HANDBOOK

FOR

DYE TRANSFER PRINTING

By

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PREFACE TO THE 2nd PRINTING

This handbook has evolved during the past five years. It is available from Charles H. Miller, 112 Moore Road, Sudbury, Massachusetts, 01776: phone (617) 443-6978 — $30.00 prepaid.

Originally it was nothing more than a set of step by step instruction sheets with brief descriptions for an evening dye transfer workshop which lasted one month. Four original sets may still be in existence. In 1977 I expanded these into the original Handbook for a one week summer workshop. There were twenty copies, of which fourteen are numbered and signed: the pages are numbered with a roman numeral and then an arabic numeral. In 1978, for another one week workshop, I expanded that into this Handbook and 100 copies were printed. It is not only for workshops but also for people who have neither the time nor the inclination to attend a workshop. The detailed procedures and instructions are for workshops so the people know what to do to get a finished print in a limited time. It's not my intention to be dogmatic about these procedures, though you might find it informative to think about the underlying reasons why a workshop is run this way, rather than some other way. The 2nd printing is also 100 copies.

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Chapter 1 — <u>INTRODUCTION</u>

Dye transfer printing is, in principle, very similar to
half-tone printing on a press with three colors plus black where
the amount of ink (colorant in an oil vehicle) in any given visual
area is controlled by the size of the dots. These dots are created
by exposing the image, at some point in the process, through a
cross-hatched screen that has at least sixty and sometimes as many
as three hundred lines per inch. These dots (the spaces between
the lines) are so small that they cannot be seen without a magnifier.
To make the printer, the image is strained through this screen; and
some of the dots get more exposure than other dots. When the printer
is developed the dots with more exposure are bigger than those with
less exposure; they control the amount of ink which is transferred
when the image is printed. A black printer is usually used because
the three colored inks in combination do not make a neutral black.

Dye transfer printing does not use a screen. Rather, the
printer is a gelatin relief image. The amount of dye (colorant in
a dilute acid vehicle) is controlled by the thickness of the
gelatin at any given point in the matrix (printer). This matrix
is soaked in dye and, when rolled into contact with the receiving
sheet, the dye transfers from the matrix to the gelatin coating
on the paper in less than ten minutes. The matrix is then removed
from the receiving sheet and returned to the dye bath where it
soaks up again for the next print. Three matrices, cyan, magenta,
and yellow, are used for each print. In effect this is a hand
operated press and the matrices (printers) will last for as many as
one hundred impressions before the edges of the relief get flattened.

The receiving sheet is a piece of paper coated with a gelatin
emulsion and soaked in a mordant. The mordant is an alkali
solution which bonds the molecules of dye to the molecules of
gelatin. The mordant holds the dyes in place, keeping the dyes
from wandering in the gelatin and diffusing the edges within the
image. The chemistry of acid dyes and alkali mordants is very

complex and for our purposes of no great interest because we take what Eastman Kodak gives us. Why the dyes transfer to the receiving sheet is not understood; it is Friedman's opinion that they physically move because the gelatin in the matrix is harder than the gelatin in the receiving sheet. (Friedman, p 479)

To make a print three matrices are required. They control the amount of red, green, and blue light reflected at any given point in the finished print. Red is not just the color red, but refers to all the radiant energy from infra-red to yellow. Green is all the energy from yellow to turquoise, and blue from turquoise to ultra-violet. These are forces (vectors) and merely a way of speaking about energy, not the visual experience which these forces cause. The three printers (matrices) for the dyes are gelatin relief images which have been processed in such a way that the actual thickness of the gelatin varies in proportion with the amount of light that exposed it.

These proportions are controlled with three separations which are made from the original, usually a transparency, with three filters — red, green, and blue. In the ideal case the red filter passes all the energy from the infra-red to yellow and absorbs (does not pass) all of the green and blue energy; the green passes everything between yellow and turquoise and absorbs red and blue. Likewise the blue passes everything between turquoise and ultra-violet while absorbing red and green. The available filters are excellent and approach this ideal case.

When the three separations (red, green, and blue) are exposed the contrast (bright-dark) becomes negative. The color is positive: the red in the transparency gets through the filter whereas the green and blue are absorbed. When the separations are exposed, usually by projection, onto the matrix everything is reversed: the contrast in the matrix becomes positive, but the color is now negative. Where there are blacks in the transparency the gelatin is thick. In the matrix made from the red separation the gelatin is thin at the places where there is red in the transparency. For white there is no gelatin on the matrix.

The colorants in the dyes are negative: the reverse of red is cyan (blue plus green): the opposite of green is magenta (red plus blue) and yellow (red plus green) is the complement of blue. In the finished print we are not adding colors; rather we are taking

out of white light, which illuminates and reflects off the paper
support for the gelatin layer, what we don't want. A black in
the print is made up with equal quantities of cyan, magenta, and
yellow dye. Red in the print is magenta and yellow dye, the
absence of cyan. At any given point in the print the color is
cummulative and usually involves all three dyes in varying amounts.

A brief history

The chemistry of relief formation goes back to 1864 when
Joseph Swan took out the original patents for carbon printing. He
had discovered that gelatin soaked in a dichromate solution will,
when exposed to light, harden selectively and in approximate
proportion with the amount of light which exposed it. In the
dichromate process the chemical reaction is caused by the light
itself, hardening the gelatin. Swan ground up carbon into a fine
powder and mixed it with the gelatin then coated this combination,
an emulsion of gelatin and carbon, onto a sheet of paper and
sensitized it in a solution of dichromate. When it was dry he
exposed it through a negative and in those areas where the light
passed through the negative the gelatin was hardened in proportion,
more or less, with the illumination in the original scene. By
washing the print in hot water, he dissolved the unhardened gelatin,
leaving a carbon relief image on the paper. This relief was a
tone reproduction from black (thick gelatin) to white (no gelatin)
with various shades of gray (some gelatin) recreating, within
limits, the brightnesses in the original scene.

From this point it was no great jump to experiment with
various colorants in place of the carbon. At the same time several
methods were developed for stripping the gelatin from the original
support and moving it to another support. This opened the way to
carbro (the abbreviation of carbon and bromide) because it had
been learned that dichromated gelatin would harden selectively
when pressed against silver bromide. In carbro a colored, dichromate
tissue is squeezed against a bromide print (positive separation by
color) with a laundry wringer and the gelatin in the tissue is
selectively hardened. The unhardened gelatin is washed off with
hot water and the several tissues, each with a different color

from a set of bromide prints are then stripped, turned over, and
stacked in register on a new support. The quality of a carbro
print is amazing; unfortunately only one print can be made from
a set of bromides and no two sets of bromides will make identical
or even similar tissues.

To get around these problems Eastman Kodak introduced the
original Wash-Off Relief process in the mid-1930's. It, like
carbro, involved dichromated gelatin but the color was not in the
reliefs which were permanently fastened to a sheet of acetate.
After the formation of the relief these sheets were soaked in dyes
and then rolled onto a receiving sheet, giving the dyes an opportunity
to transfer and make the finished print. Now it was possible to
make more than one print from a set of reliefs and this is why they
were called matrices. At the same time the Technicolor Corp was
using a similar process to make release prints in color for the
movies. Friedman was a research chemist involved in the development
of the Technicolor process.

With both carbro and wash-off there was no easy way to control
the contrast (height of the relief) in the matrices. As early as
1881 Warnerke had discovered that oxidized pyro gallol has a
tanning effect on gelatin and patented it as a way to selectively
harden an image without dichromating it. Pyro gallol by itself
does not cause sufficient contrast in the relief to make an
acceptable print. In the early 1940's Eastman Kodak found something
(which they've never identified) and with it they were not only
able to increase the contrast in the relief but also to control it.
As a consequence the Wash-Off system was replaced in 1946 with the
present Dye Transfer System and the chemistry has not changed
appreciably since then, nor has any significant research been done
by Eastman Kodak.

The Nature of the Problem

By and large any system for the reproduction of color can be
divided into two stages. The first part is an analysis, by wave
length, of the energy reflected in the original scene and the
second (synthesis) is the recombination of those wave lengths into
colors which are a replica of the original. For our purposes the
original is almost always a transparency unless we are using direct

separations made in a camera. This replica can never, with no
exceptions, be an exact duplicate of the original. This is true
not only for the film in the camera and the original scene itself,
but also for the print from that piece of film. Each reproduction
is always an interpretation (not a duplicate); so the finished
print is at best twice removed from the scene which was in front
of the camera. Visually some of these interpretations are more
pleasing than others in the mind of the viewer — the success or
failure of any print is ultimately and always a subjective
judgment. If the print looks right, then it is right.

Over the years Jones, a member of the Research Department
at Eastman Kodak, has done extensive studies to determine why some
prints are visually more effective than others. He and his
assistants made a large, very controlled set of B/W prints from
130 negatives which had been varied for both exposure and development.
The prints themselves were also varied by contrast and exposure.
The total number of prints from these 130 photographs is something
like 30,000. Various different prints of each photograph where
shown to numerous people with photographic insight. They were asked
to rank the prints of each photograph by preference: some prints
were consistently accepted while others were consistently rejected
and many in the middle would go either way. It was this pattern
of yes and no which interested Jones; his work with it has become
the basis for the theory of tone reproduction. (See chap 23 in
the 2nd edition of Mees and Chap 12 in James & Higgins)

In a general way tone reproduction is a graphical description
of the contrast gradients in those prints which were consistently
considered acceptable. Contrast is the visual difference between
the lightest and darkest areas in a print. There is more contrast
between black and white than there is between a very dark gray and
an almost white. Phrased another way, contrast describes the overall
brilliance of a print. This happens in the mind's eye: it is
sometimes called luminence. Brilliance happens within the mind and
is caused by the brightness of objects in the outside world.
Brightness is almost always, with one exception, reflected light.
It should never be confused with illumination which is what makes
things bright. The exception is looking at a light bulb which is
both a source of illumination and also an object. In a fog, or

driving wind-blown snow, there is illumination but if the stuff
in the air is thick one cannot see objects. Brightness is measured
in candles (or somethings) per square foot. Illumination is
measured in foot-candles. I have followed the nomenclature in
Ralph Evans, "The Perception of Color," Wiley, 1974.

Contrast is best thought of as a gradient which moves slowly
or rapidly from black to white and it always has to do with objects;
the way they reflect. In photography it is a way of talking about
the brightness in a print, or the brilliance which this brightness
causes in the consciousness of the viewer. It always has to do with
the relationship between lighter and darker. If all the objects
have the same brightness then, in B/W photography, there is no way
to distinguish one object from another. If these objects have color
then they will be separated into individual things, even if there
is no contrast, lighter and darker, in a color print. The visual
problem for a B/W photographer is subjective and has to do with
learning to control the contrast (brightnesses) in the print so he
or she can control the brilliances which this causes in the viewer's
consciousness. The same thing is true in color, but there are
more variables.

When Jones studied the sensitometric data describing the
prints in his collection which were generally considered visually
better than others, he found that the contrast gradient in the
upper mid-tones was more rapid than the contrast gradient in the
lower mid-tones, when both were compared with the original scene.
An effective photograph, visually acceptable, was not a point by
point replica of the light patterns as they existed when the shutter
was open — those prints were consistent failures, needing to be
flattened in the shadows and heightened in the upper mid-tones.
He also found that exposure time for the print was more important
than the contrast grade of the paper. Give or take a grade of
paper (contrast), exposure was the determinant. Though this
work was done with B/W, it's my opinion that it applies with
equal force to color reproduction.

Color is a perception that happens in the visual cortex. Its
causation is usually, but not always, the result of an event in the
external world. By the same token sound is a perception in the
inner ear: if nobody hears a tree fall in the forest, there is no
sound — just a compression wave which would have caused a sound

if something with ears had been there at the time the compression wave went by. In the same way, color happens in the mind's eye. Redness, whiteness, blackness happen when a retina is there as the radiant energy goes by.

The retina is sensitive to a very small portion of the totality of radiant energy, and this band can be divided into three parts — red, green and blue. It is indeed unfortunate that these words are also the names for colors because this energy must be thought of as forces which have the potential to cause color in the mind's eye. In and of themselves, they are just bands of energy. We are better off thinking of this division into three parts as X, Y, and Z. All reds are included within X, but not all X's result in the perception of red. The last X and the first Y, side by side form the interface between red and green, yet the two together are perceived as yellow. There is no way that we can avoid using these words — red, green, and blue — to describe bands of radiant energy, but we must always remember, though they cause the perception of color, they do not in themselves have color. They are the names of the forces which we are working to control.

All the infinitesimals of energy which can cause sensations in the retina are included somewhere between the first X and the last Z: furthermore, we have divided this set into three mutually exclusive sub-sets. Any specified infinitestimal of energy will be in one sub-set and not in either of the others. Phrased another way, X is the absence of Y and Z. Y is the absence of X and Z. Z is the absence of X and Y. In dye printing order is not important because everything gets commingled in the gelatin emulsion on the receiving sheet, so $X + Y = Y + X$. This is not true on a printing press or with carbro because the colorants are layered.

By substituting the color names for their letters, we get the statement that red is the absence of blue and green. It can also be phrased, blue plus green equals negative red. The same is true with green, negative magenta (red plus blue) and with blue for which the complement is yellow (red plus green). These transformations are valid due to the way we defined the set and its three subsets. We aren't talking about colors, just X's, Y's, and Z's.

Green plus blue is called cyan ($\underline{Y}$ + $\underline{Z}$): visually this is a very beautiful turquoise. Red plus blue is magenta ($\underline{X}$ + $\underline{Z}$) and it is a redish purple. Red plus green is the funny one because it is an absolutely different color, separate and distinct. Visually one sees neither the red nor the green — just yellowness. Another interesting thing about yellow is that it can be made with red and green light, using filters which absorb all the energy in that part of the spectrum which appear yellow in a rainbow, and we see yellow eventhough there is no yellow light getting to the retina.

Red plus cyan is neutral and whether this neutral is almost white, gray, or black depends solely upon the quantity of red and cyan in the test patch. One unit of green plus one unit of magenta equals one unit of neutral. The same is true with yellow and blue. One unit each of cyan, magenta, and yellow equals one unit of neutral. Work it out with an equation with $\underline{X}$, $\underline{Y}$, and $\underline{Z}$.

Equal quantities of dye can be put into the receiving sheet with equal thicknesses of gelatin in the mats (matrices). As the total quantity of dye is reduced, the color changes from black to gray to white (the gray scale). To get the print we're looking for we must control the relief in the mats. This is a function of exposure and development. Development depends upon time and temperature, assuming the developer is always compounded the same way and that the water is constant. This is nothing more than a procedural problem, requiring concentration and attention to detail.

The exposure of the mats is controlled with the separations and a light source in the enlarger which is constant — this means regulated voltage and bulbs that haven't blackened. To get a gray in the print then that area in the three separations must let equal amounts of light through when the mats are exposed. Assuming the development of the mats is a constant, then the reliefs in the three mats (one from each separation) will be equal, and equal amounts of the three dyes will be absorbed by the mats and transferred to the receiving sheet. To get a neutral, uniform gray scale from black to white in the print, the separations must be in balance. If the separations are out of balance, then there will be color shifts somewhere. If the upper mid-tones are neutral

then the lower mid-tones will shift toward a color dictated by the separation which is out of balance. Holding neutrality is the essence of color reproduction and dye printing is the only three color system where neutrality can be held from black to white: screen printers get around this by adding a black printer and using under-color removal to make visual space for the black.

The separations are so called because they do just that, separate the original into three elements — red, green, and blue. These components are forces with the power to cause changes in either the film or the retina, but the film does not always see the same way the retina sees. And this is the heart of the problem. Sometimes it is referred to as the actinic properties of light or, more recently, as metamerism. Either way, it is the nub of the difficulty.

Theory is all well and good, absolutely necessary for an understanding of the questions and their solutions, but ultimately the resolution of the problem is found empirically. Sometimes the theory seems utterly compelling, yet in practice it doesn't make any difference because we don't understand why the eye sees the way it sees. We can measure the brightnesses which cause brilliance, but there is no way to measure brilliance itself. It happens in the eye and the mind's eye — more than this, no person can say.

Visually some prints are more pleasing to the mind's eye than others, a subjective judgment. Some prints stay on the wall while others get turned around. If it looks right, then it is right. For some reason the mind demands that gray look like gray and when this condition is met, then the colors pretty much take care of themselves. To get a gray in the print, it's got to be in the separations; if it isn't in the separations, then it isn't in the print because there is no way to get it in by diddling with the contrast in the mats.

If we don't know what is actually happening in the separations then, any satisfying print is nothing more than a very happy accident. There is no way to know what was done, so there's no way to do it again.

The problem is measuring the effect that happens in the separations when exposure and development are varied. Sensitometry studies the sensitivity of the emulsions and densitometry is the

study of density. Though related, the two studies are separate.
Density is the result of sensitivity, without one we can't have
the other and sensitometry can only be studied in terms of density.
Nobody has ever seen a latent image, but it is there; otherwise
development would produce nothing.

By and large Sensitometry and Densitometry have developed as
emulsion makers wanted to know more about what they were doing,
making emulsions, and has not been applied (except by Ansel Adams)
to the practical problems of photographing and printing. Our
interest is applied or practical sensitometry. We want neutral
grays and to get them we must force the separations to do what
they're supposed to do. The goal is a perfect print and the
satisfaction that comes of saying out loud and to oneself, "There.
It's done and I did it, finally."

SUGGESTED READING

Photography is such a broad subject that any general
definition is, of necessity, so loose that it is meaningless.
All we can talk about are either kinds of photographs (and not
fret too much about how the various kinds are related) or the
underlying principles which are used, but not in the same way,
for each kind of photograph.

Underlying principles

Baines, H., THE SCIENCE OF PHOTOGRAPHY, 2nd edition, revised by
     E.S. Bomback, John Wiley & Sons, Inc. New York - 1967

Neblette, C.B., PHOTOGRAPHY: ITS MATERIALS AND PROCESSES,
     6th edition, Van Nostrand & Co., New York - 1962

     This was the text for the Materials & Processes course
     in the School of Photography at Rochester Institute of
     Technology. There are subsequent editions, but they
     have been watered down.

James, T.H. & Higgins, G.C., FUNDAMENTALS OF PHOTOGRAPHIC
     THEORY, Morgan & Morgan - 1960

     This has the best available discussion of sensitometry
     that's been written.

Mees, C.E.K., THE THEORY OF THE PHOTOGRAPHIC PROCESS, MacMillan

> There is both a 2nd and a 3rd edition and they do not duplicate each other. Each is equally necessary and if the discussion of a photographic question does not exist in Mees, or get noted, then the work has not been done.

Color Reproduction

Spencer, D.A., COLOUR PHOTOGRAPHY IN PRACTICE (revised by Mannheim) Amphoto, New York - 1966

Evans, R.M., Hanson, W.T., & Brewer, W.L., PRINCIPLES OF COLOR PHOTOGRAPHY, John Wiley & Sons, Inc. - 1953

> Recently reissued in paper

Evans, Ralph M., THE PERCEPTION OF COLOR, Wiley - 1974

Hunt, R.W.G., THE REPRODUCTION OF COLOUR, Wiley - 1961

Yule, J.A.C., PRINCIPLES OF COLOR REPRODUCTION, Wiley - 1967

Wall, EJ., THE HISTORY OF THREE COLOR PHOTOGRAPHY, Focal Press - 1970

> This, with an introduction by DA Spencer, is a new edition of the original which was published in 1925 and describes anything and everything that's been done since the beginning till then.

Friedman, J.S., HISTORY OF COLOR PHOTOGRAPHY, ed by Lloyd Varden and reprinted by Focal Press - 1968

> This is a continuation of Wall not only in spirit but also completeness. Unfortunately this edition does not have an index.

Coote, Jack H., COLOUR PRINTS, Focal Press, New York - 1963

Southworth, Miles, COLOR SEPARATION TECHNIQUES, North American Publishing Company, Philadelphia - 1974

Chapter 2 - APPLIED SENSITOMETRY

For our purposes an emulsion is any gelatin coating. The difference between photographic film and paper is simply a question of what happens to the light as it makes the image visible. With paper the image is illuminated with reflected light: the illumination goes through the emulsion, bounces off the support, and comes back out. The photons (lumps of radiant energy) make two trips through the emulsion, in and out, unless they get trapped inside (internal reflections) and absorbed. With film the photons make only one trip, through the support and then through the emulsion. These emulsions are gelatin with either metalic silver or dyes embedded (suspended) in it. Color film starts with silver. After the first developer it is a B/W negative with at least three layers. The undeveloped silver is then exposed and processed in the color developer, producing a positive color image; the silver is bleached out, leaving just the dyes where the silver in the second exposure became coupled with the colors. The support (paper, plastic, glass, acetate, estar, metal, plywood, cloth) is just that and nothing else - a support for the emulsion which is where the image is held. This image is visible because some areas are darker than others, or of a different color, or both.

