papers can be found in the Data Book "Kodak Papers." These values are the result of careful laboratory tests. Use them. They work.

Relation of Negative Density Scale to Paper Exposure Scale

You've probably guessed by now that we can tie these two things together. You know the exposure scale value for the Kodak paper; therefore if you determine the density scale of your negative, you can pick the paper grade to fit it. We're not going to set up any definite *rules* for you to follow. Your taste is going to enter into the picture here, but we'll put forth a few suggestions you may want to use.

On the average, you'll probably get your most pleasing prints: 1) with *soft* papers, when the density scale of the negative is *greater* than the log exposure scale of the paper; 2) with *medium* grades, when the density scale of the negative and the log exposure scale of the paper are about *equal;* and 3) with *hard* grades of paper when the density scale of the negative is *smaller* than the log exposure scale of the paper.

You'll notice we've switched to logarithms in discussing exposure scales of papers. Remember, density is logarithmic too; so we get a more direct relationship between density scale and paper exposure scale if we use logs in talking about both.

For Kodak Azo and Kodak Velox Papers

Paper Grade	Approximate Log Exposure Scale	Density Scale of Negative Usually Suited for Each Grade
0	1.50	1.45 or higher
1	1.30	1.45 to 1.20
2	1.10	1.20 to 0.95
3	0.90	0.95 to 0.70
4	0.70	0.70 to 0.50
5	0.60	0.50 or lower

For Kodabromide Paper (Grades 1-5)

Paper Grade	Approximate Log Exposure Scale	Density Scale of Negative Usually Suited for Each Grade
1	1.45	1.35 or higher
2	1.15	1.35 to 1.00
3	0.90	1.00 to 0.75
4	0.70	0.75 to 0.50
5	0.60	0.50 or lower

Pick a few of your negatives, measure the density scales, and match them with the right paper grade from this table. You'll like the results.

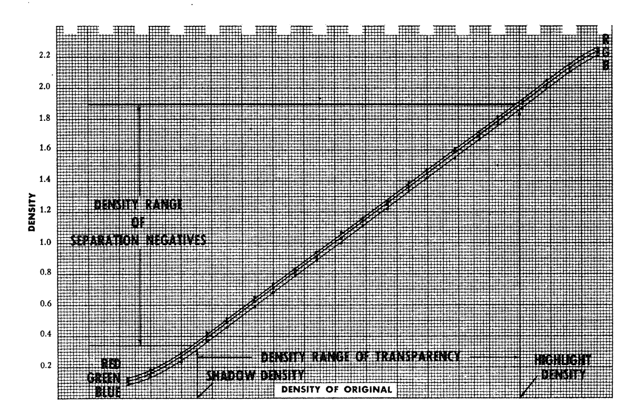
decrease its development, as the case may be.

If one of the curves is much higher or lower than either of the other two, adjust the exposures until they fall in line. If, for example, the red curve is above the green curve, and the blue curve is below the green curve, and the difference (measured horizontally) between the straight-line densities of the red and blue curves is more than 0.2, remake the negatives. Give less exposure to the red separation, and more to the blue. Get them as close together as you can, using the middle—in this case the green—curve as a balance point. The chart on page 31 of the "Color Separation and Masking" Data Book will be useful to you in changing the exposures.

In your work with color-separation negatives you are going to find that development is the critical factor. Adjusting the exposures usually won't take long, if it's necessary at all. The important thing is to get the "gammas" alike, and to be sure that the negatives are developed uniformly. Without uniform development of the negatives, a condition known as "color wedging" will arise.

Checking the Density Ranges

Measure the densities of the lightest highlight and deepest shadow (in which you want detail in your print) of the original transparency and mark these two densities on the "Density-of-Original" scale of the same Color-Separation Negative Record Sheet, or sheet of graph paper, on which you drew the separation curves. Then draw vertical lines up to intersect all three curves. Horizontal lines can then be drawn from the two points of intersection on each curve over to the "Density" (vertical) scale to show the density ranges directly. Like this:



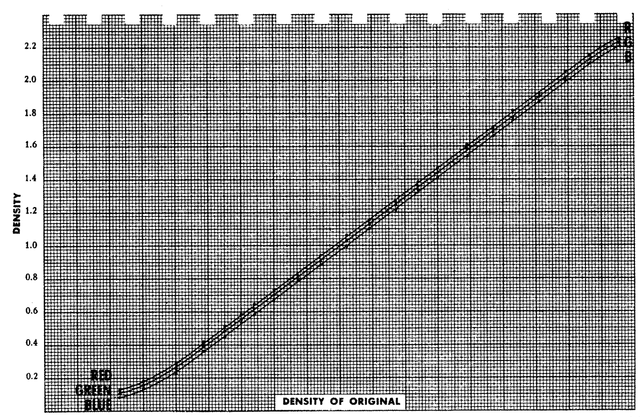
You would take three density readings of that area, looking through red, green, and blue filters. (You'll be doing this kind of thing when you make color prints by the Kodak Dye Transfer Process from Kodak Ektacolor negatives. It helps you to determine the exposures for the three printing positives.)

The applications of densitometry to the various phases of color printing are discussed in detail in the Kodak Color Data Books "Color Separation and Masking," and "Kodak Dye Transfer Process." If you're going into color work, be sure to get these two booklets—they'll prove very valuable to you.

Color-Separation Negatives from Color Transparencies

High-quality color prints can only be made from separation negatives that are "balanced" with regard to relative exposures and development contrasts.

The best way to check a set of color-separation negatives is to draw a curve for each negative. Plot the densities of the original step tablet or image (in the transparency) of the Kodak Gray Scales vs. the corresponding densities in the separation negatives, just as we described earlier. Plot the three curves on the same sheet of paper; use a red pencil for the red separation curve, a green pencil for the green curve, and a blue pencil for the blue curve. A good set of separations plots like this:



Ideally, they ought to be superimposed. In practice, they very seldom will be. Any time they are as close together as this, they can be expected to produce an excellent color print. If one of the negatives has a higher or lower gamma than the others, increase or

Finding Exposure Times for Prints

Pick a negative, measure its density scale, and select the right paper grade. Then, by trial, find the exposure time required to make the best print you can—a "straight" print. (Don't do any dodging or printing-in yet.) Now, record the exposure time and the highlight density of the negative.

Suppose our test negative has a density scale of 1.20. We want to make an enlargement on Kodabromide Paper, so that means we'll pick grade No. 2. See table on page 12.) The highlight density of the negative is 1.40, and the exposure time is 12 seconds at the magnification we want to use. Now that we know these things, we're all set.

We can take any other negative and, if the density scale is right for No. 2 paper, get the right exposure for it right from its highlight density, with no further tests. To do it, we'll use either the Kodak Enlarging Dataguide—that's the easiest way—or we can calculate our new exposure from the density—opacity table on page 30.

Those opacities are directly proportional to exposures. Let's assume that our new negative has a highlight density of 1.30 and our test negative measured 1.40 in the highlight area. From the density-opacity table we find that the corresponding opacities are 19.95 and 25.12. The exposure time for our test print was 12 seconds, so to find the exposure time for the new negative, we just make a simple multiplication: Exposure time for new negative = 19.95÷25.12 x 12 = 9.5 seconds.

Exposures are directly proportionate to opacities.

Remember that, and you can figure exposures for any number of negatives just from one test, if the negatives all print on the same grade and type of paper. If you go to a different grade of the same paper, make a new test. If you change to a different type of Kodak paper, use the relative speed values in the Kodak Data Book, "Kodak Papers."

We've used the highlight density method here, but you can use relative shadow densities exactly the same way. When we get into color, we'll be using highlight densities again to find relative exposures, so you should be familiar with this method first. We'll try the other system now:

We mentioned the Kodak Enlarging Dataguide. It's a dial-type calculator and is on sale at Kodak dealers. With it, you won't need to convert densities to opacities; it reads direct from the relative densities themselves.

As an example, let's go back to the two negatives we were comparing before. Our test negative had a shadow density of 0.20, and its printing exposure time was 12 seconds. The shadow density of our new negative is 0.10. Now let's use the Dataguide:

In making an enlargement, let's assume we used a magnification of 5X. On the front dial of the Dataguide, set 12 seconds (the correct exposure time for the test negative) opposite 5 on the magnification scale. Now, without moving the dials, turn the Dataguide over, and draw an arrow opposite the shadow density of 0.20, labeling the arrow with the paper grade and lens opening used in the test.