Exposure

There's no point in developing film until it's been exposed. The amount of exposure at a selected point in the emulsion is dependent upon two variables: 1) the illumination that gets to the emulsion, and 2) the length of time that it's there. Using a perfect lens, all the energy that enters at one end will exit from the other end, forming a projected image on the plane of focus. There is a point near the center of this lens where all the energy comes together, like the vortex of a cone, then crosses

over and expands. The intensity of the energy that exits from a lens can be controlled by varying the size of the hole that it must pass through near the center of the lens. This plug is the aperture. In the old days of Waterhouse Stops it was just that. There was a slot in the top of the lens barrel and the photographer had a box of metal slides, each drilled with a different sized hole. He chose the stop then controlled the duration of the exposure with the lens cap.

Aperture is the focal length of the lens divided by the diameter of the actual opening in the center of the lens. The number engraved on the retaining ring is the aperture when the lens is focused at infinity. At distances less than infinity the focal length increases, which decreases the aperture and requires the adjustment in exposure known as bellows factor. Focal length is not an absolute distance but rather it is relative, depending upon the relationship between the image and the object and one limit of this is infinity focus. Most everything in photography is relative.

For illustration we'll use a 128mm lens. If the diameter of the opening in the center of the lens is 128mm and the focal length at infinity is 128mm, then the f# is 1 — the effective focal length divided by the diameter of the actual opening in the lens. The area of this hole is pi times the square of the radius, half the diameter or 64mm. The square of 64 is 4,096, so the area of the aperture is 4,096 pi. To reduce the amount of energy getting through the lens by half, we divide this area by 2. This new area is 2,048 pi. The formula for the area of a circle can be turned around and solved for the radius. The pi's cancel out, so the new radius is the square root of 2,048, or 45.25mm. The diameter of this aperture is 90.5mm. When divided into the effective focal length, 128mm, the f# is 1.414. Continuing this, the area of the hole is again divided by two which equals 1,024. The radius is 32, the diameter 64 and the f# is 2:

Multiple	1	2	4	8	16	32	64	128	256	512	1,028
f#'s	1	1.4	2	2.8	4	5.6	8	11	16	22	32

When we speak of a stop of exposure, we are saying that the

quantity of energy that gets to the emulsion has either doubled
or been cut in half. This series, the power series of two, is
fundamental to an understanding of the photographic process. It
shows up everywhere because, within limits, it is a quite accurate
numerical description of the way the eye responds to brightness.
If brightness is progressively doubled, the eye sees these increments
as equal steps. This is known as the Weber-Fechner law whereby the
visual perception of an arithmetic progression depends upon a
physical geometrical progression. Zero energy on the retina is
seen on the visual cortex as total blackness. One unit of energy
is seen as an almost but not quite black, and so the series goes:
0, 1, 2, 4 ... 1,024, 2,048, 4,096, 8,192, 16,384 ... These numbers
get big and very hard to handle, but they are related in either
direction by a factor of two,— visually the progression is uniform.

On a clear summer day with the sun slightly obscured in the
edge of a cumulus cloud, the eye will respond to detail in the
deep shadows under a tree and simultaneously see detail in the
cloud near the sun. This brightness range is like 4 units of
energy in the shadows and 16,348 units from the cloud near the disc
of the sun. In stops this is the difference between f/2 and f/128,
12 stops. As a logarithm the difference is 3.6.

If neither the aperture nor the intensity of the illumination
are changed, then the quantity of energy reaching the emulsion can
always be controlled by varying the duration of the exposure — double
the time or cut it in half. Theoretically exposure is a function
of intensity (aperture) and duration, so long as the product of
these two is a constant, then the exposure (effect in the emulsion)
is constant. Unfortunately the sensitivity of most emulsions is not
constant and this reciprocity does not hold true in practice. With
multi-coated films these departures from reciprocity are significant
as soon as the duration is longer than one second.

Development

There are three silver salts (halides) which, when exposed
to radiant energy, change to metalic silver — the bromide, the
chloride, and the iodide. If the exposure is long enough, the
intensity of the light will reduce these salts to metalic silver,

but it takes a very long time. The process can be hastened with
chemicals. When the emulsion has been exposed to light, but before
any reduction (either physical or chemical) has taken place, there
are some grains of silver salt in the gelatin ready to switch from
the salt to metalic silver. The pattern of these grains, suspended
in the gelatin, is the latent image. Each grain of halide is either
exposed or unexposed, no half-exposed grains. During development
they either change to metalic silver or they do not and disappear
in the fix — on or off. Development is possible because certain
chemicals react with exposed silver salts in preference to unexposed
silver salts. The exposed grains reduce to metalic silver in a
much shorter time than is required to reduce the unexposed grains.
But, if the emulsion is left in the developing solution long
enough then, ultimately, all the grains will be reduced to metalic
silver. It is this time differential which permits the developer
to reveal the image which is, till then, only latent in the emulsion.

Density

The developed image in an emulsion can be evaluated by measuring
its ability to hinder the passage of light. If we know the intensity
of the illumination that goes into an emulsion, then measure what
comes out the other side, we can, without too much difficulty
compute the ratio of light in (illumination) to light out. The
incident illumination must be constant.

If the illumination is 256 units and the recording device on
the other side measures 256 units, then the ratio is 1. 100% of
the light is getting through and the film appears transparent. If
the machine measures 128 units coming out, then the ratio is 2.
50% of the light is getting through. Once again we are dealing
with the power series of 2 — in short, stops. This time they are
stops of density. 0, 1, 2, 4, 8, 16, 32, 64 ... For analytic
purposes these numbers are very unwieldy and they are much easier
to use when converted to logarithms, then rounded. The commercially
available densitometers are only accurate, at best, to plus or minus
0.01. The problems of uniform development, let alone repetitive
consistency from sheet to sheet in development are such that any

errors introduced by rounding are negligible in comparison. Density
does not measure the amount of metalic silver in an emulsion, but
rather it is a measurement of the metalic silver's ability to prevent
the passage of the standard illumination. Sometimes it is called
optical density, but we will call it density and talk about stops
of density.

	Incident Light (Units)	Transmitted Light (Units)				
		Units	Percentage	RATIO	Logarithm of the RATIO	DENSITY
IX	256	256	100%	1	0	0
VIII	256	128	50%	2	0.301	0.3
VII	256	64	25%	4	0.602	0.6-
VI	256	32	12.5%	8	0.9031	0.9
V	256	16	6.25%	16	1.2041	1.2
IV	256	8	3%	32	1.5052	1.5
III	256	4	1.5%	64	1.8062	1.8-
II	256	2	.75%	128	2.1072	2.1
I	256	1	.4%	256	2.4082	2.4

This table is a restatement of the previous paragraph in
tabular form. It is just another way of talking about stops, the
power series of two, and it represents the mathematical basis of
photography.

In the outside world some things are brighter than other
things: this reflects more light than that. These brightness
differences can, with a camera, be recorded in an emulsion. Minor
White, at one time, made his students set up two sheets of mat
board, one black and the other white, then illuminate them in such
a way that the black photographed as white and the white as black.
This was his way of telling them that everything in photography is
relative. Bright things, no matter what they are, make denser
images in the emulsion than darker things.

As the exposure is increased dense images get denser, though
the relationship between darker and lighter in the same sheet of
film does not change. This continues up to a point, then the

density decreases with increased exposure until the latent image
is gone. This is solarization and is of interest to us only because
it is the upper limit of sensitivity in an emulsion.

No matter how dense something is on film or paper we cannot
see it unless there is something, either less dense or more dense,
with which it can be compared. The photograph of a black cat in a
coal bin reveals nothing, no contrast. As a general statement,
which is absolutely true most of the time, a photograph to be
effective must have a full brightness scale to be brilliant in the
eye of the beholder. Brilliance itself cannot be measured, but with
a reflection densitometer we can measure the brightnesses in the
print and determine the amount of light being reflected in various
areas, like # circles 5mm in diameter.

In black and white prints the lower mid-tones (dark gray to
almost black) and the upper mid-tones (very light gray to almost
white) control the brilliance. With some prints the shadows are
more important visually than the highlights, while with other prints
the opposite is true. There are prints that don't need deep blacks,
the platinum prints of Frederick Evans, but I have as yet to see
an effective photograph that does not have detail in the upper
mid-tones. Possibly white is more important than black and the
Jones work with tone reproduction might well be an indication of
this, but who knows for sure? (See pages 9-10)

What we need is a way to measure, in the abstract, shadow
detail and highlight detail, just tonalities — density itself.
If I take a sheet of film and expose it step by step, then at one
end the density will be zero and at the other end D(max), the point
at which it begins to solarize. In steps we will let the density
increase by half-stop increments: 0, 0.15, 0.3, 0.45, 0.6 ....
Visually this step tablet looks like a flight of stairs; with each
step less and less light gets through. We don't have to make one
of these because Eastman Kodak has done it (Cat # 152 3398). In
effect this is a poor man's sensitometer because with it the exposure
can be controlled and the density response of a specific emulsion
measured. The densities of the steps are numbers (logarithms)
which indicate the amount of light getting through at each step.
In theory, developed density in a perfect emulsion should increase
at the same rate that the Exposure Density decreases in the tablet

used to control the exposure. It is perfect because it gives a
one to one correspondence, with a negative which has the same
characteristic curve, between the object brightnesses (Developed
Density) in front of the camera and, when viewed by a spectator,
with their replica, brilliances caused by the Developed Density.
This tone reproduction is perfect in name only: even if the emulsion
were possible in reality, the print made with it would be flat
and dull.

Figure 1.

The Relationship between Exposure Density and Developed Density in the Ideal Case

Table of Coordinates

Exposure Density (Step Tablet)	2.4	2.1	1.8	1.5	1.2	0.9	0.6	0.3	0
Developed Density	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4

EXPOSURE   DENSITY
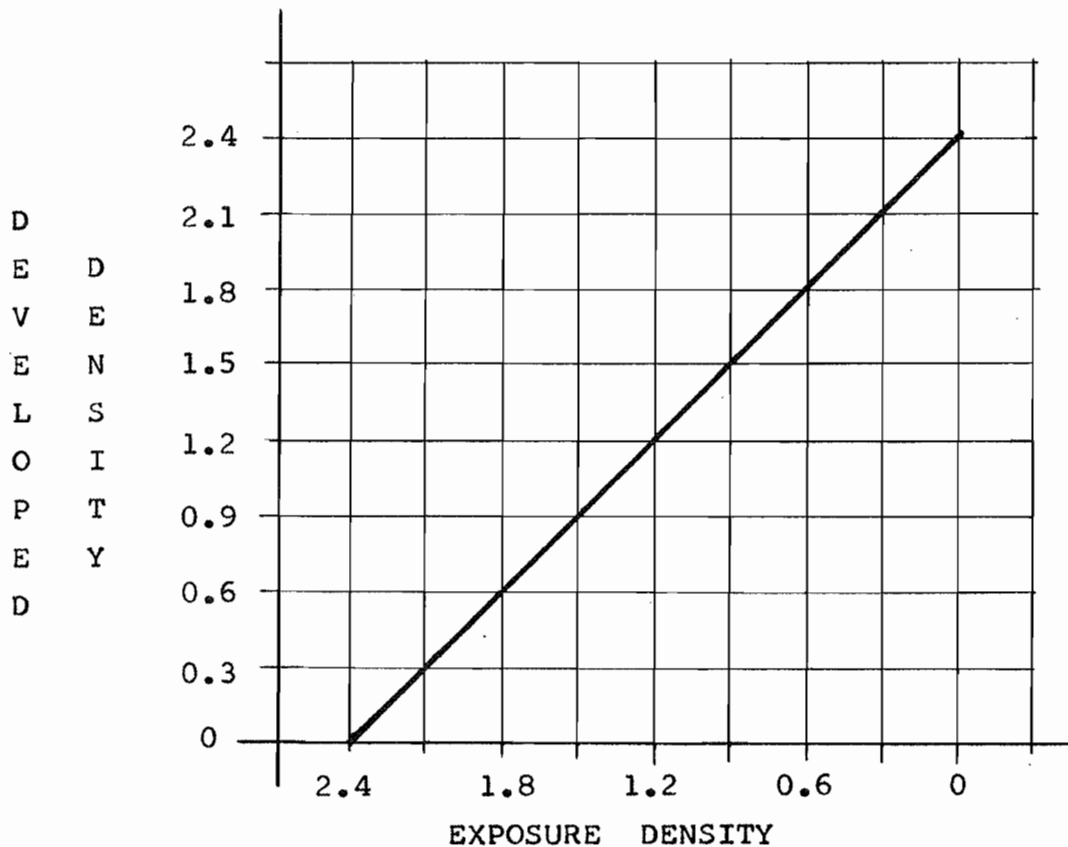
The Characteristic Curve

The diagonal line in Figure 1. is the characteristic curve for the perfect emulsion. It was plotted by drawing a pair of rectangular coordinates, any two lines which intersect in a right angle (90°). The horizontal line (abscissa) has been, by convention, assigned to exposure. For us it is the Exposure Density because we vary the exposure with a step tablet. As density increases in the step tablet, the amount of light getting through decreases; so, the numbers (densities) on the horizontal axis are reversed, letting exposure increase from left to right. This is another convention.

Sometimes the horizontal axis is called the Log Exposure scale (Log E) because exposure is also measured in ergs per square centimeter per second. The use of logarithms for density and exposure is a convenience. Logarithms are a series of numbers which can be substituted for another series of numbers and there are specific rules for manipulating logarithms which differ from the rules for natural numbers (the series we use in everyday arithmetic). When logarithms are added, it is the same as multiplying the natural numbers which they stand for; subtraction is the same as dividing natural numbers. Return to page 20 and compare the series of numbers in the RATIO column with their corresponding logarithms. The RATIOS are in a geometric progression whereas the logarithms are in an arithmetic progression. See the discussion of the Weber-Fechner Law on page 18.

By using the densities in the step tablet for exposure, we are measuring the exposure in log UNITS of energy without specifying what the units are. The table on page 17 comparing f#'s with the multiple used to reduce the area of the aperture states this differently and the multiple is UNITS of exposure in reverse order. These units could, if we wished, be converted to ergs per square centimeter per second with Planck's Theorem and then, by experiment with the ASA instructions for film speed, relate UNITS to ASA film speed, but we don't need this information. It is sufficient to refer to the steps of exposure as so many units, for which we have substituted the logarithm, and leave it at that.

The vertical axis (ordinate) represents the Developed Density.

The numbers in the table of coordinates on page 22 are matched pairs. Part of the emulsion which we are testing was exposed through a density of 2.4; from the table on page 20 it can be seen that 0.4% of the light illuminating the tablet got through this step to expose the film. The resulting Developed Density in this matched pair was zero. At the next step, 2.1, 0.75% of the light got through and it resulted in a Developed Density of 0.3. These pairs of coordinates represent a progression and Developed Density, at any point in this progression, can be thought of as a function of the Exposure Density which caused it — what we did and what we got.

       To get a characteristic curve the step tablet which we actually use must be calibrated. This is done by measuring the density in each step with a densitometer and then putting these numbers in a safe place where they can be found, like a notebook. This calibrated step tablet is then used to modulate the exposure given to the emulsion being tested. After this emulsion (paper or film) is developed these Developed Densities are measured with a densitometer and written in tabular form opposite their corresponding densities in the step tablet (Exposure Densities). Now we have the coordinates for the characteristic curve of that emulsion, exposed with a certain kind of light, developed in a specific developer for a specified time at a set temperature. All that remains is the plotting of these coordinates.

       The easiest way to do this is with graph paper that is ruled 10 millimeters to the centimeter (Dietzgen 341-M or National 12-188); Paper ruled 20 squares to the inch is equally good, National 12-282. The 10 millimeter paper has a heavy line for each centimeter, a not so heavy line for 5 millimeters, and a light line for each millimeter. Densitometers are usually calibrated with density increments of 0.02 because they aren't any more accurate than this and all measurements should be rounded to the nearest 0.02. Using 10 millimeter paper let each line equal a density increment of 0.02; every five lines will represent a density increase of 0.10 and a density increase of 0.30 (one stop) will be 15 millimeters. Every coordinate has a line, which makes the plotting easier, and the squares are not so large that the resulting curve covers half of a wall. Plotting curves with this kind of accuracy can be very frustrating because every little difference tends to be magnified

and look like a sore thumb when, in reality, it is a very small,
insignificant variation.

On a sheet of graph paper draw the two axes, Developed
Density and Exposure Density, and assign numbers to the grid.
Every coordinate is represented by a line which is perpendicular
to its own axis. A matched pair of coordinates have two lines,
each perpendicular to their own axes, and they intersect at a point.
It is this point, for each pair of coordinates, that we are looking
for. Using the table of coordinates in Figure 1. for illustration,
find the point represented by (1.5, 0.9). When writing coordinates
the horizontal axis is always listed first, in our case Exposure
Density. Follow along the horizontal axis (Exposure Density) to
the vertical line at 1.5, then follow the vertical axis (Developed
Density) to the horizontal line at 0.9. The intersection of these
two lines is the point described by the coordinates (1.5, 0.9).
Mark this point on the graph, then find the points for the other
matched pairs (coordinates) in the table. When all the points
have been found, they are joined together in a smooth curve — in
this case a straight line.

Now we have a way to measure, in the abstract, shadow detail
and highlight detail, just tonalities — density itself — and be
able to make comparisons which have nothing to do with subject
matter.

Black & white sensitometry is easier to understand than color
sensitometry because there is only one variable, contrast. Zones
are a way of talking about tonalities in a print. They are
brightnesses which cause brilliance. Brilliance, because it is
in the eye of the beholder, cannot be measured but the brightness
which caused it can be measured. A Zone VII white, when set
alongside a pure white, forms a distinct edge: there is contrast
and this contrast will reveal shape. At this edge there is a
density gradient and the two densities do not merge visually. The
same statements can be made about a Zone III black. If the black
cat in the coal bin is Zone III and the coal jet black, then the
shape of the cat will be revealed in the print.

Zones are an abstraction, a generalization which is at best
an approximation of the real thing, brilliance. There is reason to
think that Zone VII by itself can never be brilliant in the sense

of glowing, and that this visual event only happens when a Zone
III or Zone IV black (dark gray) is present in the print. If
Jones is right, when he states that in his set of prints exposure
was more important than contrast, then, if Zone VII in the print
is visually right (neither too dark nor too light) the lower
mid-tones will take care of themselves and the print will be seen
as brilliant. Ansel Adams would agree, but he would demand, in
his own work, a Zone III black (at least) and probably a Zone I black.

By making a black and white print from the step tablet and
studying the progression from black to white we are able, with a
reflection densitometer, to determine the densities, within limits,
that cause the visual experiences.   If we take the Developed
Densities in this printed tablet and plot them against the Exposure
Densities in the step tablet, we get the characteristic curve on
page 27.

If Zone III in the printed tablet is caused by an Exposure
Density of 0.45 in the step tablet (negative), then a density of
1.35 in the step tablet will cause a Zone VII white in the print
of that tablet. This, the difference between 1.35 and 0.45 (0.90)
is the exposure range for this specific kind of paper (BN 111)
exposed in my diffusion enlarger and developed for 2 minutes in
Ansco 130 at 68° F. Change the enlarger, change the developer,
change the developing time or temperature, and it will be a
different characteristic curve. The exposure range will probably
not be the same. But this is what I use; so, when I see something
and say, "That's a photograph!" then I know that whatever is going
to be Zone III and Zone VII in the print must have a density
difference in the negative of 0.90 because this is the only density
range that will cause both a Zone III black and a Zone VII white
in the same print on Agfa BN 111 in my system. This can be changed
to some extent, but not too much, by changing paper grades and
even less by changing developers. The disadvantage of changing
paper grades is that each grade has a different characteristic
curve. This is most noticeable in the toe and shoulder sections.
If the toe and shoulder are slow, easy curves, then they cause
considerable compression in the print: density does not increase
very rapidly with increases in exposure.

Figure 2.

Characteristic Curve for Agfa BN 111
Exposed 11 March 1978 in a Diffusion Enlarger and Processed
for 2 minutes in Ansco 130 (1:1) at 68° F

Table of Coordinates

Exposure Density	1.65	1.50	1.35	1.20	1.05	0.9	0.75	0.60	0.45	0.3	0.15
Developed Density	0.08	0.12	0.20	0.36	0.60	.88	1.22	1.56	1.82	1.92	1.94
Percent Reflectance	84%	76%	63%	44%	35%	13%	6%	3%	1.5%	1.2%	1.1%
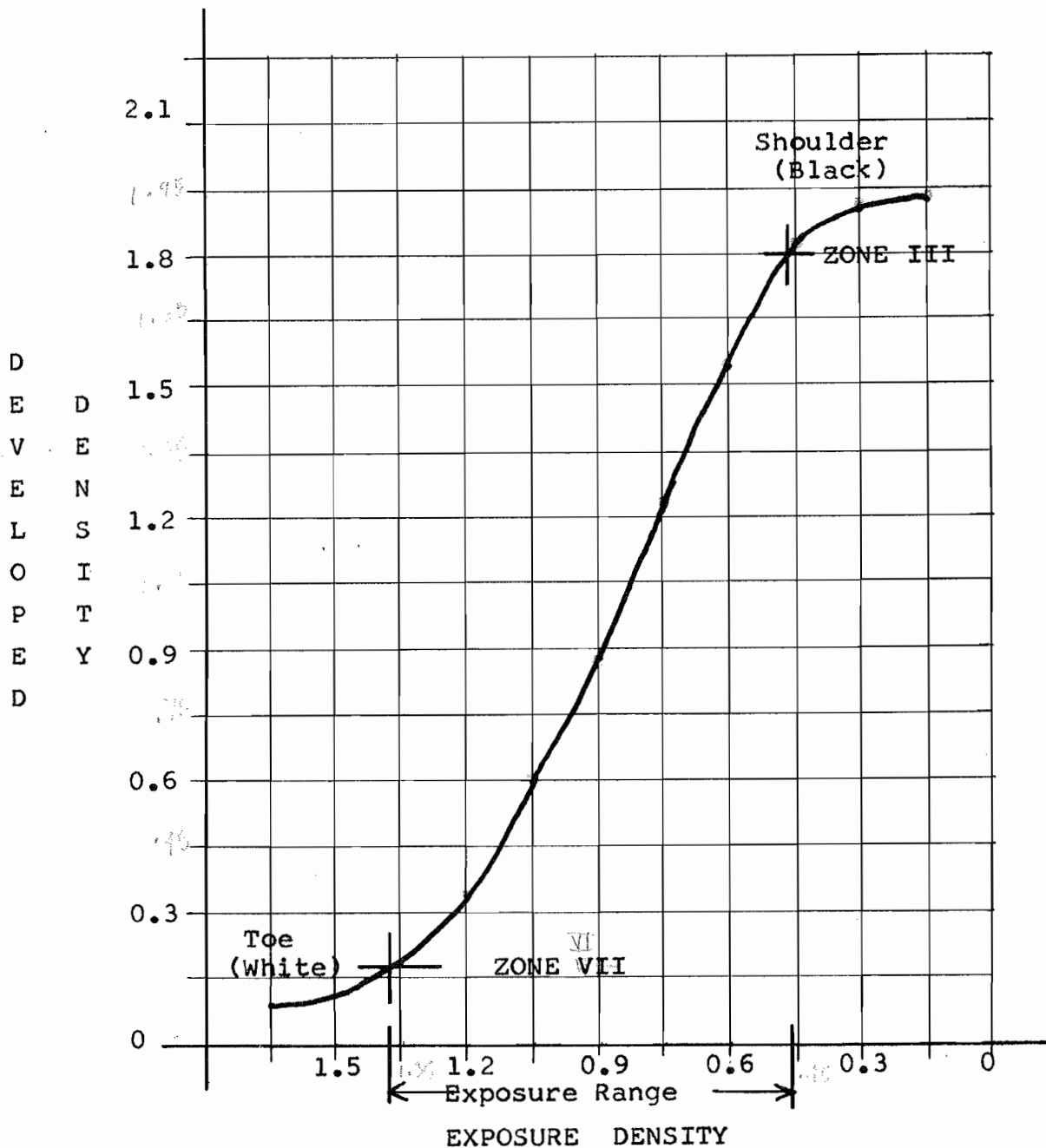
The Zone System

The essence of the Zone System, for both Ansel Adams and Minor White, is expose the negative for the shadows and develop it for the highlights.

Until the early 1930's no commercially available emulsion was sensitive to red light, so film was always developed with the safe light on. The photographer could watch the image come up and pull the negative out of the developer when he had the highlight density that would give him the print he wanted. With panchromatic film, unless it has been desensitized in one of the pinacryptols, this cannot be done and it is the problem which Ansel Adams has been attacking over the years in his books. Unfortunately he has changed his nomenclature several times; information has either been revised or accidentally dropped out of the various editions, so he now sometimes seems like a man trying to jump over his own shadow. However, if you think he didn't know what he was talking about, just look at his prints for a while. Minor White learned the Zone System from Adams in the late 1940's and early 1950's then went his own way with it. White's interest was much more involved with the question of pre-visualization and took for granted, especially in his later years, that his students understood the underlying craft, which is what we're involved with.

To my way of thinking, everything in the Zone System begins with the print because that is what we are trying to make. My B/W system is standardized around Agfa BN 111 paper, a diffusion enlarger with a Rodagon lens, and Ansco 130 developer. These are constants and I spent several years experimenting with the same photograph (different negatives) on various papers with different developers until I found the combination which pleased me most. Since then I've stayed with it. Now, when I see a photograph there are only two variables: the film-developer combination and waiting for the illumination which will give me the negative I want. I know that the negative must have a density range of 0.90 between Zones III and VII because this is the way Agfa BN 111 prints.

It is impossible to make an intelligent choice about films and developers until the sensitometric work is done. Each emulsion has inherent advantages and disadvantages, likewise developers.

For no good reason, except that it is the film I know most about, we'll use Plus X in sheets. Pure theory says that this sheet of Plus X, with the step tablet taped to it, should be exposed in the camera with a mat white surface for illumination and a normal shutter speed, like a twenth-fifth. I have found that an enlarger with condensers and a lens with an 80A or 80B filter to convert the tungsten to daylight is equally efficient and much easier. The step tablet is exposed in contact with the sheet of film being tested on the easel at a twenty-fifth of a second. I process all sheet film one sheet at a time, flat in a tray at 68° F with continuous agitation. The reason is simple: I get better consistency, not only sheet to sheet because the developer is always fresh but also the development is uniform across the emulsion on any given sheet. I have never been able to do this with tanks, let alone a replenished gas-burst system.

To get a Zone VII white and a Zone III black we know, from the characteristic curve for BN 111, that the exposure range between these zones (developed density in the negative) must be 0.90. From the graph for the characteristic curve (page 30) for Plus X developed in DK-50 (1:1) for 5 minutes with continuous agitation at 68° F we can find the coordinates for a Developed Density range of 0.90. This 0.90 range can be any place on the curve and its actual location depends upon what we choose for a Zone III density. This placement of Zone III cannot be so low on the toe that there isn't any separation between it and Zone I. For reasons that will be apparant when we discuss the effects of changing the development time, the Zone III placement must be at the point where the straight line section joins the toe. A density of 0.4 is a good compromise: 0.45 is a good upper limit and 0.35 for the lower limit. No one number is really any better than any other number and making photographs is the only way to make the final choice. When Zone III is placed at a specific density then, for Agfa BN 111, we know that Zone VII is 0.90 up the line.

From the coordinates for Zones III and VII on the curve for Plus X we can calculate the Exposure Density range —— 1.35 or $4\frac{1}{2}$ stops. This is true for Plus X the way we are using it. For another film and paper exposed in a different enlarger, the numbers will be different. If we increase the development time from 5 minutes to $6\frac{1}{2}$ minutes, then the exposure range will be four

stops between Zones III and VII. See Figure 4. on page 32. Each
zone in the print will represent a stop of brightness in the original
scene. Suppose the area which will be Zone I in the print reflects
1 unit of light, then, in the print, the Zone II area will reflect
2 units in the original scene, Zone III, 4 units ... Zone VII will
reflect 64 units and Zone VIII 128 units. Beyond this there will
be so much density in the negative that it won't print on BN 111.
Refer back to the table on page 20. The negative that will do this
is called, by Ansel Adams, the normal negative. These are the
Exposure Zones. They cause Density Zones in the negative which
become Brightness Zones in the print.

Figure 3.   The Characteristic Curve for Plus X
                  Developed for 5 Minutes in DK-50 (1:1) with
                  Continuous Agitation in a Tray at 68° F

Table of Coordinates

Exposure Density	3.6	3.3	3.0	2.7	2.4	2.1	1.8	1.5	1.2	0.9	0.6	0.3
Developed Density	.16	.20	.30	.46	.64	.83	1.02	1.21	1.4	1.6	1.83	2.12
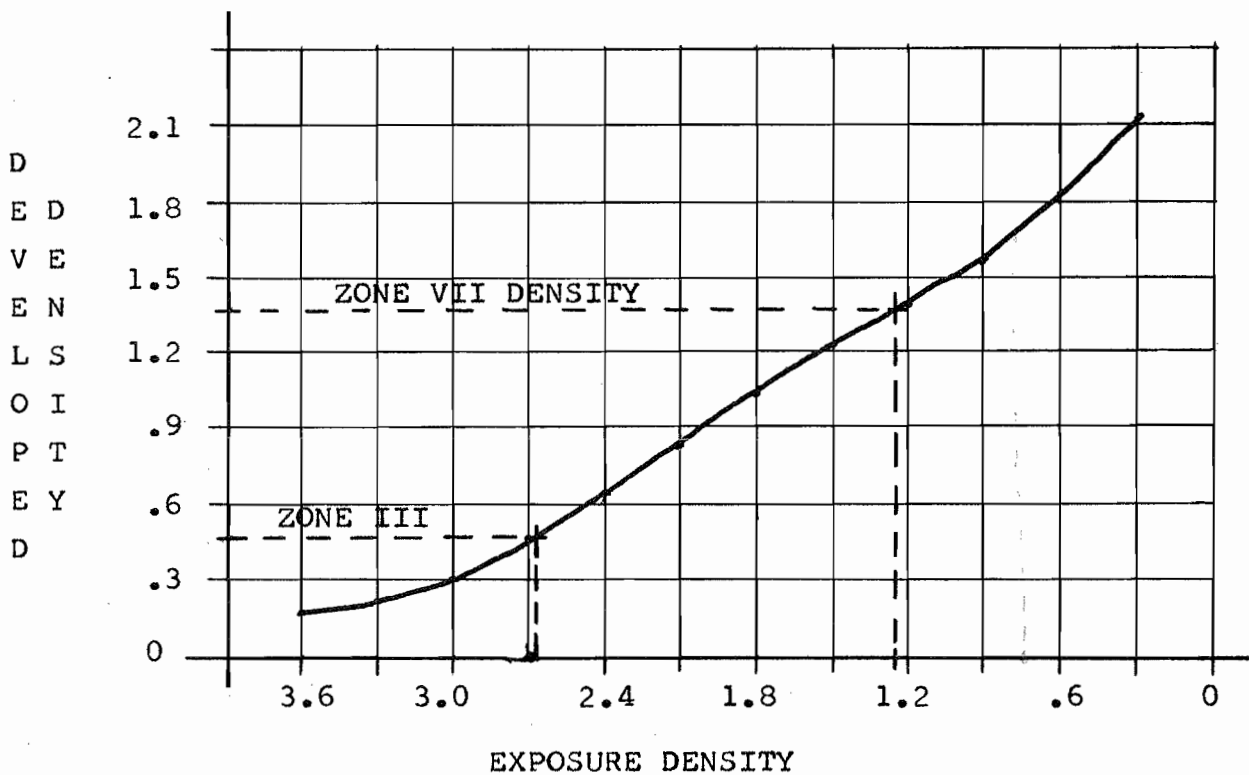
EXPOSURE DENSITY

Gamma

Plus-X is a multi-coated film with two emulsions, high
intensity and low intensity on the same support. The straight
line section does not shoulder: the density continues to increase
uniformly with increases in exposure through the whole range that
is useful for everyday photography. The small hump which appears
on the characteristic curve between densities of 0.9 and 1.2 is
caused by the overlap of the high and low intensity emulsions.
The shoulder of one is meeting the toe of the other. As developing
times are reduced, this hump becomes more and more evident. Some
commercial films are so bad that the curve looks like a corkscrew,
but you won't find it in the published data sheets. This is the
principal reason why I prefer Plus-X: the hump does not become
serious.

From the characteristic curve for Plus-X we can read off the
Developed Density range (0.45 to 1.35, which is 0.90) and the Exposure
Density range (2.7 to 1.25, which is 1.45) for the section between
Zones III and VII. The ratio of these two ranges, Developed Density
and Exposure Density (0.90 divided by 1.45) is 0.62. This is the
rate at which density changes as a function of exposure. With each
additional stop of exposure, 62/100ths of a stop of density is
created in the negative. This, the number 0.62, is called gamma.

Unless the limits, for us Zones III and VII, are stated,
gamma is a meaningless number and quite useless. In technical terms
gamma is nothing more than the slope of the curve between two
points. As these points get further and further apart, the slope
(gamma) becomes more and more an average of the various slopes in
between. Gamma is one thing for the straight line section of the
curve and quite another for the toe. The curve on page 30 has a
gamma of 0.4 in the exposure density range between 3.6 and 2.4:
toe density as a function of exposure does not increase as rapidly
as density does on the straight line.

For any given emulsion gamma on the straight line section
is determined by the amount of development. Usually, but not
necessarily, it is a function of time. The amount of development
can also be changed by varying the alkalinity of the developer or
its temperature. If the developing time is varied without changing
the illumination when the step tablet is exposed, then developed

density is the only variable.

With different developing times, using fresh developer
for each sheet, the straight line section behaves as if hinged
with the pivot at Zone III. The shape of the toe does not change
appreciably, though the whole curve will move left or right on
the graph. This hinge, Zone III, is at a density of 0.40, more
or less. As the developing time is increased, gamma for the
straight line section between Zones III and VII increases to D(max),
at which point all the exposed silver salt in the emulsion has been
reduced to metalic silver. Up to this point, D(max), there has
always been some latent image that does not get developed and is
removed in the fix.

Figure 4. on page 33 is a summary of what happens to the
straight line section of the characteristic curve between Zones
III and VII when the amount of development is varied from 3 minutes
to 15 minutes which is D(max) for Plus-X in DK-50 (1:1). Using a
different developer the times would be different and with some
D(max) would be lower because these do not have sufficient strength.
With them the curve goes into a slow shoulder which is very good
for printing with condensers in the enlarger. (See page 37.)

Film speed, the ASA number (125 for Plus-X), is determined
according to specified procedures established by the American
Standards Association which is the trade organization for the
photo manufacturers and has nothing to do with the Bureau of
Standards in Washington DC. The ASA numbers for film speed are
not absolutes (always true) because they are based on an average
developing time in an average developer. Using this, the film
speed number is based on the amount of illumination necessary to
get a density of 0.30. Even so, it is a very useful reference.

In Figure 4., as the developing time increases the position
of Zone III on the Exposure Density axis moves 2½ stops from right
to left, 2.25 to 3.0. The ASA speed increases from 125 at 5 minutes
to 250 at 15 minutes and decreases from 125 to 48 at a developing
time of 3 minutes. In photography everything is relative: what we
do at one place has an effect someplace else and our only point
of departure is the characteristic curve for the paper we use
when making prints.

Figure 4.   The Relationship between Developing Time and Gamma
for Plus-X Developed in DK-50 (1:1)

Table of Coordinates		E X P O S U R E D E N S I T Y							
		Developing Times							
Exposure Density	Developed Density	3'	4'	5'	6'	7'	8'	10'	15'
Zone III	0.45	2.25	2.55	2.70	2.75	2.84	2.86	2.90	3.0
Zone VII	1.35	0.35	0.90	1.26	1.45	1.70	1.78	1.85	2.0
Difference	0.90	1.90	1.65	1.44	1.30	1.14	1.08	1.05	1.0
Stops		6.3	5.5	4.8	4.3	3.8	3.6	3.5	3.3
Gamma		.47	.55	.62	.69	.79	.83	.86	.9

The coordinates underneath the developing times are the Exposure
Densities for Zone III at a Developed Density of 0.45 and Zone VII
at 1.35.   The DIFFERENCE line is the Exposure Density RANGE for the
various developing times; STOPS is the same information in stops
rather than density (logarithms).   GAMMA is the Developed Density
DIFFERENCE divided by the Exposure Density DIFFERENCE.

EXPOSURE DENSITY
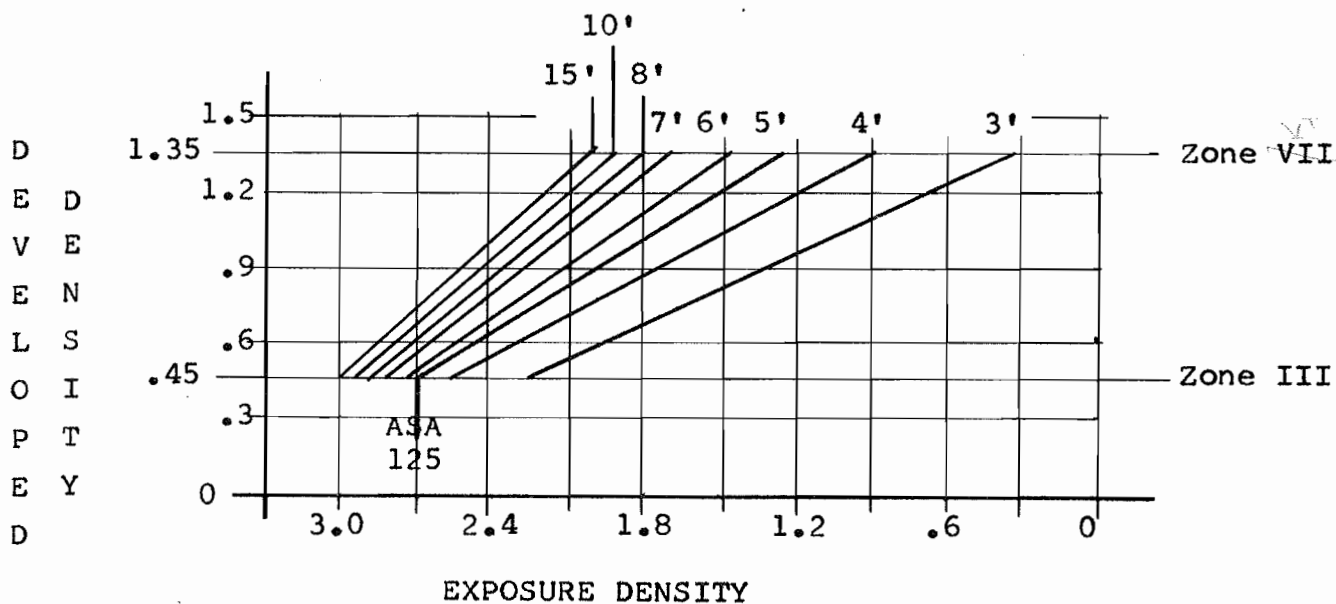
Refer back to page 30 for the discussion about a normal negative. If, what I want at Zone VII in the print is 4 stops brighter than the area I want at Zone III and I will be making the print with a diffusion enlarger on Agfa BN 111, then I expose the negative for the shadows at Zone III and give the negative a normal development: 6½ minutes in DK-50 (1:1). This will produce a density range of 0.90 that puts Zone VII where I want it.

Supposing the area that I want at Zone VII in the print is 5 stops brighter than the Zone III area. If I give this negative a normal development what I want at Zone VII will be at Zone VIII, so I reduce the developing time. Zone III stays the same because it is at the pivot and I get less density in the area which I want to be a Zone VII white in the print. By reducing the developing time I have also changed the film speed, so I will need more exposure for the shadows (to make them printable) but this added exposure has no effects on the highlights because, except at D(max) there is always undeveloped latent image.

If the reverse is true and what I want at Zone VII is only 3 stops brighter than Zone III, then I must increase the developing time to get a density range of 0.90. This increases the film speed, so I need less exposure for a Zone III black.