Set the shadow density of the new negative (0.10) opposite the arrow you marked, then turn the Dataguide over and read the exposure for the negative opposite any magnification you wish to use. If you use 5X again, the time will be 9.5 seconds, as we found out by using relative highlight densities in our previous example. The beauty of the Enlarging Dataguide is that—once your test exposure has been made—you can use different magnifications in making prints from different negatives without further tests or calculations; provided, of course, that you don't change lens openings and/or paper grades. If you want to change either or both, though, it's easy to do.

How to Make a Characteristic Curve

First, you'll need a Kodak Photographic Step Tablet No. 2. This is a negative "step wedge" consisting of 21 densities running from about 0.05 (base + fog density) to about 3.05. Each step differs from the preceding step by a density difference of about .15, corresponding to an actual exposure difference of 1.414 (square root of 2). Read all the densities of the steps and record them.

Now, make a *contact print* of this calibration step tablet (we'll call it the "original" step tablet from now on) on the black-and-white film you normally use. Just use a printing frame, but be *sure* to back up the film with black paper. Sheet film is the easiest to handle, but you can also work from roll film (including 35mm) or film packs.

An enlarger is an excellent light source to use in making your exposures, since most contact printers are too "fast." We need an exposure long enough to control easily. If you have an exposure meter, measure the light intensity on the baseboard. Three to five foot-candles is about right with the lens at f/4.5. With the Kodak Flurolite Enlarger, you'll get the right intensity at f/4.5 if the lens

If you want to use any particular gamma for any reason, find it on the "gamma" axis. Then draw a horizontal line over to the curve. From that point on the curve, drop a perpendicular line down to the "time" axis. Develop for that time and, provided you do everything as you did when you made the time-gamma curve, you'll get pretty close to the gamma you want. You never will come out *exactly* right unless you do everything *exactly* the same way each time, but you ought to be within ± 0.04 of the predicted value. If you're not, standardize your technique some more!

Remember that such projects as we've been discussing are not intended to replace the time-gamma information, etc., that the photographic manufacturers provide for use with their products. However, the manufacturers obtain their sensitometric data under the most carefully controlled conditions imaginable. The worker in the field may need to get similar information that directly applies to his own techniques and darkroom. He can do it as we have just described.

Densitometry—in Color

You've seen how the application of some of the basic principles of densitometry can help you take the guesswork out of your black-and-white photography. You can do the same thing in your color work. Take out the guesswork—the trial-and-error methods.

Black-and-white films have one emulsion. Color films have three—one sensitive to red light, one to green light, and the third to blue light. After processing, these three emulsions (in the case of Kodachrome and Ektachrome) contain positive images consisting of dye alone. The image in the layer that was sensitive to red is composed of cyan dye; in the green-sensitive layer, magenta dye; and in the blue-sensitive layer, yellow dye.

A photographic silver deposit absorbs light of all colors about equally, so it makes very little difference what color of light is used to measure its density. This is not so with color films. The cyan, magenta, and yellow dyes in the dye layers are selected because their maximum absorptions are in the red, green, and blue parts of the spectrum, respectively. A neutral gray area, then, in a color film will be neutral because just the right proportions of all three dyes are there.

So how would you find out how much red, green, or blue light is being absorbed by the dyes in a "neutral" area of a color film?

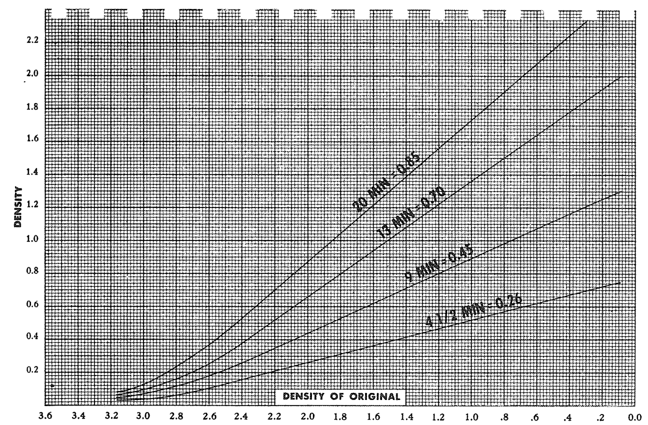
manufacturer? If it's low, increase your development time. If it's high, decrease the development time.