In practice the easiest way to do this is meter the Zone III area and the Zone VII area, take the average and use this to determine the exposure. If the difference between Zones III and VII is more than 4 stops, decrease the developing time by 15% or so and increase the exposure by a half stop. When the difference is less than 4 stops, increase the developing time and decrease the exposure. Don't be bashful with the increases and decreases in developing time because Jones has already said that, in the print, correct exposure is more important than contrast. If by chance you go too far, or not quite enough, the photograph can be salvaged by adjusting the contrast with a change of paper grade. This is a remedial action because more contrast can be controlled with developing time than with a normal development and paper grades. It is possible to make an 8 stop exposure difference printable with D-23 and Kodalk. See Ansel Adams, THE NEGATIVE, 2nd Edition, p 117.

SUGGESTED READING

Adams, Ansel, THE NEGATIVE: EXPOSURE & DEVELOPMENT, Morgan and Morgan, New York — 1948

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James, T.H., & Higgins, G.C. FUNDAMENTALS OF PHOTOGRAPHIC THEORY, Morgan & Morgan — 1960

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Chapter 3.   SENSITOMETRY APPLIED TO DYE TRANSFER PRINTING

There are only two real sensitometric differences between
black & white printing and dye transfer printing. In B/W the
paper has one sensitometric curve, black to white, whereas in
dye printing we use matrix film with three superimposed dye
curves (cyan, magenta, and yellow) which, when combined on the
receiving sheet, make a curve that is continuous from black to
white. The other difference is the original. In B/W the original
is the scene in front of the camera and in dye printing, unless
the separations are direct, it is a transparency, usually called
chrome. We will be concerned with E-6 Ektachrome: 35mm, 120, and
sheets. The various numbers (exposures and developing times) can
also be used with E-3 and E-4 Ektachrome. The current Kodachrome,
both 25 and 64, are special cases due to the technical problems
that Eastman Kodak has had with these emulsions. Since the films
were introduced Kodak has been trying with no appreciable success
to correct for the crossovers of cyan and magenta dyes: sometimes
one, sometimes the other, and occassionally both at the same time.
With each batch of film the characteristic curves for the three
layers have been different, so there is no way of knowing in advance
what to expect when it is separated, and the only way to print it
is by trial and error. Make a print then reseparate, changing the
contrast in the separations, to adjust for the crossovers.

In dye printing the density is caused by dyes, not metalic
silver, but it is still density, though selective because the dyes
absorb light (red,green and blue). The density range in the print
is controlled by the thickness of the gelatin. The characteristic
curve for matrix film is plotted by making a step tablet then
transferring it in one of the dyes and measuring the densities in
the receiving sheet with a reflection densitometer. It takes three
tablets, one for each dye. If the same tablet is used in all three
dyes, something happens in the gelatin that causes a mottle in the
receiving sheet. I suspect that the gelatin cannot adjust to Ph
changes between the three dyes.

The dye density range in a dye print is 1.8 between Zones III and VII (2.0 to 0.20). The characteristic curve for the matrix-dye pair using cyan, magenta, and yellow (black to white) goes well beyond a dye density of 2.5 which is the upper limit for reflection densitometers. For the eye, black is black beyond a density of 2.3 (0.5% reflectance) and no visual distinction can be made between the steps, though they can be measured with a reflection densitometer.

The Exposure Density range in the tablet to get a Dye Density range of 1.8 in the receiving sheet is one number with a diffusion enlarger and a different number with an enlarger using condensers. Either type of enlarger can be used to expose matrix and tablets which are visually identical can be made, though the characteristic curve of Exposure Density for each will not be the same. The choice between enlargers, with or without condensers, is a serious decision.

Enlargers for Exposing Matrix

It is my opinion that the light source should be double diffusion, no condensers. Enlargers with condensers are usually single diffusion because the light source is a big opal bulb, a #212. In an opal bulb the filament is not the light source because the photons bounce around inside the glass envelope and then come out, through the opal coating, at all angles in a random pattern. The opal is an actual coating on the glass rather than a chemical etch which is done on the ordinary household bulb. In a household bulb, when it is on, you can see the filament, but you can't in an opal enlarging bulb.

When printing with condensers the light gets scattered, for reasons unknown, in the heavier densities which control the upper mid-tones in the print. This scatter may have to do with the fact that the photons have been directed by the condensers and don't have as much opportunity to get past the metalic silver as the photons in a diffused light source which come from wider angles. With condensers less density is needed, due to the scatter, in the negative to get a Zone VII white: the silver has more optical density (ability to hinder the passage of light) than it does in a diffusion light source. In prints made of a step tablet with both light sources, using the same tablet to control the exposure,

there will be fewer steps between Zone V and pure white (paper base) with the condensers than without them. By being much more noticeable in the upper mid-tones than in the shadows, this has nothing to do with the Callier Coefficient which is a pronounced jump that happens at densities near 0.30. For a further discussion of this see page 828 in the 2nd edition of Mees, THEORY OF THE PHOTOGRAPHIC PROCESS.

This increase in contrast (gamma) which happens in the upper mid-tones with condensers amounts to a stop almost in the Exposure Density range. Even worse for the purposes of dye printing (or black and white for that matter), it is an accelerating curve; therefore, to maintain equal visual increments in a step tablet printed with light which has been focused with condensers, the characteristic curve for the Exposure Density range (separations) must, to offset this, decelerate. In short, the upper mid-tones must be put on the shoulder of the characteristic curve for the separations. If this shouldering isn't there, then detail in the Zone VII whites is lost. This is especially evident in photographs with clouds which have been printed with condensers — the fine detail is gone. Highlight masking is no help because they add contrast and there is already too much contrast. By shouldering the characteristic curve to make the upper mid-tones print, there is no latitude whatsoever for the placement of Zone III at the pivot. With a diffusion light source in the enlarger, the relationship between Exposure Density and Developed Density is pretty much linear with no scatter problems so, give or take a bit, Zone III placement is not critical and the characteristic curve is not asked to do what has been designed out of it with multiple coatings, the shoulder. See page 30 and 32.

It is an open question whether diffused light (a #212 bulb) which has been collimated to some extent with condensers makes a sharper image than double diffused light (no condensers). The whole question turns on a definition of sharpness. If sharpness is defined as lines per millimeter (resolving power) then I could be convinced, maybe, depending upon how the test was arranged, that more lines are revealed with condensers than without. Accutance describes the density gradient at the edge of a line and for the resolving power test to be conclusive the accutance must be the same in both prints; this is a very difficult condition to meet.

In most resolving power tests the accutance is very low, so the
lines are not messed up with turbidity and adjacency effects. At
the same time the print has no snap whatsoever, which is accutance,
the steepness of the density gradient at the edge of the line.
The steeper and longer this gradient, the edge between lighter and
darker, the sharper the edge looks. Sharpness is a balance between
resolving power and accutance. To my way of thinking sharpness is
in the eye of the beholder and a subjective judgment.

The only way to make an intelligent choice about condensers
is to print two negatives, one that is perfect for condensers (with
the upper mid-tones on the shoulder) and the other perfect for a
diffusion light source, with identical subject matter and illumination
(like pine needles or a cat's whiskers), then compare the prints.
In this test the only variable is the condensers; using a five power
magnifier there will be very slight differences, very slight and I
suspect that for the majority of viewers, so long as they don't
know which was made with condensers, the double diffused print will
appear sharper. The principal reason why most enlargers have
condensers is that they're easier (cheaper) to manufacture: it is
quite difficult to make a diffused light source that is uniform
over a small area, like 35mm and 2¼ square, in a small housing.

Matrix Film

Matrix film is developed for two minutes in a mixture of
Tanning Developer A (the developer) and Tanning Developer B (the
alkali). Both are proprietary products of Kodak and the formulations
have never been published. When the two are mixed, the solution
begins to oxidize immediately. Whatever procedure you select for
mixing them and getting the film in, don't vary it. When the
flasks of A and B are at 68° F put the Tanning B in the tray, get
the sheet of matrix and put the Tanning A in the tray with the B
20 seconds before the film goes in and tilt the tray several times
to make the solution uniform. In the safelight you'll see the
solution turning brown instantly. It's my hunch that the longer
the developer has had to oxidize, the more dichroic fog it will
make in the emulsion — relief in the highlights which will carry

dye and degrade the whites. For a set of matrix the development
must be a constant; otherwise the contrast in the finished print
could be a result caused by the separations or the matrix and, with
only the finished print to look at, there is no way to tell which
did it. This also assumes the dyes are a constant because their
contrast can also be changed.

The relief in the matrix is created by the reaction of the
oxidized tanning developer with the exposed silver salt in the
latent image. As development progresses the gelatin surrounding
each grain of developing silver is hardened as a consequence of
the chemical reaction between the gelatin, the oxidation products,
and the exposed silver salt as it is reduced to metalic silver.
Only the gelatin which is in contact with the reduced silver gets
hardened during development. The rest remains soft and is removed
with hot water during the wash-off. This leaves the image in a
hard gelatin relief which remains soft until it dries. Mats cannot
be rolled without having been dried first. The silver in the matrix
is of no further interest.

Matrix film is sensitive only to blue light. It has a yellow
dye in the emulsion that comes out in the fix. This dye, which
absorbs blue light, limits the depth of the image in the emulsion.
Along with the amount of exposure, it controls the height of the
relief. If the emulsion is exposed facing the light, then the
image will be on top of the emulsion because the yellow dye prevents
it from going all the way through. By being on top, there will be
a layer of unexposed emulsion between the image and the support.
During the wash-off it will melt like jello in the summer sun
and you'll say to yourself, "Man, did you see that image. First
it was there, then it was gone. It just slid off the support and
crumpled against the end of the tray."

The published range for the ratio of Tanning A and Tanning B
to make the solution is from 1:1 to 1:4. As the amount of alkali
(Tanning B) increases, the contrast in the matrix increases, but
at the same time the exposure for a Zone VII white decreases quite
rapidly. The change in contrast from one extreme to the other
amounts to no more than one paper grade in B/W. It's been my
experience that the visual effect in the print is minimal when the
comparison prints have equal densities in the upper mid-tones. The

exposure adjustment as the alkalinity is changed is strictly
trial and error, more test prints.

I use a ratio of one part Tanning A and 2.25 parts of
Tanning B (200mls and 450mls in an 11x14 tray) because the
quantities leave enough room in the 250ml and 500ml boiling flasks
so the solutions don't slop out when the flasks are being spun in
a jar of hot or cold water to bring the temperature to 68° F. In
short, there is nothing to be gained by varying the contrast in
the matrix developer.

Step Tablets for Dye Printing

Using a diffusion enlarger (no condensers) project a silver
tablet onto three separate, pin registered sheets of matrix film
and develop them for 2 minutes in a developer mixed 1:2.25. If
you will be printing with condensers, use the condensers, and if
you will be using a different developer ratio, use it also.
Whatever you have selected for a procedural system, do it because
these three sheets of matrix (cyan, magenta, and yellow) will
determine your control numbers for exposing matrix and also the
Zone III to VII gamma in your separations.

When these three matrices are soaked in normal dyes (5 ounces
of dye, 5 ounces of buffer, and distilled water to make 64 ounces)
with no added acid they will make a tablet which has a Dye Density
range of 1.8 between Zones III and VII. For all practical purposes
the dyes themselves are a constant; however, we know that later on,
if we wish, we can change the color by changing the contrast in the
dyes selectively. These adjustments should be used only for small
visual corrections at the end of the process and not as a way to
straighten out major mistakes made at the beginning.

Figure 5. on page 42 is the characteristic curve for matrix
using cyan dye and reading the reflection densities from the print
in red light. The exposure density range between Zones III and VII
(1.54 to 0.44) is 1.1.

The maximum Developed Density range in E-6 Ektachrome is 2.1
between Zones III and VII, though this is a floating number because
Zone VII in a transparency is not a fixed point. The brilliance
which is seen as Zone VII can be caused by brightnesses in the

chrome which vary in density from as much as 1.4 to 0.4. These
are extremes, but they happen more frequently than one might
expect. At the same time, in a properly exposed chrome, Zone III
tends to be a fixed point between 2.3 and 2.5. Beyond 2.6 black
is visually black and there is no apparant separation; below 2.4
the densities are visually dark gray, rather than black. Zone VII
is the problem because, in the print, it is a fixed point (density)
and the eye will not readily adjust to exposure differences: the
print either looks too dark or washed out, though this washing out
may be related to a Zone III which is dark gray rather than black.
It is anybody's guess, but for the moment we will assume a full
range chrome for the discussion of sensitometry and leave the
question of contrast for the concluding chapter. The Dye Density
range of 2.1 in the chrome must be reduced to 1.1 in the separations
to make a print that retains the tonal range of the chrome.

Figure 5.   Characteristic Curve for Cyan Dye and Matrix Film
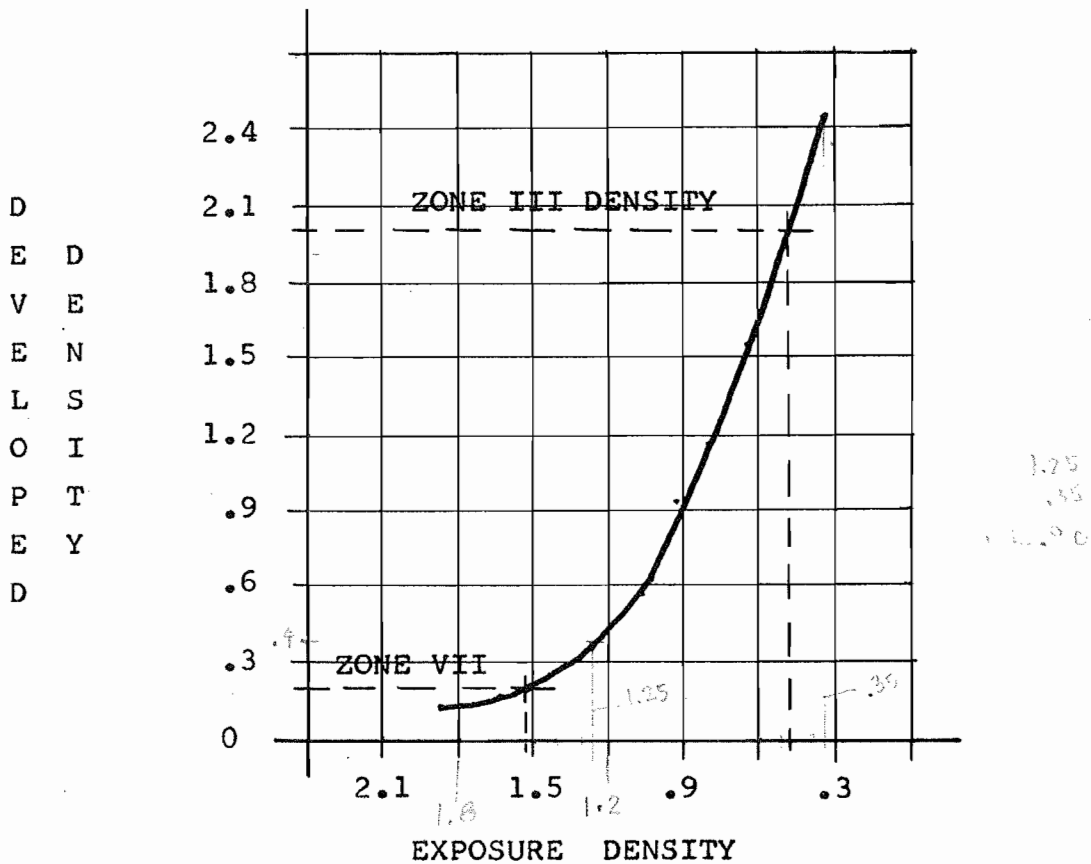
By exposing a sheet of E-6 Ektachrome contact with the silver step tablet in the light for which the film is balanced and then having it processed, we can make a color step tablet. It is a dye image and made with the material that we'll be printing. We must use it, rather than a silver tablet, to expose the separations because light does one thing when it passes through metalic silver and something else, quite different, when it passes through a dye image. A silver tablet was used to expose the matrix test because the separations are silver, but this is not the case with the separations.

This difference between a silver tablet and a dye tablet is particularly evident when the characteristic curve of each on similar film is compared, one exposed in green light through silver and the other in the same green light through a dye tablet. In this test the tablets are the only variable. Not only the gammas are different, but also at equal densities in the tablets the amount of light necessary to get equal Zone III densities in the two is not the same. Nothing with green light matches. Red and blue aren't as far out, but they aren't in line either. For why? Nobody knows ... it's just the green problem and labs processing movie film go nuts with it. There is no point in doing the sensitometric work for balanced separations with a silver tablet: the information is spurious and prints made with this information are a mess.

Filters for Separation Work

The choice between glass and gelatin filters is a lesser of two evils. Gelatin filters are very fragile if abused. They scratch and one drop of water will leave a mark which the light passing through will project onto the film, even in contact printing. They wrinkle with extreme heat and this causes discontinuities in the cone of light. On the other hand the colorants are probably more stable than those used to make glass filters. Unfortunately there is no way to check, except at great expense, the spectral changes that happen with time. With glass you never really know that the filters are what you think they are. I prefer gelatin because they are cheaper.

The choice of filters —— red 29, red 25, green 61, green 58, blue 47, blue 47B (the B is an ultra-violet cut-off) —— in any combination of three makes no visual difference in the print. You'll hear a lot of talk about narrow pass, broad pass, overlaps and spectral peaks. It is all very interesting and theoretically the difference should be important; however, in practice, for separations it doesn't make a bit of difference. The 25 and 58 pass more light than the 29 and 61 (different filter factors), so you wind up with more or less neutral density, but it all costs the same. I use a 29 and a 61 only because they are what I have always used: to keep my sensitometric information uniform, I continue to use them.

A detailed discussion of filters, plus neutrality, can be found in Evans, Hansen, & Brewer, PRINCIPLES OF COLOR PHOTOGRAPHY, Wiley, pages 298-303

Balancing Separations

If I were to make dye prints with a condenser enlarger, I would use Plus-X rather than Super XX because Plus-X has a very fine grain structure and more inherent contrast. The Kodak data sheet for Super XX says nothing about the grain structure. Super XX at D(max) in HC 110 has a gamma of 0.70. DK-50 (1:1) will bring this up to 0.75 which is still 0.15 below Plus-X. With a diffusion enlarger Separation Negative Film, Type 1. is ideal. It has an adequate grain structure, though no where near as fine as Plus X, but it has more inherent contrast which is necessary.

All multi-coated films have serious reciprocity departures and Separation Type 1. is no exception. Reciprocity says that exposure is the product of intensity and duration (time). If I double the time and divide the intensity by half then the exposure (resulting density) should be the same for both exposures. Reciprocity departures happen with very short exposures and exposures longer than one second. If the calculated exposure is 4 minutes for a Zone III density, then the actual exposure to get this density is 64 minutes. Also with reciprocity departures there is a contrast increase as the film speed decreases; consequently the developing time must be decreased to offset this which further reduces the

film speed. As the developing time is reduced then the hump where the high intensity and low intensity emulsions meet becomes a broad plateau. This pronounced shoulder and toe is a real disaster. (See page 31)

Film, and this is true for all emulsions, is not equally sensitive to red, green, and blue light. With green light the emulsion needs less exposure but more development to get a developed density range from Zones III to VII of 1.1, which is what we need to get a dye density range of 1.8 in the print. With red light it takes more exposure but less development to get a range of 1.1. Blue requires a lot more of both; knowing this it is no great problem to expose the three separations in their respective light with separation filters for a Zone III density of 0.40 and develop them to a Zone VII density of 1.5.

As a practical thing it is best to start by over exposing and giving the sheet a full development. As you shorten the exposure times the effects of reciprocity (increased time and contrast) are minimized. Going the other way it is very hard to guess what's going to happen. The blue separation, for reasons we'll get to later when discussing the dyes, is not particularly critical, even in the upper mid-tones and totally unimportant in the shadows. On the other hand, the match between the red and green curves is very important — the closer the better and if the blue drops right in for the upper mid-tones, perfect.

Masking

Three separations made with a developed density range of 1.1 from Zone III to Zone VII and characteristic curves which not only have a reverse match to the Ektachrome curve but also fit together like spoons would duplicate the original, if we had perfect dyes. A perfect dye passes its own color 100% while absorbing everything else. For cyan this would be green and blue with no red. Unfortunately, though cyan does an efficient job of absorbing red, it also absorbs some blue and a considerable amount of green, as if it were contaminated with both magenta and yellow dye. Cyan will give a maximum red density of 3.0. Magenta dye has a maximum density in green light of 2.2, but the unwanted blue absorption is serious, though the unwanted red is minimal.

Yellow dye has a maximum blue density of only 1.3 with near as no matter no unwanted red or green absorptions. In the print the failure of yellow to absorb blue light is corrected by the unwanted blue absorptions in cyan and magenta. Without these unwanted blue absorptions to make up for the yellow there would be no neutral blacks in the print. Up to a point the unwanteds are necessary.

The following table for Zone III black is a summary of the color densities, measured separately by dyes and colors from three prints (cyan, magenta, and yellow) of the step tablet. In white light the combined density of all three is 1.95 (1.90, 1.95 and 1.65). It is visually neutral.

| | Density | | |
	Red	Green	Blue
Cyan	1.90	0.85	0.40
Magenta	.25	1.40	.80
Yellow	.10	.20	.90
Total	2.25	2.45	2.10
Combined	1.90	1.95	1.65

When I saw these numbers for the first time, my immediate reaction was that something had blown up in the densitometer. When thinking about these numbers it is most important to remember that they represent a very dark gray which is visually neutral. The absence of blue in the combined tablet (cyan, magenta, and yellow), 1.65 compared with 1.95 and 1.90 may have to do with the fact that the eye is not as sensitive to blue as it is to red and green. Be that as it may, the step looks neutral. The real dilemma is that the red components in cyan, magenta, and yellow total 2.25 separately and only 1.90 collectively. In the green it seems that the unwanted green in magen cyan is the only thing that gets the green density up close. This problem is known as the failure of additivity and probably has to do with the internal reflections that happen inside the gelatin layer between the top and the bottom. The same sort of thing happens with screen printing but with it the colorants are layered. In dye printing the colorants are commingled, so what may be true in screen printing is not necessarily

valid for dye printing. The problem for screen printing is
discussed by Yule, PRINCIPLES OF COLOR REPRODUCTION, Wiley, in
chapter 8. These failures prompted Ralph Evans, who was involved
with all the research at Eastman Kodak for Kodachrome, to make the
observation that ultimately color photography is an empirical
process and no amount of theory can predict the finished product.

A print from separations which have not been corrected for
some of the unwanted absorptions in cyan and magenta will have
degraded color, each having been mixed with its complement. The
greens and the blues are darker while the reds and yellow orange
become lighter. Before masking this was gotten around by adjusting
the contrast in the matrices for the visually important color in
the print and then doing what was possible to correct for the color
shifts caused by the original adjustment. Masking for the unwanted
absorptions in the dyes did not become common before the mid 1950's.

A mask is an image which adds density to selected areas in
another image: for dye printing this other image is the separation.
Two-stage masking is the ultimate system and in high quality screen
printing as many as twelve masks may be used. The first stage
corrects the contrast in the separations and the second stage
corrects for the unwanted absorptions in the inks when the
separations are used to make the screened positives. These
positives are then contact printed to make the negatives which
are the printers on the press that control the ink in the impression.
The second stage is necessary because the colorants in the inks,
even the best, are further from perfect than those used to make
the dyes for the transfer process.

In the first stage three highlight masks (red, green, and blue)
are used because the relationship between dot size and visually
equal increments of density in a printed gray scale is not lineal.
To make the steps visually equal in the upper mid-tones the dot
size must be reduced, less exposure. This is done with a highlight
mask which is negative in register with the chrome when the contrast
mask is exposed. This contrast mask is now positive in the upper
mid-tones and negative in the lower mid-tones. The contrast mask
is registered with the chrome when the separation is exposed: the
positive portion increases the contrast while the negative portion
decreases the contrast in the shadow densities of the separation.

These six masks balance the separations for contrast.

For color correction a full scale positive with a gamma of 1.0 is made from each separation. These are the pre-masks. If the red separation is registered with the red pre-mask, there will be no density difference between the highlights and the shadows because everything gets canceled out. To correct for the unwanted green absorption in cyan, the green positive (pre-mask) is registered with the red separation and exposed on masking film. The resulting image represents those areas where cyan and magenta will be printed. The unwanted green in cyan can be thought of as some magenta contaminating the cyan and anyplace where there will be both cyan and magenta, some magenta wants to be removed. This is done by registering the red color mask with the green separation when the magenta matrix (printer) is exposed. Its effect is to reduce the exposure in the magenta matrix. For more information about two-stage masking see Yule, PRINCIPLES OF COLOR REPRODUCTION, pages 55-66 and 246-250.

The effects of various masking procedures can be evaluated numerically by making a test target which has cyan, magenta, and yellow tablets transferred from matrices, the two color overlaps (red, green, and blue) transferred from the same matrices, and the three color overlap which is the gray scale. By making direct separations from this color tablet and printing them, then the print and the target can be compared with a reflection densitometer. They can also be compared visually, which is more important, because a print is viewed by people with eyes, not reflection densitometers. The direct separations are interesting because they make the unwanted absorptions visible. An Ektachrome of the target is more useful because most prints are made from chrome and not direct, in camera separations. The fidelity of E-6 Ektachrome to the target is truly impressive, especially when compared with E-3. Kodachrome 25 and 64 are a disaster, especially in the greens.

Masking for dyes is much less complex than it is for screen printing because the image is not screened: a dye print is continuous tone. For comparison purposes I made a print from an E-3 Ektachrome of the target using twelve masks. When this print was compared with the print from the direct separations with no

color correction on one side and the original target on the other side, the print from the Ektachrome was amazingly close, both in color purity and brilliance. Nonetheless, twelve masks represent much labor.

The least number of masks for dye printing is two, one to correct for the unwanted green in cyan and the other for the unwanted blue absorption in magenta. With a set of separations using two masks from the E-3 Ektachrome I made a print and compared it with the target and the twelve mask print. The colors in the two mask print do not have quite the purity or the brilliance of the twelve mask print, but the difference is very small. It's like the difference between 96% and 98% and in a finished print with detail (edges and objects) rather than rectangles of tonality, I doubt that a viewer would do better than 50-50 in a scrambled set of twelve mask and two mask prints. So far as I am concerned, the extra work is not worth the effort.

The next question was highlight masks, once and for all. Are they necessary? If so, why? I made a set of separations from the E-3 Ektachrome with three contrast masks, but no highlight masks, and six masks to correct color and printed them. Visually there was no difference between the print with highlight masks and the one without highlight masks. The densitometer found a 0.04 decrease with highlight masks in Zone VI but nothing else. There was no increase in contrast in the highlights. Out of curiosity I made another set of separations with two masks but I added a green highlight when I made the two principal masks. The effect in the print was staggering to the eye. The gray scale was fine, but all the colors were horribly degraded from Zone VI up to white, except blue. Everyplace with green, that highlight mask was adding cyan and yellow, one or the other or both, and completely upset the color balance.

Out of all this there is no doubt in my mind that, for dye printing, there are only two masking procedures worth thinking about: two principal masks, a red to correct for the unwanted green in cyan and a green to correct for the unwanted in magenta, or a two-stage system with nine masks, three for contrast and six for color correction. In either case highlights are unnecessary. If I knew the print would be compared with the original, a reflection

print or a label, then I'd use nine masks, otherwise two masks.

Masked Separations

Masks are described with a percentage. In two-stage masking
the pre-mask is a 100% mask: it has a gamma of 1.0. Principal
masks in either procedure can never be more than 40%, otherwise
they cause edge effects, a dark line at the boundaries between
low and high densities, in the finished print. In days of yore
when masks were registered by eye and taped to the chrome, registration
was a real problem and the effects of misregister were minimized
by blurring the edges, either with spinning or diffusion sheets.
Eastman Kodak still recommends eye registration because nobody in
Rochester will acknowledge the existence of 1/16 inch pins and
Condit punches. There is sufficient diffusion, because it has no
anti-halation backing, in Pan Masking film by itself to eliminate
edge effects up to a gamma of 0.40, which is more than sufficient
for the required color correction.

Expose the Ektachrome tablet with the red filter which will
be used for the separations so Zone III in the chrome has a 0.30
density in the mask and then develop the mask for a Zone VII
density of 0.75. DK-50 is fine for Pan Masking film. It can be
diluted 1:4, 1:3, or 1:2. At 1:1 it produces too much gamma, but
at 1:2 for 3 minutes one solution can be used for both the red
and the green principals. Both should have the same density at
Zone VII so that Zone VII in the separations will have the same
density.

In theory the curve for the unwanted green in cyan should
be steeper than the unwanted blue in magenta because there is more
unwanted green than blue and we need some of the unwanted blue
in magenta to help the yellow. In practice it doesn't make a bit
of difference. One can almost argue, though no mask is bad,
anything within reason will work. The reason, I suppose, is that
nobody really understands all the variables involved. Among dye
printers talking about masks is almost as much fun as talking
about filters and there doesn't seem to be any good reason for
doing one thing rather than another, so long as something is done.

The red mask is used to make the red separation to keep
the contrast and density range in balance with the other separations.

It is also used to make the green separation. The green principal mask is used to make the blue separation. The red mask takes out magenta dye anyplace where there will be both cyan and magenta dye in the print. The green mask takes out yellow dye anyplace where there will be both magenta and yellow dye. At Zone VII in the mask there is a density of 0.75 and at Zone VII in the chrome there is a density of, say 0.4. By adding this to the 0.75 in the mask, more exposure is required with a mask than without a mask to get a density of 1.5 at Zone VII in the separation. At the same time the mask is adding 0.3 to the chrome at Zone III; relatively Zone III is getting more exposure than Zone VII. This increase in density at Zone III in the separation progressively decreases up the curve to Zone VII. These increases reduce the exposure proportionally when the separation is projected onto the matrix film. With less exposure in the matrix, there is less relief which becomes less dye in the print.

To get balanced separations, make a chrome tablet. Expose the principal masks for a density of 0.3 at Zone III and develop them for a density of 0.75 at Zone VII. Using these with the chrome, expose three separations for a Zone III density of 0.4 and develop them for a Zone VII density of 1.5. Make matrix from them and roll a print. Now you have it: from here on it's all adjustments to express your personal preference.

Suggested Reading

Hunt, R.W.G., THE REPRODUCTION OF COLOUR, 2nd edition, 1967,
        John Wiley & Sons. New York

Yule, John A.C., THE PRINCIPLES OF COLOR REPRODUCTION, John
        Wiley & Sons, New York, 1967

Spencer, D.A., COLOUR PHOTOGRAPHY IN PRACTICE (revised by Mannheim)
        Amphoto, New York - 1966
        Section III

Ryan, Roderick T., PRINCIPLES OF COLOR SENSITOMETRY, 3rd Edition
        Society of Motion Picture & Television Engineers, Scarsdale,
        New York - 1974

Chapter 4.   EXPOSING CONTACT MASKS & SEPARATIONS

It is possible to make contact separations from 120 and 35mm chrome by making a cut-out in a sheet of 4x5 Kodalith and taping the chrome along one side in the hole. The scotch tape should be on the support side of the chrome and the Kodalith. If you can read the literature, right way to, along the edge of 120 and 35mm film, then you know the emulsion is facing away from you. By taping on the support side there is nothing to interfere with the contact between the emulsion of the chrome and the emulsion of the separation film. The Kodalith, or any other thin film, should be exposed and developed to a more or less uniform density of 1.0 which will shield the borders around the chrome when the separation is exposed and developed, otherwise the potential of the developer will be expended doing nothing important. 120 chrome is 0.005 inches thick and 35mm chrome is 0.006 inches thick. Masking and separation film are 0.008 inches thick; if they were used for the cab, the printing frame would not push the chrome into contact with the separation film.

Equipment to Expose Contact Masks & Separations

       4x5 Film Punch
       4x5 Registration Printing Frame
       Light Source with a timer and a voltage regulator
       3" Gelatin Filters in frames
            Neutral Density — 0.6 and 0.9
            Separation — #29 (red), #61 (Green), & #47B (blue)
       Scissors
       Dry Offset Powder
       Palette knife for jumping the film off the pins
       Empty box for exposed film

Materials

       4x5 Pan Masking Film (4570) - EK# 153 4304

       4x5 Separation Negative Film, Type 1 (4131) - EK# 153 9485

Light Sources for Exposing Contact Masks & Separations

     Any condenser enlarger can be used for contact work. The
Q-80 Light Source described in EK pamphlet Q-80, "Contact Printing
Lamp for Photomechanical Work" has the advantage that it can be
used for many things; there is plenty of light and the cone, when
it hits a flat surface, is very uniform. It uses Kodak gelatin
filters and the lamp housing does not get so hot that the gels
krinkle. Once you've got it, you'll be glad, but not until then
because the making of it is a botheration.

     The Q-80 uses a GE 100T8/1SC-20V projection bulb which is
generally available from jobbers who are GE distributors. The
bulb is mounted in an EK safelight housing (EK# 152 1178) with a
$2\frac{1}{2}$" medium base to single contact, bayonet adaptor #455 made by

              Frank W. Morse Co.
              PO Box 94
              Saco, Maine 04072

The cord for the safelight should be changed to a Hubbel Midgit
Twist Lock cap (the end with the prongs) so there is no way that
the bulb (20 volts) can be burned out immediately with 110 volts.
The twist lock cap in turn fits a Twist lock body on the output
side of a 100 watt signal transformer at the 16 volt tap. The
input side of the transformer is connected to a timer which is
separated from the line with a Sola Basic harmonic voltage regulator
(CVN - Cat# 20-14-112) with a switch. The regulator needs a
short warm up period, 10 to 20 seconds; after this the output will
be 120 volts even if the line voltage is as low as 95 volts or as
high as 130 volts. It will make the correction automatically in
3 cycles, or about a twentieth of a second. By maintaining a
constant voltage across the filament in the bulb, then the number
of photons emitted by the filament and their spectral arrangement
remains constant.

     K & M Manufacturing Co makes this up and call it a Tri-Level
Point Source Light Unit.

General Procedures for Exposing Masks

1. Make sure you have the materials and equipment on the list.

2. Familiarize yourself with the punch and the printing frame.

3. If there is any dust on the counter, remove it with a damp sponge then wipe the counter dry with a paper towel

4. Dust the flat side of the punch

5. With windex and a photo-wipe, clean the finger prints off the glass in the printing frame, then check it for lint. Continue until the glass is truly clean.

6. If your chrome is dirty, clean it with EK Film Cleaner on a cotton ball and remove all dust with Omit and a sable brush.

7. Punch your chrome EMULSION DOWN with the holes for the pins on the end away from the notch code.

8. When making masks the chrome goes on the pins with the emulsion facing the glass (toward the light).

Registration Pins in the Dark

As soon as you get into the exposing room, take a sheet of practice film and experiment with the punch. Think about which way you want the emulsion to face and find the notch code. Make your choice then slide the film into the blocks on the punch and line it up on the guide. Don't let go of the film: in the dark, the edge is very hard to find and finger prints leave an image because the developer is repelled by the oil.

The film must be punched on the short side which does not have the notch code: in the carrier for the enlarger there are no pins on the long side. When you punch the film, you will feel the resistance in your fingers and the release — this tells you there are holes in the film. Turn off the lights when you punch the practice film; if you can see the punch, look for the light leak and tape it.

Don't put the pixax film on the pins in the frame with the lights on because, instinctively, you'll start thinking you must see it to do it. In the dark your fingers will, if you give them

the opportunity, know where everything is. The holes in the film
are three-eighth's of an inch in from the edge of the film. With
the finger of your choice, find the pin in the glass. You are
holding the edge of the film, so you know where the hole is. Very
gently let the hole find the pin which has your finger on it.
This is a very tight fit; once the film is on, press it down with
your thumb nail. Using this pin as a pivot, rotate the film till
the edge hits the other pin and it will pop on. Press it down with
your thumb nail.

Notch Codes

With all sheet film, if the notch code is in the lower
right hand corner, then the emulsion is facing you. In the dark,
hold the film between your thumb and middle finger with your
right hand, short side pointed up. When you can feel the notch
code with your right index finger, you'll know the emulsion is
facing towards you.

ALWAYS KNOW WHERE THE NOTCH CODE IS

Identification of Exposed Film

To identify masks and separations (red, green, and blue)
it is necessary to establish a code. Any code is acceptable, so
long as it never changes and you always do it. There is no way
to make a positive identification of color in a silver image
once the sheets of film have been scrambled: it's throw them out
and start over. One way to code is with a pair of scissors:

Any sheet exposed in RED light has all four corners.

GREEN — Clip the notch code corner

BLUE — Clip the two corners on the notch code end. Find
the notch code and clip that end, then there'll be no way to
remove the holes for the registration pins.

Newton's Rings

These are concentric bands of colored light which sometimes form around areas where two, smooth and transparent surfaces are slightly out of contact. These rings are an interference pattern that happens when the separation between the surfaces is of the same order as the wavelength of light. The image they form is irregular with alternate light and dark bands. They happen in humid weather and also, for no apparent reason, at other times when you least expect them. They only form between two smooth surfaces, glass and the film support or two pieces of film, back to back.

The emulsion on the film is sufficiently irregular to ~~prevent the~~ prevent the formation of these pests, which makes for no problem with masks. With separations it is another matter because the support side of the mask is against the glass in the printing frame. Newton's rings are fought with dry offset powder, which is used in lithography and can be bought in a graphic arts supply house. The dry offset powder is put in a small plastic nose drop bottle from which the inside tube has been removed. The inside cap with the little hole for a nozzle just pulls out of the bottle. Fill the bottle ¼ full with offset powder and replace the cap with the small hole. To use, shake the bottle sideways with some vigor, then, holding it almost vertical, give it a squeeze. A small poof will come out the hole. Do this over the printing frame and the dust will settle on the glass. You won't see it, but it is there. If you do see it, clean the glass and do it again. If you see the little cloud and it is above the printing frame, then gravity will do the work.

Exposing Principal Masks

You will be making two principal masks. One is exposed
in red light with the #29 red filter and the other is exposed
in green light with the #61 green filter. The distance between
the Q-80 Light Source and the printing frame is like 3½ to 4 feet,
but it isn't particularly critical. Now and then you'll hear
people make a long and important harrange about ten feet using
mirrors, but this is for the graphic arts when the film measures
20x24. The printing frame should be directly under the light,
no offset. The intensity of the light is reduced with the 0.6
Neutral Density filter. It and the separation filter, in their
frames, fit in the bracket on the baffle of the Q-80. Do not
change the voltage. The bulb is rated for 20 volts; at 16 volts
they burn for ever with no blackening. At 12 volts there is a
real shortage of blue light because it is the first to go as the
temperature drops.

Separation Filter	Neutral Density	Duration (Seconds)	Developing Time (DK-50 1:2) *
#29 (red)	0.6	25"	3'
** #61 (green)	0.6	25"	3'30"

    * The same developer is used for both sheets
  ** Clip the corner next to the notch code, after the film
      has been exposed

Procedures for Exposing Contact Masks & Separations

1. For masks the chrome is punched EMULSION DOWN and goes on
    the pins with the emulsion towards the glass (facing the light).

2. Put the neutral density and the separation filters in the
    bracket on the Q-80 Light Source.

3. Set the timer.

4. Turn on the power supply, then turn on the light with the
    timer and figure where the center of the cone is. This is
    where you put the printing frame. When you're satisfied,
    turn the light off.

5. Where are the scissors? If it is a green mask, you will need
    them to clip the corner by the notch code.

6. Where is the box for the exposed sheet of film?

7. Double check everything and review, step by step, what you're
    going to do. Turn on the power supply and turn off the room
    light. Check the door for a light leak; if there is one,
    tape it. If you can't see it in the first minute, don't worry
    about it because there isn't enough light getting through to
    fog the film.

8. Punch the unexposed masking film EMULSION DOWN and put it
    on the registration pins EMULSION DOWN. There is no smooth
    surface contact, so there should not be a problem with Newton's
    rings if you have pushed the film onto the pins with your
    thumb nail.

9. Is the film box closed?

10. Make the exposure

11. Open the printing frame and with your thumb nail against one
    of the pins, lift the film off and handle it by the edge.

12. If it is green, clip the corner and put it in the box for
    processing.

13. Before you turn on the room light, review what you've done. If
    you have any doubts, throw the film out and make a new exposure.
    RAW FILM IS CHEAP

Procedures for Exposing Contact Separations

The RED SEPARATION is made with the red principal mask.
The principal mask goes on the pins first with the emulsion facing
away from the glass. If the air is very damp use the offset powder.
See page 56. The chrome is next on the pins and its emulsion also
faces away from the glass. The back of the chrome is against the
emulsion of the principal mask. The separation film to be exposed
is punched EMULSION UP and goes on the pins EMULSION DOWN, facing
towards the glass — emulsion to emulsion with the chrome.