While you're at it, why don't you make your own time-gamma chart? Expose 4 test scales from the original. Expose them just alike. Then develop them like this:

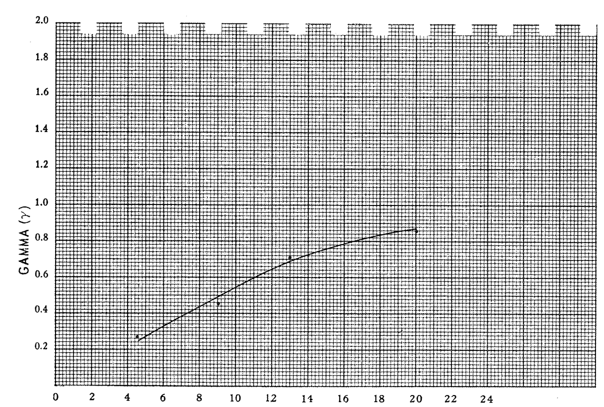
Develop one of them 1/3 of the time that is recommended. Another for 2/3 the recommended time. Another for the recommended time, and the last for 1 1/2 times the recommendation.

For example: Suppose you're using Kodak Super-XX Roll Film and you use Kodak Microdol Developer at 68 F. Cut up a roll of the film and expose 4 test scales. Develop them (if you use a roll-film tank, use it here) for 4 1/2, 9, 13, and 20 minutes.

Now, plot all four curves on one sheet of graph paper; and measure the gamma produced by each developing time:



Take a fresh sheet of graph paper and plot time of development (on the lower axis) against γ on the vertical axis. Draw a smooth curve through these points:



is in focus about 18 or 19 inches above the easel. The exposure time will be about 10 seconds at f/16.

Exposure here is *not* critical except that all the 21 steps of the original must show in the reproduction. Don't use an exposure that's too heavy; try to get a density of about 0.1 or so in the reproduction under the heaviest step of the original. You can do it easily after a couple of trials. (If you need to or want to read wet negatives, wipe them off as you usually do before drying them, and then fold a sheet of clear Kodapak Sheet, or cellophane, or some waterproof transparent material around them. You won't get exactly the same readings as with dry negatives, but as a quick check, the results are accurate enough.) Don't work for *exactly* 0.1 in your lightest step, just something close to that value. The idea is to include *all* the steps of the original in your reproduction, *without* getting too much density in the lightest steps. We want some "toe" in our curves.

Develop your "test scale" just exactly as you normally do your films at whatever temperature you use regularly. If you usually use a tank, use it here. If you tray develop, do so now. *Follow your normal procedure until you make a few curves.* Then, you'll know whether you need to change your routine or not.

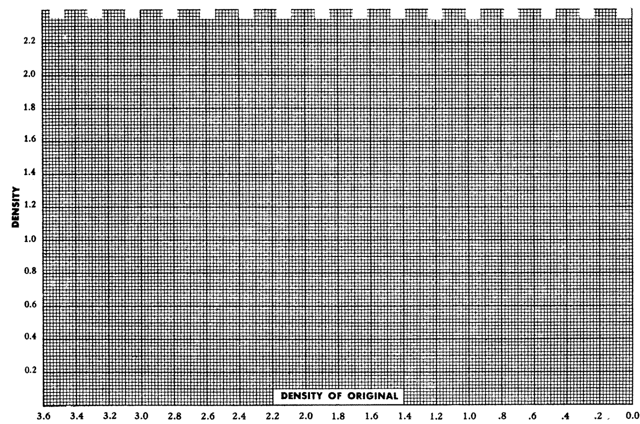
Fix, wash, and dry your test scale in the normal way, then read the densities of the steps. Write them down beside the densities of the original step tablet, but *backwards.* That is, start with the heaviest densities of your test scale, and write them opposite the *lightest* densities of the original. Like this:

Density of Step No.	Original Density	Density of Test
1	0.08	2.20
2	0.27	2.13
3	0.41	2.03
4	0.57	1.94
5	0.74	1.84
6	0.86	1.74
		and so on.