The separation film is punched emulsion up because the
chrome was punched emulsion down: the pin placement in the punch
and the guide bar are slightly off axis. If all the film were
punched facing the same way, then the edges would not be in
alignment.

The GREEN SEPARATION is made with the red principal mask,
so there is nothing to change other than the filters and the timer.
Check the chrome for dust.

The BLUE SEPARATION is made with the green principal mask. The
order and placement are the same as for the red separation. The
emulsion of the mask and the chrome face away from the light.
When changing the masks, redust the glass with offset powder.

Separation Filter	Neutral Density	Duration (Seconds)	Developing Time (DK-50 1:1) *
#29 (Red)	0.6	10"	3' 30"
** #61 (Green)	0.9	9"	4' 30"
*** #47B (Blue)	0.6	14"	4' 50"

* Fresh developer with each sheet

** Clip the corner next to the notch code

*** Clip both corners on the short side away from
the holes for the registration pins

Chapter 5. ENLARGED SEPARATIONS

There is no easy way to make enlarged separations from 35mm chrome. They can also be made from 120 chrome (2¼ square) but for anything smaller than a 16x20 print they aren't necessary. Contact separations in a 4x5 Kodalith cab with a cut-out (see page 52) for the chrome are perfectly adequate and don't involve the aggravation of castor oil. A 2¼ square chrome will fit in the glass inserts made by Condit, but getting uniform illumination from the available equipment that will cover a 2¼ chrome is very difficult.

The system for enlarged separations from 35mm chrome has evolved because the advertising crowd on New York's Madison Avenue demanded 16x20 prints from poor to mediocre chrome. In the beginning there was no black and white film with an extremely fine grain structure which would enlarge like 20 diameters. The only way to get around this was project the image and start with a separation on 8x10 film. The immediate problem was how to get the chrome flat and then to keep it in the same place. If the chrome moved, then the separations were out of register. Taped in a glass carrier with everything locked solved the registration but there were refraction problems with the layer of air between the glass and the chrome. Castor oil, as a medium for immersing the chrome, has the advantage that the refractive indices are very close to perfect; also gelatin is totally impervious to it. It has no effect whatsoever on gelatin, but there is one big disadvantage — it is a real chore to clean it off the glass inserts. From time to time freon is used, but it evaporates so rapidly that a pumping system is necessary to maintain a film of freon between the chrome and the glass.

The equipment for enlarged separations is very expensive. Unless one is making 16x20 prints, it is hard to justify the cost; unfortunately people don't realize this until afterwards and by that time they not only own the equipment but they have also

invested an inordinate amount of energy trying to make it work
well. The argument for 8x10 separations is quite compelling.
The chrome, if the separation measures 8 inches on the long side,
has been enlarged 5½ times. The one inch border on the separation
leaves plenty of room for finger prints. An 11x14 print from
an enlarged 8x10 separation (8" x 5¼" actual) has been magnified
less than two times; therefore the grain in the separation material
is invisible. There is a lovely smoothness in an 11x14 printed
this way, but it requires an 8x10 enlarger. This smoothness has
nothing to do with the oil, the modified point light source for
the separations, or the carrier; it is achieved with a big separation
and is strictly a function of size.

Some 35mm chromes make visually more effective 16x20 prints
than others, even when printed from the same kind of chrome. If
the spacial arrangement of the photograph itself has to do with the
relationship between textures and texture gradiants then, from
35mm chrome, the print will not suffer for being enlarged to 16x20
because the small detail is visually unimportant. When this same
photograph is articulated around a pine tree, then the texture
gradiants become secondary and the detail in the tree is important.
Every pine needle in a 16x20 print is enlarged at least 13 times.

The chrome measures 1.45 inches on the long side, 0.95 inches
on the short side. It is very difficult, with matrix measuring
16½ x 21¼ to get a print larger than 19 inches on the long side:
full 16x20 prints are always made on 20x24 matrix, just for borders
so these monsters can be handled. If a density edge in the 35mm
chrome occupies one-four hundredth of an inch (0.0025") then,
when magnified 13 times, the same edge will be spread across a
thirtieth of an inch in the print. If this edge in the print
chrome has density differences in it then, in the print, it will
break up completely. At a viewing distance of four feet, this
pine needle will be seen as a general diffusion. At 20 diameters
the grain in the chrome begins to print as grain and further
destroys the edge because it is now a twentieth of an inch wide.

Suppose the separation was made contact onto Plus-X and
enlarged 13 diameters. This will generate interimage effects
between the grain of the chrome and the grain in Plus-X because
they are both about the same size. Up to 11x14 these effects

are not particularly noticeable, but at 16x20 they are serious.
As a compromise, mostly for the benefit of the pocketbook, it is
possible to make enlarged separations onto either 4x5 or 5x7 film,
depending upon what one wants or is willing to spend for an
enlarger. With 4x5 separations the chrome is enlarged 3 times and
with 5x7, 4½ times. To make 11x14 prints from 4x5 separations it
requires a magnification of 3 diameters from the separation and
with 5x7, 2¼ diameters. With 5x7 separations it is possible to
go to 16x20 in 3 diameters. 4x5 separations require 4 diameters.
This is about the limit for Separation Negative Film, Type 1. It
has a grain and the optical qualities of the enlarging lens begin
to be felt.

There is no easy answer, nor is there any one way which is
better than all others to make a dye from 35mm chrome. Any system
is a compromise and like all compromises each has advantages and
disadvantages. It is best to remember, as a starting point for
the compromise, that 35mm dye printing is pushing the procedures
and techniques to their absolute limit. There is no room or margin
for sloppiness.

Equipment

A 4x5 Omega D series enlarger with the following modifications:
Microfilm Lamphouse Type DM (Cat# 407-814). This has a 20 volt,
base up, BEV bulb on a movable support which can not only be turned
but also raised and lowered to adjust bulb position for even
illumination on the easel. The glass envelope of the bulb is clear
and must be lightly sandblasted to break up the light and prevent
the filament itself from forming an image at the plane of focus.
In most metropolitan areas there will be a small company doing
small area sandblasting; the bulb must be roughed up over a circular
area of an inch on the axis of the lens.

A voltage regulator (Sola, General Radio, GE) rated for at
least 200 volt-amperes to stabilize the line voltage at 118 volts.

A timer, then a separate transformer to reduce the regulated
voltage from 118 volts to 20 volts for the bulb. The 20 volts
should, in turn, be controlled with a variable transformer to
adjust the intensity of the illumination on the easel. If the
BEV bulb is run at 18 volts, its life is almost indefinite without

any blackening. Condit Mfg Co., Inc. puts this all together in
a control unit which also has a selenium probe to measure the
intensity of the illumination in ~~the~~ micro-amperes.

A Variable Condenser Housing which supports the Modified
Point Light Source. A piece of glass is placed at the bottom of
the housing, just above the condensers. It measures 6" x 6½";
this can be, but doesn't need to be, heat absorbing glass. It
serves to keep dust off the top condenser and, more important,
it is a platform for a black paper baffle with a rectangular
cut-out which restricts the illumination to an area sufficient,
and then some but not a lot, to cover a 35mm chrome. This
eliminates the flare generated by the condensers.

6 Filter Holders which will slide on the supports for the
variable condenser in the housing. Condit makes these with clips
which will accept gelatin filter frames. He recommends glass
covers for the gelatin filters, but they cause the filters to
wrinkle.

105mm condensers, Omega # 472-034

4x5 Condit Registration Carrier with pins for glass inserts.

At least 4 glass inserts with cover glass. They scratch
very easily because the glass is on the bottom, cemented to an
aluminum frame which has been drilled for the pins in the carrier.
The glass can be replaced.

A rack with side supports to hold these glass carriers so
the glass never touches anything.

A 105mm enlarging lens, Componon or Rodagon. With a 105mm
lens for 35mm chrome only the center of the lens is being used
which limits the effect of any chromatic aberration which the lens
might have.

2 Telescoping Braces (Condit) to make the enlarger rigid.
One goes from the top of the enlarger rails to the back wall and
the second from the side of the base for the registration carrier
to another wall which is at a 90° angle to the back wall. Done
this way, two braces with a 90° angle between them, there is no
way that enlarger can wiggle so long as the enlarger is bolted to
the counter, the tracks for the easel are screwed to the counter,
the easel is fastened to the tracks and the counter is held with
lag screws to the studs in the two walls where the telescoping

braces are fastened. With this, vibrations of any form don't matter because the enlarger and the easel will shake in unison. The image of the chrome will not move relative to the chrome.

4x5 Condit film punch and vacuum easel with matching pins and two rectangular channels with valves, one for 4x5 sheet film. The second channel is oversized for a thin mylar sheet which will hold the mask in contact with the separation film during exposure: the masking film and the separation film are the same size, so there is nothing holding the two sheets together. Another solution to the problem of holding the mask and separation together in register is with an easel that has been milled for 4x5 and 5x7 film with the pins set for the 4x5 film. The rectangular channel for the 4x5 film is inside the 5x7 channel for the mask. The pan masking film is punched with a 4x5 deep throat punch so the registration pins are one inch in from the edge. This way the XXXXXXXX separation film is held flat by the 4x5 channel and the 5x7 channel pulls the mask into contact without the need for a sheet of mylar in the image path. It is also possible to have an easel with two sets of pins, 4x5 and 5x7. This saves the cost of a deep throat punch but the 4x5 pins on the easel must retract. I personally prefer this last solution because the easel can be used for other things. With the mylar there will be no air space between the mylar and the principal mask, so there isn't a refraction problem, but the mylar does like static electricity which causes a dust problem and it scratches.

Preparing Chrome for Enlarged Separations

Materials

       Castor oil - available in 2 oz bottles at the drug store.

       EK Film Cleaner (Heptane)

       Palmolive Liquid Detergent or its equivalent

       Windex

       EK Lens Cleaner - this comes in 16 oz bottles which can be transferred to the small squeeze bottles by pulling the nipple out of the small bottle (it's a jam fit) then filling it and replacing the nipple.

       Cotton balls

       Photo-wipes - or any non-linting tissue so long as there are no silicones in it. Silicones are often used in tissues for eye glasses

       Scotch Tape - 3/4 inch.

       Small exacto knife with a stub blade and a pair of tweezers.

       2 pieces of ¼" plate glass with ground edges, 6x8 inches.

       Sable Brush - not an EK camel hair brush with cut bristles; if there is a stiff one in there, it will scratch the chrome.

Setting the chrome in Oil

Wash the insert and the cover glass with hot water and kitchen detergent (palmolive, liquid ivory). If the glass is streaked with residual oil, use another cotton ball soaked with film cleaner then rewash with hot water and detergent. The cover glass is seldom a big problem, but the oil has a way of lingering in the corners of a Condit insert and then appearing after you're sure and certain that it's clean. Be extremely careful with the cotton and where you put it because one piece of grit is all that's needed to scratch the glass. The final wash of the insert and cover glass is with EK lens cleaner and a small piece of photo-wipe.

Put the bottle of castor oil in a waterbath that starts with a temperature about 80° F. In twenty minutes or so this will stabilize between 70° and 75°. It wants to be warm enough to

flow but not pour, nor so cold that it is slow. Always handle
the bottle of castor oil gently, otherwise you may shake a bubble
into it. With a damp sponge clean up the dust where you intend to
work. Someplace else clean off the front of your shirt or sweater
with a clothesbrush. Clean the pieces of plate glass with windex
and paper towels. Hold the sable brush up to the light and snap
the bristles with your finger until the dust stops rising out of
them. Any dust that gets into the oil will be magnified many
times and appear in the print.

Remove the chrome from the cardboard mount by cutting off
all four sides with a pair of scissors. When cutting the mount
be sure you don't cut the perforations. With an exacto knife
separate the front of the mount from the back. One edge of the
chrome will be fastened to the cardboard mount with adhesive. Use
the exacto knife to break this bond. Some of the cardboard fibers
will be stuck to the chrome and they should be scraped off, but
don't worry about getting them all because the chrome will be
floating in a layer of oil that is thicker than this last little
bit of adhesive and cardboard.

Have a hook nearby where you can hang the cardboard chrome
with a paper clip that has been bent so one end will go over the
hook and the other end through one of the perforations in the
chrome. Clean the dust off the chrome with the sable brush then
put the chrome on the piece of plate glass. Clean both sides of
the chrome with EK film cleaner on a cotton ball till, with the
chrome at an oblique angle to the light, you see only the
irridescence of the emulsion or the smooth shine of the back.
Hang the chrome on the hook.

Set the steel mask on the bottom of the carrier so it is
centered on the axis of the lens: it is held with magnetized tape.
Give the insert and cover glass another inspection for dust and
oil streaks. If you are satisfied that it is clean, put it in
the carrier and arrange the light box underneath it so you can
look straight down at the opening. Have the scotch tape nearby and
give the chrome a final check.

Get the castor oil and be sure the bottle is dry, no water
on it or your fingers. Clean the lip of the bottle with a photo-
wipe and, if it needs it, a little film cleaner. You'll need a

photo-wipe when the oil is poured to clean up the oil which dribbles down the side of the bottle.

Put the chrome on the glass, EMULSION SIDE UP, and reversed top to bottom. This is especially important if you are working with several chromes at the same time and changing them in the enlarger. It is very easy to get the insert onto the pins back-way-to. If the chrome is always taped the same way and the tape always faces the same way in the carrier, then the chrome should always face the same way. Using the light box, align the chrome in the opening so you can see the same amount of perforation top and bottom then, with a piece of scotch tape that is a half inch longer than the chrome, two inches, fasten the chrome to the glass so the tape only covers about half of the perforations.

Hold the chrome with one hand so it is almost perpendicular to the glass and give it one last check for dust. Also check the glass: if there is any, brush it to the side and out of the way. Holding the chrome with one hand, take the bottle of castor oil with the other and pour slowly but steadily from the wide side of the bottle, making a puddle underneath the chrome which is a bit smaller than a quarter but larger than a nickle —— better too much than too little. Lower the chrome, letting it settle into the oil which will slowly spread into the perforations and towards the free corners. The air is moving in front of it. If this is sped up, the air is likely to get trapped, forming a bubble. Check the cover glass for dust then wait till the oil has spread into the perforations — don't rush.

Pour an equal amount of oil on the top of the chrome then set the cover glass at an angle with one end against the back side of the insert. Lower it slowly until it just makes contact with the oil. As the oil spreads out, lower the glass very slowly. When your finger gets to the frame of the insert, support the lower edge of the cover glass with the blade of the exacto knife and continue lowering the glass slowly till it is supported by the layer of oil. Better too slow than too fast.

With a magnifier look for the bubbles. Very often, if they are big bubbles, they can be squeezed out by pressing down on the cover glass. Medium sized bubbles often work themselves out over a period of a few hours as the oil thickness stabilizes. If there are

a lot of little, itty-bitty bubbles, then you didn't use enough oil or worked too fast. Return to start without passing go: the chrome must be removed, everything cleaned up and done again.

Removing Chrome from Condit Oil Inserts

Using the blade of the exacto knife as a pry-bar, lift the cover glass not only slowly but also gently till you've broken the oil bond between the glass and the chrome.

Soak a cotton ball in film cleaner and swab up the oil on the cover glass, then clean up the rest of it with another saturated cotton ball. Put the cover glass to one side by propping it up with one end on a support so the face of the glass never touches anything.

Now it gets really messy.

With more cotton balls and film cleaner slop up the oil in the insert until it is more or less clean. Use the exacto knife to lift the corner of the scotch tape. Lift it far enough off the glass so you can either catch it with your finger nails or the tweezers. Thanks to the oil, the chrome is really slippery — work very carefully as you lift the tape. When the tape is mostly off, hook the bent paper clip in one of the perforations. By using both the clip and your fingers to hold the tape, you won't touch the image area of the chrome as you peel the last of the tape from the chrome and the glass. When it is loose, hang the chrome on the hook.

Slop up the rest of the oil in the insert with film cleaner, then wash it and the cover glass with detergent. To clean the chrome, put it on a piece of plate glass and go over it with cotton balls and film cleaner until there are no streaks. This doesn't take long, then let it hang for a few hours before remounting it in cardboard.

Sometimes the inserts get what appears to be watermarks and they almost look like Newton's rings, but they don't usually have color. It is something either in the glass or some of the cement used to hold the glass to the aluminum frame. It can be polished off with cerium oxide and a wet finger.

Adjusting the Point Light Source

In the filter box (Variable Condenser Housing) make certain that the piece of protecting glass at the bottom is clean. Set the vacuum easel with a 4x5 focusing paper directly underneath the lens. Turn on the light and with the variable transformer in the control box bring it to 70% of its rated voltage. This is enough to see by, but the bulb isn't wearing itself out or getting too hot. Set the paper baffle with the rectangular cut out on the protecting glass and adjust it so the center of illumination is on the center of the easel. Slide the carrier with your glass insert and chrome into the base and lock it. Adjust the magnification and focus until the image measures about $4\frac{1}{2}$ inches on the long side, allowing space for the pins. Remove the insert from the carrier and put it in the rack. Never put the insert down on the counter because the glass will scratch and the scratch will print.

Replace the carrier in the base, lock it and turn on the light. Set the lens aperture wide open and look for a yellowing of the light in the corners on the focusing paper. There is nothing uniform about the illumination of a BEV bulb because the glass envelope has irregularities in it. Loosen the set screw which holds the adjusting rod for the bulb to the top of the lamp house. As you twist the rod, the yellowing in the corners will change. It may even turn bluish after going through white. What you are seeing is the chromatic aberration of the condensers relative to the filament in the bulb. If the bulb is too high, further away from the top of the condensers, the corners will be yellowish. If the bulb is too close to the condensers, the corners will be bluish. If one corner is yellow and the opposite corner blue, make certain that the can for the condensers is sitting flush on the top of the carrier base. There is a point where the whole focusing paper will be white, but only if you are using a bulb that has been sandblasted.

With the selenium probe on the control box, measure the illumination at all four corners, the middle of each edge, and in the center. Suppose, after you have adjusted and adjusted it without yellowing the corners, the low reading is 250 micro-amperes in one corner and the high reading is 270 micro-amperes in the center. Is this serious? A full stop difference at 250 micro-amperes

would be the addition of 250 micro-amperes, so 25 is a tenth of
a stop, approximately. If this worries you, take a sheet of
paper used for B/W prints from color negatives and expose it for
a density of 0.8 (the gray card). It should be visually uniform;
if it isn't, the BEV bulb hasn't been sufficiently sandblasted.
A tenth of a stop is a very small difference, especially when the fall
off is gradual. For amusement, stop down the aperture and watch
what happens. It's a wonder the thing works at all.

Preparations

1. Be sure there is no dust on the bottom glass of the insert or
    on the top of the cover glass. Sometimes the oil will work up
at the corners where the cover glass is in contact with the metal
edge of the insert. Remove this oil very carefully with a cotton
swab and film cleaner. If there is dust on the cover glass, remove
it with Omit — not the brush. It is very easy to get oil in the
brush and then track it all over everything. If you do, clean the
brush with film cleaner.

2. When putting the registration carrier into the base (the box
    which is between the bellows and the light source) push the
carrier all the way in until you feel it pressing against the back
lock: it is spring loaded. Turn the locking knob until it seats,
then let the back spring push the carrier into it. This way you
are certain that the front lock is seated. If you push the carrier
in part way, then twist the locking knob, letting it force the
carrier into the locks, there is a chance that the front lock will
not be fully seated and you will have a small shift in registration.

3. Loosen the thumb screw on the telescoping rod attached to the
    base for the carrier.

4. With the focusing paper on the easel, turn on the light source
    and bring the image to 4½ inches, leaving room for the pins.
Check the focus and also all four sides of the image to be certain
that the metal mask on the carrier is not cutting into the image.

5. Tighten the telescoping rod.

6. Double check the focus and the location of the image on the
    focusing paper. When you're set, tighten the clamps which
hold the easel to the tracks. This is it; nothing can be changed
until the separations are finished. If you diddle with anything,
other than the carrier and the filters, the separations will be
out of register.

7. Review pages 54-59

Procedures for Exposing Enlarged Masks & Separations

1. Is everything ready?

2. Put the neutral density and the separation filter in the
    middle position of the filter box: one is up and the other
    down. Order is unimportant. Never leave them in when you
    are checking focus because the bulb gets very hot and the
    filters will cook.

3. Set the timer and put the scissors where you'll be able to
    find them in the dark. Clean the dust off the film punch
    and get the empty box for exposed film.

4. Double check everything. Is the carrier locked? Is the
    telescoping brace tight? Are the easel clamps tight? Step
    by step, review what you're going to do. Turn on the voltage
    regulator, if there is one, and turn off the room light. Check
    the door for a light leak; if there is one, tape it.

5. Punch the unexposed masking film EMULSION UP, and put it on the
    pins, EMULSION UP. Turn on the vacuum pump and wait a moment
    for the film to pull down. Be sure the mylar sheet is out of
    the image path. Notch code in the lower right hand corner.

    For separations, punch the separation film EMULSION UP and put
    it on the pins EMULSION UP. Get the principal mask, red for
    red and green, green for blue, and put it on the pins the same
    way it was exposed — notch code in the lower right hand corner.
    Start the vacuum pump and push the valve for the 4x5 channel.
    Wait and listen for a leak - it will hiss. When you are
    satisfied that it is sealed, cover the film with the mylar sheet
    and open its valve. Hold the far edge and let the vacuum take
    it out of your fingers. This way there won't be any wrinkles.

6. Is the film box closed?

7. Make your exposure

8. If required, clip the corners and put it in the box for processing.

9. Before you turn on the room light, review what you've done.
    Are you satisfied?

Procedures for Exposing Enlarged Principal Masks & Separations

The following numbers work with my light source, a sand
blasted BEV bulb, and 105mm Componon lens. This is no assurance
that they will be correct in another set up, though they should
be a good starting place.

	Separation Filter	Neutral Density	Duration (Seconds)	Developing Time
Masks				(DK-50 1:2) *
	#29 (Red)	0.9	7"	3'
	#61 (Green)	0.9	7"	3' 40"
Separations				(DK-50 1:1) **
	#29 (Red)	0.9	14"	3' 15"
	#61 (Green)	1.2	11"	4' 15"
	#47B (Blue)	0.9	14"	4' 30"

Continuous agitation

* Use the same developer for both sheets

** Fresh developer for each sheet

K-14 Kodachrome

K-14 is the Kodak process number for Kodachrome 25 & 64.
(See page 36.) With this film, which was made and processed
prior to 1977, you will have problems. Kodak has published
Data Release sheetE-80d which describes their solution, the use
of a #24 (red) separation filter rather than a #29 (red) and
combining the green (rather than the red) principal mask with the
chrome when the red separation is exposed. This, in effect,
removes cyan dye in the print where-ever there is magenta. It
is my opinion that the #24 filter is unnecessary, but that the
masks should be switched — green principal with the red separation,
red principal with the green separation, and green principal with
the blue separation. From here on the corrections to get neutrality
must be made for each individual print by changing the contrast
in the matrix developer and, if this is not enough, the contrast
in the dyes.

Chapter 6.   FILM PROCESSING

The characteristic curves in a set of separations will never
match when the individual separations have been developed at
different temperatures.   Eventhough there is seldom a true gray
in a print, this neutrality, which the various shades of gray
represent, is the control for the whole process. If the density
in these grays is the same in each separation then, when the
matrices are exposed and developed, each matrix will have an
equal relief for these grays and, as a consequence equal amounts
of dye will be transferred to the receiving sheet. In any print,
any given point will almost always have a percentage of all three
dyes. If a set of separations is capable of making gray, then we
know that the ratio of cyan, magenta, and yellow dye at any point
will be in the same ratio that red, green, and blue have in the
chrome.

If the three characteristic curves for the individual
separations in a set are out of phase, each with a different gamma
between Zones III and VII, then the color ratios in the print
will never equal the color ratios in the chrome, except possibly
in one place, if the three characteristic curves happen to
intersect at one point, which is very unlikely.

If the separations are developed at different temperatures
then, to get the color into a reasonable balance in the upper
mid-tones, you will be forced to make a big compromise in the
balance for the lower mid-tones. If the three separations are
out in both directions, one with too much contrast, the second
with too little and the blue someplace in the middle, you might
in the print get a cyan shift in the upper mid-tones and a magenta
shift in the lower mid-tones.

To a certain extent this can be corrected during the development
of the matrices by changing the alkalinity of the developer, but
if you can't hold the temperature constant when developing
separations, then there is no good reason to assume that the

temperature for the matrix developer will be constant. Suppose there is not enough contrast in the green separation and you increase the alkalinity of the matrix developer for the magenta matrix, which will increase the contrast. Now there is a temperature drop in the developer and the matrix loses more contrast than you put in with the extra alkali. The color shift will be even worse and there's no way from the finished to print to know why.

The next temptation, rather than remake the separations, is to increase the acidity of the magenta dye. By adding 10 ml's, maybe 20, of 25% acetic acid to the dye bath, the gelatin will take up more dye, especially in the shadow densities, when the matrix is soaked. This is, effectively, an increase in contrast. However, are you really sure what the acidity of the dye was when you started. Maybe it was already saturated and the added acid will have no effect. You either have separate bottles for low, medium low, normal, medium high, and high contrast dyes, or start with fresh dye for each print, which gets expensive. With fifteen bottles of dye, rather than three, it is just that much easier to get confused and have the wrong dye in the wrong bottle. Also, your record keeping must be accurate because, at a later date, you may want to roll additional prints from these matrices and you'll need to know what you used for dyes. All of a sudden the problem is compounded and totally out of control ... you will get very frustrated, then irritable, and when you see the print you will not only be extremely angry but also totally out of control.

The Variables of Development

The amount of development that happens in an emulsion is a direct function of developing time, developer freshness and quantity, along with agitation and temperature. All are equally important and each must be controlled so that time is the only variable. If this isn't done, an effective print is the result of fortuitous good luck rather than a system which makes many good prints a real possibility.

Freshness & Quantity are easy, just mix it up with clean water then measure it and never reuse it. For masks the same developer can be reused for the second mask because they are

developed to a very low gamma which does not exhaust the developer.
With separations it is another matter.

The quality of the water you use to make the developer must
be consistent. Water Departments have a habit of dumping anything
necessary into their systems which will get the quality up to the
minimum standards set by the state, usually chlorine and caustic
soda. Neither of these improve the reduction potential of a
developer. What is worse, you never know how much they've added.

If you live in the mountains then wound cotton filters with
a mesh that will catch 5 microns are sufficient to remove the small
stuff like minerals and organic matter, mostly the algae that makes
summertime hot water smell so sweet. If your tap water comes from
sources like the Hudson river or the Ohio river, where there is no
way of knowing what has been dumped into it, or has passed through
wooden pipes, like New York City and Boston, then the crap is in
solution. Use distilled water which can be bought through any
drugstore.

Filtered water of any kind (within very wide limits) is fine
for the Stop, Fix, and Permawash, but the chemistry of developers
is quite precise and extraneous substances will change it. When
the developer ceases to be a constant, the trouble has started. When
four or five things are all changing at the same time, then it's
impossible to say which is doing what in the finished print.

Agitation is, in many ways, the most difficult to control.
Too much is worse than not enough: the solution gets to moving so
rapidly that there is no time for the fresh developer to get into
the emulsion and replace the exhausted developer along with its
oxidation products. Experiment with a sheet of practice film
and 200 ml's of water in a 5x7 tray. You will see the waves moving
across the film and colliding: this collision keeps the solution
uniform — used and fresh are being mixed at the contact point. If
the solution is too deep, then the wave action (which is circular
within the wave front) does not reach to the surface of the film.
If there isn't enough solution in the tray, then the developer is
exhausted before the time is up. Use a 5x7 tray for 4x5 film
because the sides on a 4x5 tray are not high enough, when the
agitation and quantity are adequate, to keep the solution from
slopping out.

When you are putting the film into the developer, hold the film with dry fingers by the edge in the middle of the long side. With the other hand lift the back of the tray, which will bring all the developer to the front. Slide the bottom edge of the film, EMULSION UP, into this pool. As you release (drop — don't push) the film, tip the tray in the opposite direction. The wave of developer will move in a straight line across the film. Immediately rock the tray from either side, which will ensure that the corners of the film are covered with developer. Also, you will hear the film click against the sides of the tray. If you don't hear the click, then fish around for a corner of the film and make certain that it hasn't gotten stuck to the bottom of the tray. On a 10 second cycle, or as short as six seconds but no shorter, lift all four sides, one at a time. Raise the tray about an inch, hold it a moment, set it down then wait a moment before lifting the next side. The four lifts make one cycle. This is the only known way to get repeatability.

Temperature changes are the quickest way to vary the amount of development. A two degree change will cause a 10% change in the amount of development. To get neutrality (no color shifting in the grays) the separations must balance and to get repeatability in the printing process, every set of separations must balance in the same way. To get this, the agitation and temperature must be constant. Whatever you select for procedures, do it every time and don't change them — unless they cause trouble.

In the after processes - stop, fix, permawash, and wash - temperature is important but by no means critical. It doesn't hurt the image if everything is a bit warmer or colder. If it's too cold, then the fix works very slowly but it works. If everything gets too hot, like 85°, and you plunge the film into cold water, then the emulsion will reticulate. Within reason and so long as it goes in the same direction, plus or minus three degrees is no problem in the after processes. See Chapter 11, Baines, THE SCIENCE OF PHOTOGRAPHY, Wiley.

For development the ideal solution to the temperature problem is a water jacket with moving water at 68° F, a stainless steel tray with a flat bottom and a plexiglass (acrylic) cover for the tray. The cover is a good insulator and separates the air over

the developer from the atmospheric conditions in the wet bench which tend$ to resemble the tropics, hot and humid. If the tray, fiberglass or stainless, has been soaked in water at 68° F, the developer is at 68° F, the cover is at 68° F, and there is a quart of water at 68° F in the jacket, then the whole unit will be inclined, God willing, to stay at 68° F — no matter what — for five minutes.

If the temperature in the lab is 68° F with a humidity near 50% and the wet bench has not been warmed up with a lot of hot water, then, just possibly, the water jacket and cover are unnecessary. Maybe ... but don't bet on it. Really dry air, like what comes out of an air conditioner on a clear day, is a menace. Radiational cooling, even when the ambient is 70°, will drop the temperature of the developer in the tray by 5° F in five minutes. Evaporation varies inversely as the 4th power with the thickness of the solution. As you are agitating the solution, it gets very thin as it rides up the side of the tray and the 4th power business cools it in a hurry. Myself, no matter what, I always use a water jacket.

Uniformity.and consistency within a set of separations are so critical and the effects in the print, when a set of separations is out of balance, are so pernicious and subtle that it is better to be safely on the conservative side, rather than sorry. It is very difficult, when looking at a print, to say whether or not the problem is with the separations because the effects could just as easily have been caused by a variation in matrix development, the dyes, or the acid rinses.

In the ideal system, exposure time for the matrix is the only variable and the actual number used is decided by the person making the print. Then, when looking at the print, this person can ask, "What would happen if I changed the contrast in the separations?" then do it and know, when comparing print #1 with print #2, that contrast in the separations was the only change. This kind of control opens up all manner of possibilities for self-expression which, to my way of thinking, is what printing is all about.

Equipment to Process Masks & Separations

Timer

Thermometer

5x7 Tray (Developer)

Trays for Stop and Fix

> 500 ml's of Rapid Fix is good for three sets of separations or five sets of masks. If your film does not clear in 30 seconds then, after this sheet, it's time to get a beaker with 500 ml's of fresh fix. The stop turns purple when it is exhausted.

4x5 Tank with water at 68° F

4x5 Film Hangers

2 or 3 plastic jars, if necessary, to keep the flasks of developer at 68.

Materials:

Masks	1 - 250ml flask with 200ml's of DK-50 (1:2)
Separations	3 - 250ml flasks with 200 ml's of DK-50 (1:1)
	Indicator Short Stop
	Rapid Fix

Developing Times for Contact Masks & Separations

Times

Masks - DK-50 (1:2)
    Both sheets in the same developer

Red	3'
Green	3' 30"

Separations - DK-50 (1:1)
    Fresh developer for each sheet

Red	3' 30"
Green	4' 30"
Blue	4' 50"

Procedures for Film Processing

1. Do the best you can to get the temperatures of everything to 68°

2. Dry your hands and set the timer for the developing time plus 10 seconds.

3. Turn the lights off, check for light leaks then get the film. Close the box and check the corners of the film to be certain you've actually got the one you think you've got.

4. Start the clock and with the same hand lift the tray by its back edge: the solution is along the front. At the end of 10 seconds slide the film in, EMULSION UP, and lower the tray. You will hear the film click against the sides of the tray. Agitate on a 10 second cycle (see pages 76 & 77).

5. 15 seconds before the end of the developing time, find the film in the developer and pull it out by one corner. Let it drain, but don't shake it: if you do, the drops will still be there and you'll have cracked the emulsion.

6. At the end of the developing time put the film in the Stop and reset the timer for 5 minutes.

7. 10 seconds in the stop is plenty. Fish the film out, let it drain for 5 seconds, then into the fix.

8. Agitate it on a 10 second cycle in the fix. After 30 seconds, turn on the light. If the emulsion looks milky it is time for fresh fix. Total time in the fix is 2 minutes.

9. Put the film in the hanger with the notch code in the lower right hand corner and leave it to soak in the tank of rinse water while you process the remaining sheets.

FILM WASHING

Materials & Equipment

    1 - 4x5 Tank (Perma-Wash)
    1 - 4x5 Tank (Photo-Flo 200)
    2 - 4x5 Tanks - rinse water
    Film clips of some form

Procedures

1. With separations (masks don't matter) make certain that the last sheet processed has soaked in the rinse tank (preferably fresh water) for five minutes. This, plus fresh fix, removes the anti-halation back from the film.

2. The film, in hangers, stays in the Perma-Wash for one minute. Every 15 seconds lift the hangers up and down a couple of times. Do the whole group together, otherwise the corner of a hanger may scratch the sheet of film in the hangers on either side.

3. Dump the rinse tank and clean it out thoroughly with fresh water. It has fix in it and that's what you're trying to remove. Fill the rinse tank and move the hangers from the Perma-Wash into it. Cover the Perma-Wash and get it out of the way.

4. Fill another tank with fresh water. For 5 minutes, on a one minute cycle, move the hangers back and forth between the two tanks, changing the water each time.

5. After the 5th cycle, let the hangers sit for 30 seconds, without agitation, in the Photo-Flo 200 diluted 5ml's / quart.

6. Lift the hangers out and put them in an empty tank to drain.

7. At the drying box take the film out of the hangers and hang them by one corner, all facing the same way.

       Keep track of your masks and separations.
    When they are dry, get them out of the box and into glassines.

Forced Hot Air Drying Box:

The box should be about 36" high (80" if you want to dry
36 exposure rolls of 35mm film). 18" deep and 24" wide. The door
is on the 24" side and should be as wide as possible. Make it
with acrylic plastic, quarter inch, then you can see what is
happening inside. Set 3/8th's aluminum rods, like in a clothes
closet, with a hole on one side and a slot on the other, across
the 24" side. The air intake is near the top, or on top, and
protected with a spun glass filter for air conditioners and hot
air furnaces. I use a 10" x 20" filter, partly because that was
a convenient size for the hole, but mostly I wanted as much area
as possible for the air to come in. The heat is provided with a
250 or 500 watt photoflood lamp placed between the middle and the
top which, I think, sets the air to circulating. Finding a place
for the bulb is usually difficult because it cannot be too near the
film, like 3 or 4 inches at least, and it must be away from the
drips as the film drains. At the bottom a small exhaust fan pulls
the air through and sends it out.

    With something about this size, film will dry in 20 minutes
if the ambient humidity isn't too high and the final drop is
removed from the low corner of the film. After 20 minutes the film
is dry to the touch but remember that the separations will not be
sufficiently dry to store in closed boxes for a day or two. Masks,
separations, and matrix should be hung from one corner and face
the same way with the notch code either always up or always down.
If you use film clips be certain that they don't touch the holes
for the registration pins. If the quarters in the drying box are
close, it is best to hang matrix from two corners.

Chapter 7.   EXPOSING AND PROCESSING MATRIX FILM

Matrix Film (4150) is supplied in 25 sheet, sealed packages
inside a double box. There are yellow, folded interleaves
underneath the package of film to protect the finished matrices
and it is best to store them, one to an interleaf, in the original
box. In the sealed film package itself the top sheet, after the
cardboard stiffener, is a protection sheet. It does not have any
emulsion, nor does it have a notch code: the only identification
is a clipped corner. 10x14 matrix (EK# 140 4433) has a list
price (1977) of $38.05 and 11½ x 15¼ matrix (EK# 140 4276) costs
$54.80. If you are printing 2¼ square chrome you can get a 9"
square print on 10x12 matrix with plenty of room on the borders;
the best you can get with 11½ x 15¼ is a 10½" square. With 4x5
you can get a full 8x10 on 10x12 matrix. For both 10x12 and
11½ x 15¼ matrix the developer quantities are the same, unless
you buy EK 10x12 trays (EK# 140 8798): these will reduce the
developer quantities by 20%, more or less. Matrix film is
sensitive only to blue light, so any safelight rated for black
and white graded paper can be used — OC, red, or sodium. See
pages 39-41 for a full description of matrix film.

Test Prints

Every photograph is a new reality, an object which never
existed before. In black & white printing we are only dealing
with one variable — monochromatic tones which can be modulated
from black to white in a continuous, uninterrupted progression.
As the exposure for the whole print is increased from obviously
too light to obviously too dark, there is a point where, visually,
the relationship between black and white is balanced. When viewed,
the image itself will seem to lift right off the wall. This

probably has to do with "brilliance" (light as it exists in the
mind's eye) but nobody understands it. It is, I suppose, possible,
though I've never been able to do it with any consistency, to make
a test strip which will provide the information to determine the
ideal exposure for the finished B/W print. Actually it probably
only determines the proper exposure for the photograph which is
the test print.

With color prints, a test strip is out of the question.
There are four variables, all acting on each other at the same
time. They are the contrast (black to white tone reproduction)
and the three dyes, thinking of each as a separate layer. There
is also the multitude of colors which can be mixed from these
dyes. This makes the variables very complex: whatever happens
as a visual event in one corner of a color print has a profound
effect on what happens visually in the other areas of the print.
The big single problem in printing (color or black & white) is
that we never really know what we are trying to do until we've
done it. Everything is in flux and then, all of a sudden,
looking at it we can say, "That's it."

For these reasons the test print must include the whole
photograph and the trick is seeing the test print as if it were
the finished print, adjusting mentally for the area which is too
dark and the area which is too light. If the photograph is
divided into thirds and the second third gets more exposure than
the first third and the final third gets more exposure than the
second third and the base exposure has been figured to make the
first third too light, then the final third should be too dark.
It is important that one section be underexposed (too light) and
another section too dark (overexposed). This can be done by
making an overlay with black matte board and cutting a hole in
it for the image. By punching one end with the matrix punch
then the opening for the image will always be in the same place.
There will be no misregister at the edges of the print when the
three matrices are exposed.

If the overlay has bumpers on it, then the carboards used
to cover parts of the image during exposure will make a clean
edge with no color fringing. To make a test print the matrix is
put on the pins, then the overlay, and the whole thing is given

an exposure of, say, nine seconds. Now, one-third of the opening
in the overlay is covered with a cardboard which is right up against
the bumpers on the overlay and the film is given a second exposure
for six seconds. Cover another third of the opening in the
overlay and give this last third an additional exposure of ten
seconds. The first third has a nine second exposure; the second
third has a nine second plus a six second exposure, or fifteen
seconds which is two-thirds of a stop more. The third section has
an exposure of ten, plus six plus nine or twenty-five seconds which
is two-thirds of a stop more than the second third. This is done
for all three matrices. By looking at the finished print in normal
viewing conditions it is usually possible to decide on an exposure
time. If the nine second section is too light, but the fifteen is
too dark, though not too too dark, then Half way is nine plus three
or 12 seconds, but that will be too light, so I add another second
and expose the matrix for thirteen seconds. This is a fine system,
so long as the illumination in the enlarger is constant which can
only be done with a voltage regulator. Without a voltage regulator
there is no way to know that what I do now will be the same as
what I did an hour ago.

There are many different ways to think about the visual
synthesis which happens when the set of three dyes are commingled
in the receiving sheet. For me the cyan controls the contrast
because there is more inherent contrast in cyan (red density)
than there is green density in magenta or blue density in yellow.
(See the table on page 46) From the cyan image, before the magenta
and the yellow have been transferred, I figure the exposure for
the finished cyan matrix so that Zone III and Zone VII are in
balance visually. This has nothing to do with color, just the
progression black to white, as if the print had been toned. In
my eye, the bulk of the color happens with the transfer of the
magenta. Zone III and most of the lower mid-tones are almost
complete because yellow dye does not have, in itself, enough
blue density to make a Zone III black when added to equal amounts
of cyan and magenta dye. Finally the yellow printer removes the
excess blue from the upper mid-tones. It also adds some red and
green, but the visual effect of yellow dye is quite weak, like
nothing, when compared with cyan and magenta.