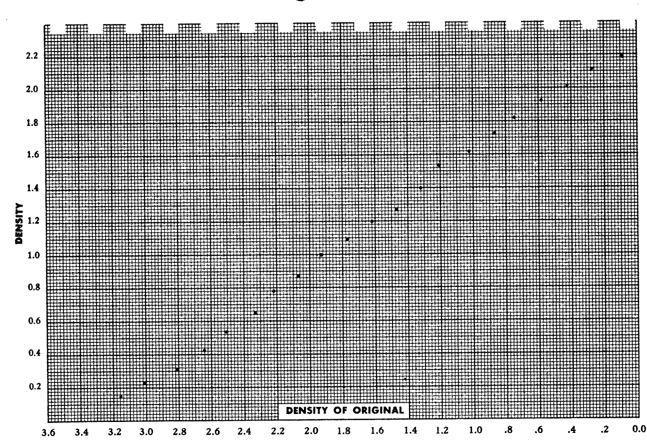
Now, make a graph. Use regular (not log) graph paper, or better still, use a Kodak Color-Separation Negative Record Sheet.

Along the *horizontal* axis (abscissa) set up a "Density-of-Original" scale. Start with 3.6 and go *toward the right* in intervals of 0.2 down to 0. Along the vertical axis (ordinate) plot the densities in the test scale you made from the original. Start with 0 and go *up* in intervals of 0.2. That's done for you on the Color-Separation Record Sheets.

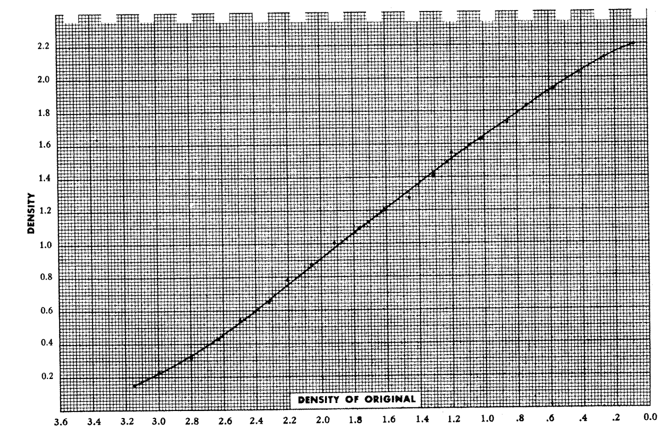
Here's what your paper will look like when it's set up right:



Now, just plot the densities in the steps of the original opposite the densities in corresponding steps of your test scale. (The Density-of-Original scale is turned around backwards because we want the curve to go up from left to right. That makes it a negative curve. If it runs *down* from left to right, it's a *positive* curve.) You'll come out with something like this:



Now, draw a smooth curve through the *average* of these points. Don't connect all the individual points until you've had quite a bit of practice reading your densitometer, and even then they'll probably never line up perfectly for you. Your first curve ought to look like this:

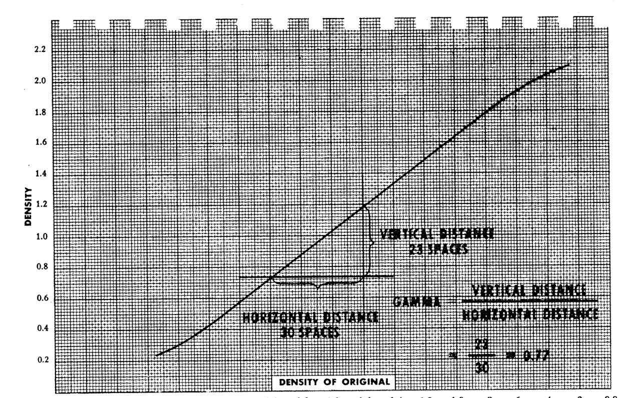


That's it. A characteristic curve that shows what you are getting out of your film under *your* working conditions. As a few exercises, answer the following questions: What is gamma (γ)? What are the toe densities? What are the straight-line densities? Shoulder densities?

In figuring gamma, you don't need to use trigonometry. Pick any point on the straight-line portion and count to the right 30 small units (0.6 on the lower axis). Now count the small units up to the curve (on the vertical axis). Let's say there are 23 of them. Then-

$$\text{Gamma} = \frac{\text{Vertical Distance}}{\text{Horizontal Distance}} = \frac{23}{30} = .77$$

Here it is:



How does your gamma check out against what you thought you were getting—according to the recommendations of the film