Four times out of seven, the exposure of the magenta matrix
will determine the overall color quality of the finished print.
Two times out of seven it will be the cyan, and once in seven the
yellow printer will be the difference. If your separations have
not gotten out of control, then the color balance in the test
print will be pretty good with neutral blacks. With practice
you will learn when the yellow-blue relationship is visually
critical. Most of the time it isn't, so the exposure for the
finished cyan matrix is also the exposure for the finished yellow
matrix. Expose and process these two matrices then roll a print
using them along with the magenta test matrix. Contrast in this
print will be right and the color will shift from magenta to green.
The eye is much more sensitive to green light than it is to red
and blue, so small density changes make big visual differences.
I've found it is best to make a new magenta test matrix, along
with the finished cyan and yellow matrices, which has smaller
increments than the two-third's of a stop used for the original
test mats. Suppose the exposure for the finished cyan matrix is
sixteen seconds and the color balance in the test print looks
pretty good, no big throws, a magenta test matrix which starts
at twelve seconds and progresses to twenty seconds in five two
second increments will provide a controlled spread from magenta
to green and the balance point between them will be obvious. This
is best done in an enlarger with a shutter, so there is no warm
up time for the bulb. A cold light source, like the Aristo,
comes up faster than a filament bulb, but there is a lag so the
increments are not quite two seconds and this must be considered
when picking an exposure time for the finished matrix. Needless
to say this approach to test prints can only be done with pin
registered separations and registration easels.

Registration

The whole purpose of pinned separations, other than registering
the masks, is to make registered matrices and avoid all the
problems of eye registration. The Condit registration carrier
is not only equipped with pins which match the holes in the
separations, but it is also designed so you can take it out of
the enlarger, change separations, and put it back with the new

separation in the exact position where the other one was. These
are one-sixteenth inch pins; they can be bought separately,
fastened to small brass plates which can be taped to anything.

The pins on the easel and transfer board are three-eighth's
of an inch in diameter with flat sides; they are either high or
low. High pins come to a point and low pins are flat, just high
enough to hold a sheet of matrix. These pins are available from
Condit set in strips or loose on small stainless steel plates.
They are also made with with 4 - 40 threads so they can be fastened
to anything.

If the enlarger is not absolutely rigid it will change
position when the carrier is taken out. The registration is lost
and once lost, like Humpty Dumpty, it cannot be put together again.
The easel must also be secure and it's best if the easel and the
enlarger are a self-contained entity — a unit — with each fastened
to a counter. The counter is bolted to two walls which form a
corner; the tracks for the easel are screwed to the counter; the
easel is clamped to the tracks and the enlarger is clamped to the
counter. The counter stiffens the wall and the enlarger is
fastened to the walls with two braces which, when loose, will
telescope and pivot but can be tightened with a thumb screw so they
are rigid. The back of the enlarger, from the top of the rails,
is braced against a stud in the wall. The side of the enlarger,
from the front of the base for the carrier, is braced from a
stud in the side wall. When everything is tightened, the whole
corner is rigid. If the building shakes, the enlarger and the
easel will shake together — in unison. So long as the two shake
together, then the pins in the carrier and the pins on the easel
do not change position relative to each other, though they will
have moved relative to some other point.

Changing Separations

When putting the carrier into the base (the box which is
between the bellows and the light source), push the carrier all
the way in until you feel it pressing against the back lock: it
is spring loaded. Turn the locking knob until it seats, then let
the back spring push the carrier into it. This way you are
certain that the front lock is seated. If you push the carrier

part way, then twist the locking knob, letting it force the carrier into the locks, there is a chance that the front lock won't be fully seated and you will have a small shift in registration.

When removing the separations from the carrier, use the palette knife. Slide it between the glass and the film till it touches the pin, then give it a gentle twist: the separation will pop off. If you pull the separation off with your thumb and index finger, you run the risk of damaging the registration holes because there isn't any easy way to get in with a finger.

Setting the Pins in a Registration Carrier

The distance between the pins is adjustable with a 3/32nd's allenhead wrench. In the carrier one pin is fixed and the other is locked in place with an allenhead screw. To adjust it for your film punch, punch a piece of film, release the loose pin and put the film on both pins. Run your finger along the edge of the film from the fixed pin to the loose pin. When it is flat (no buckling), tighten the pin then tape the wrench to the wall so you can find it when you want it. Once the pins are set, you won't need to change them unless you are printing old separations which have changed dimensions. Even estar supports expand a bit with time, but it is like nothing either in distance or time, when compared with the old acetate supports.

Equipment to Expose Matrices

Safelight (OC or red)

Timer

Voltage Regulator (with a switch)

4x5 Omega D series enlarger with an Aristo Diffusion cold cathode
      (blue light only) lamp house. (See pages 37-39)

Condit 4x5 Registration Carrier with extra glass (top and bottom)

1 - 12" Condit Telescoping Brace w/ brackets

1 - 16" Condit Telescoping Brace w/ brackets

Lenses - 150mm Rodagon for 4x5's

          80mm Rodagon for $2\frac{1}{4}$ sq

Vacuum Easel with channels for 10x12 (actual size) and $11\frac{1}{2}$ x $15\frac{1}{4}$
      matrix, high pins on 9" centers at one end and valves

2 - 24" Condit Easel Tracks with clamps and 7/16th's Spin-Tite

Magnifier to check focus (Condit makes the best)

Kodak Registration Punch (EK# 147 6969)

Gast Vacuum Pump with a pressure relief valve

A cardboard overlay (cab) which covers the borders of the matrix
      film and has bumpers for test prints

Cardboards to cover the matrix by thirds for the test prints

Focusing Paper

Palette Knife

Scissors

Sable brush

Windex

Photo-wipes

Lens Cleaner

Empty Box for exposed film

Materials

10x12 Matrix Film (4150) EK# 140 4433

$11\frac{1}{2}$ x $15\frac{1}{4}$ Matrix Film   EK# 140 4276

Procedures for Exposing Matrix Film

1. Clean the glass in the carrier

2. Contact Separations go into the carrier EMULSION UP
    Enlarged Separations go into the carrier EMULSION DOWN

3. Release the side brace on the enlarger

4. Release the clamps so you can move the easel.

5. When everything is the way you want it, and the image is in
    focus, tighten everything. The easel clamps fit over the
    lower lip on the easel.

6. Set the aperture on the lens

7. Set the timer

8. Check the vacuum pump and the easel: if the valve is open,
    it will hiss. Turn it off.

9. Turn off the room light and check for light leaks

10. The matrix goes on the pins EMULSION DOWN

11. Start the vacuum pump and wait for the film to pull against
    the easel.

12. Put the cab (overlay) on the pins

13. Make the exposure

14. If the mats are for a test print:
    A. Reset the timer for the first additional exposure
    B. Put the cardboard on the cab so it makes contact with
        the bumper in the center

    C. Make the exposure
    D. Reset the timer for the second additional exposure
    E. Cover the other side of the cab with the cardboard:
        now each side is covered with only the middle open

        Remember which way you are adding the cardboards — left
        then right, or right then left: do it the same way for
        all three matrices
    F. Make the exposure

15. Clip the corners: one for magenta and two for yellow.

Equipment for Processing Matrix

OC or red safelights

1 - 11x14 tray with a smooth bottom (EK# 150 6633) - Developer
1 - 11x14 tray (smooth or ribbed) for the water rinse which will
        nest with the developer tray
1 - 11x14 tray (smooth or ribbed) - Fix

> Once upon a time all 11x14 trays were oversized and could
> handle 11½ x 15¼ matrix, but no more. Many of the trays now
> being sold are from new molds and for any given size are just
> that, with no leeway. If you use a 14x17 tray for developing
> matrix, you'll need 20% more developer per sheet and it
> doesn't take long for this to equal the extra expense of
> Kodak trays.

2 - Thermometers. Use one for Tanning A only and the other for
        everything else. This way there is no risk that the A will
        have been contaminated with B before you are ready to mix them.

3 - 250ml Erlenmeyer Flasks with gradations
3 - 500ml Erlenmeyer Flasks with gradations
1 - 500ml Beaker
Storage Bottles
Film Clips
Drying Wire for 3 mats

Materials for Processing Matrix

Tanning Developer A — packets to make 1 quart (EK# 169 1971)
These packets ($1.25 each) are sold in boxes of 10 which
are packed in cases of 10. You will use 5.7 quarts per
25 sheet box of 11½ x 15¼ matrix film. It must be mixed
with distilled or de-ionized water. The chemistry of
pyro-gallic acid is ambiguous and mostly unknown. It will
oxidize very rapidly with small quantities of alkali.
Using distilled water to mix it, the developer is a
constant — otherwise not.

Tanning Developer B — packets to make 1 gallon (EK# 146 8571)
These packets ($2.15 each) are sold in cases of 10. If
the developer is mixed 1:2.25 you will use 3.2 gallons
per 25 sheet box of 11½ x 15¼ matrix film. Filtered tap
water is fine.

Color Liquid Film Fix & Replenisher — 1¼ gallon jugs (EK# 153 2274)
These jugs ($6.00 each) are sold only in cases of 4. For
use it is diluted 1:6.5: with an 11x14 tray the mix is
200ml's of concentrate and 1,300ml's of tap water. Mix
it fresh for each set of three matrices, then dump it. If
you don't, then you'll get patterns with small blotches in
the finished prints. These do not show up until several
weeks after they have been processed, like when you're
rolling additional prints and don't have the time to make
new mats. You will use 2.3 quarts of concentrated fix for
each 25 sheet box of matrix film.

General Procedures for Processing Matrix

1. Put 200ml's of Tanning A in a 250ml flask. You will need 3.
    Put 450ml's of Tanning B in a 500ml flask. You will need 3.
    Bring one pair to 68° F.

2. Fill two 11x14 trays with water at 68° F. After a few minutes
    check the temperature. If it is above 68°, then refill the
    trays with water at 66° F

3. Prepare the Fix — 200ml's of concentrate and 1,300ml's of
    water at 68° F. (With 14x17 trays 250ml's and 1,600)

4. Fill one of the 2,000ml graduates with water at 68° and put
    it to one side. This is the chill rinse.

5. Fill the tub with water at 125° to 130°, more or less.

6. Check the temperatures of the developers

7. Dump the water out of the developer tray and partially dump
    the rinse tray, leaving it about a quarter full. This water
    will be the rinse between the developer and the fix. Put
    the developer tray on top of the rinse tray, using it as
    a water jacket.

8. Pour the 450ml's of Tanning B into the developer tray

9. Get your film box, set the timer for 10' plus 20", turn off
    the room light, get your film and close the box.

10. Hold the film with your fingers in a registration hole with
     the emulsion facing you. With the other hand (don't rush)
     start the clock, then dump the Tanning A into the developer
     tray. Mix the two solutions by tilting the tray with the
     same rhythm you used for separations. (See pages 76-77)

TIMETABLE FOR DEVELOPING MATRIX FILM

10' + 5"   Get ready to put the film in the tray. It is the
            same procedure you used with masks & separations
            See page 77

10'   Film in the developer, EMULSION UP.
            The agitation is continuous for two minutes

8' + 30"   Separate the developer tray from the rinse tray

8' + 5"   Lift the film out of the developer - no drain

8'   Into the water rinse - continuous agitation for 30 seconds

7' + 35"   Lift the film out of the rinse - no drain

7' + 30"   Into the Fix with continuous agitation for the first
            minute, then turn on the lights and open the door.
            Dump the rinse and the developer, rinse both trays
            with hot water and fill the developer tray with 1,500 ml's
            of hot water from the bucket. From time to time
            agitate the film in the fix. The fix can be used as
            a holding bath, even if it bleaches the silver which
            is unimportant because we have no further interest in
            the silver image - just the relief.

5' + 35"   Film out of the fix — if you have run over, reset
            the clock

5' + 30"   Film into the hot water rinse - forty-five seconds
            Fill the other tray with 1,500ml's of hot water

4' + 45"   Film out of rinse # 1 and into # 2 - forty-five seconds
            Rinse the first tray and refill with water (1,500 ml's)

4'   Film out - EDGE WIPE   (See page 95)

3' + 30"   Film into the first tray - thirty seconds
            Rinse and refill second tray with 1,500ml's of hot water

3'   Film into the second tray - thirty seconds
            Rinse and refill the first tray with 1,500ml's of hot water

2' + 30"   Fifth Hot water rinse. This time cool the second tray
            with cold water and fill it with the water at 68° in
            the graduate

2'   Into the final (chill rinse)- thirty seconds. Twice
            lift the film out, let it drain briefly, and agitate.

1' + 30"   Hang it up to dry (which completes the hardening).

Edge Wipe

Between the second and third hot water rinses, remove the
film from the tray with one hand and with your other thumb nail,
scrape all four edges, the notch code, and the holes for the
registration pins. The gelatin in these places was hardened
when the film was cut to size and punched. It must be removed;
otherwise, as time goes by, it will loosen and fall off in the
dyes. Then, when the mats are soaking in the dyes, it gets back
onto the mats.

During the acid rinses, when rolling, always look for them:
they are small dark chunks. If you find one and it's just sitting
there, dip a Q-Tip or a cotton ball in the rinse then compress it
so it's fairly stiff but also wet. Dump the tray, leaving the
mat on the flat bottom and just touch that little rascal with the
cotton and it will stick. There will be no damage to the relief,
but filter the dyes because for sure it ain't no orphan.

If this pest is not caught first time around in the rinse,
then, when the matrix is rolled, it will be embedded in the relief.
It will also prevent the transfer of the dye immediately surrounding,
so you will see a red or green halo around the spot in the print,
no cyan or magenta dye transferred. If this has happened, it is
a work of art to dig the chunk out of the matrix with a knife and
not damage the surrounding relief. This whole problem can be
avoided, most of the time, by doing a thorough and meticulous
edge wipe and also always looking for them in the dyes.

Chapter 8.   THE TRANSFER PROCESS

Dye transfer printing did not replace three color carbro
until the early 1950's when it became possible to register
matrices with pins rather than use the blanket board system.
At that time matrices were lined up in register over a light
box then taped onto a piece of glass and punched. Done this
way it is impossible to make a single matrix as a replacement
for one in a set of three and register it with the other two:
there is no way to get two back to where they were and then
punch the new matrix. As a result many things were done in the
rolling process to get an acceptable print and avoid the work
to remake and register a set of matrix. Over the years many
tricks have evolved that are not only very ingenious but
sometimes truly amazing. Unfortunately, there is one big
disadvantage — the results are seldom repeatable.

With small pins and registered separations most of these
tricks became unnecessary because the quality custom labs knew
it was less expensive to spend fifteen minutes making a new
matrix which would print right with no effort rather than
struggle for two or three hours with a matrix that would never
make a good print. The low quality custom labs seldom make
matrices which will print right, so they are still doing the
tricks with the dyes and the rinses: they don't have a system
to control the processing of separations and matrix, so they
are out of balance.

At the same time Eastman Kodak will not admit the existence
of small pins and registered separations, so the Kodak instructions
describe eye registration as if it is the only thing. For
different reasons, both Kodak and the low quality custom labs
have an interest in getting the best print possible without
having to remake the matrices. The labs know that a new one

is unlikely to be any better than the one they're already using;
for Kodak, with their eye registration system, it takes three
to get one which is not economical, either in time or money.
This has had the unfortunate consequences because it has led
people to minimize the importance of balanced separations and
matrix processing which is consistent. Both of these are stressed
in the Kodak instructions, then they turn around and describe
procedures which make them seemingly unimportant.

Dyes and Replenishment

The Kodak Instructions for Matrix Dyes specify 4 ounces of
dye, 6 ounces of buffer, and 54 ounces of water to make a half-
gallon. They do not say anything about distilled water, but
this paragraph is followed by a long section about "adjusting
the dyes to produce a good neutral scale". It has been my
experience that, when made with distilled water, the dyes stay
neutral for long periods of time — like many, many months — with
no noticeable changes, whether or not they're being used. They
also recommend replenishing the dyes with 2 ml's of dye for
every 4 8x10 prints, or the equivalent. Several years ago I
ran matrix tablets through the dyes after every tenth print,
transferred them and read the densities with a reflection
densitometer. After 120 prints (8x10's and 11x14's) the volume
of the dyes was down by half and the densitometer revealed no
significant changes in either the contrast or the Zone III
densities. Since then I have not replenished the dyes and, if
I had it to do over again, I'd mix the dyes 5 ounces of dye, 5
ounces of buffer, and 54 ounces of distilled water. This makes
for a small but noticeable increase in contrast; and I haven't
changed because, when I figured it out, I already had a great
many sets of matrices exposed for the four and six ratio.

Most of the space in the Kodak instructions for the dyes
discusses changing the color balance in the finished print by
varying the contrast in the dyes with the addition of 28% acetic
acid for increases and using a 10% solution of tri-ethanolamine
for decreases. There is a considerable difference in Zone III
densities between the two extremes; however, if the normal dyes

used as a starting place are in the middle, then the change is like half of a paper grade either way and this isn't enough to save a set of separations which are out of balance. In one place Kodak recommends three sets of dyes — low, medium, and high contrast — in separate bottles, which is fine so long as they don't get mixed up, but the instructions don't say why they are necessary. With two sets — low and high contrast — it is possible to see the photograph at two contrast levels without having had to change the alkalinity of the matrix developer and the exposure time. Needless to say, this takes for granted that the separations are in balance.

It is one thing to have two or three sets of dyes in separate, well marked bottles and quite another to follow the next set of Kodak instructions. Kodak recommends the addition, a little at a time, of either 28% acetic acid or 10% tri-ethanolamine to the dye baths until the print looks right. Doing it this way, each print requires a special set of dyes. The dyes are no longer constant and, when the time comes to make additional prints which are identical with the original, it's unlikely that the mix can be recreated, even with very detailed records. Also, one should start with fresh dyes for each print because tri-ethanolamine and acetic acid should not be added to the same dye bath. All in all, it seems to me that messing with the dye baths (making them a variable) is a very bad habit with no redeeming features whatsoever.

Dye Transfer Paper

Often the paper is called a receiving sheet because it receives the dyes and then holds them. Any support which has been coated with gelatin and then treated with the mordant, any substance which will hold a dye and prevent bleeding, can be used to make a print. Ordinary black & white paper can be used if the silver halide has been removed and then treated in the mordant. It is best to remove the silver with Kodak F-5 Fix (EK# 197 1746) because the hardener is potassium alum which works, to some extent, with some emulsions as a mordant.

The literature is quite barren on this subject and the best that I could find is Friedman, HISTORY OF COLOR PHOTOGRAPHY, p 483.

He discusses the dye absorption of freshly mordanted film which was used in the Technicolor process. They found that over a three day period the mordanted film loses a stop in density and then stabilizes. He doesn't say if this applies to paper also. The following formulation is from Coote, Jack H., COLOUR PRINTS, Focal Press, 1963 — p 110

M-1 Mordant

A	Aluminum Sulphate	200 grs
	Water to make	1,000 mls
B	Sodium Carbonate (Anhydrous)	40 grs
	Water to make	500 mls
C	Sodium Acetate (Anhydrous)	50 grs
	Water to make	1,000 mls

Solution B is slowly added to solution A with continuous stirring until the solution is clear. It may throw a white precipitate which usually redissolves during the stirring; if it doesn't go into solution, it must be filtered out. The paper, after being fixed and thoroughly washed, is soaked in this solution for five minutes and then washed for five minutes. It is then soaked for five minutes in solution C and washed for another five minutes. It can either be dried or used immediately. In either case it should be soaked in the paper conditioner for the normal time.

For paper the soaking period in the paper conditioner is 20 minutes or more, but it should not be left for more than 30 or 40 minutes. When paper has soaked for a long time, something happens during the transfer and you'll find small blotches, like water marks, where the dye has not completely transferred. With transfer film the soaking period is no more than 3 minutes and this is critical. If you soak a piece of paper in the conditioner and don't use it, let it dry and then, to use it later, just retreat it in the conditioner.

Materials

11x14 Dye Transfer Paper (EK# 145 5385) — 250 sh boxes only

10x12 Dye Transfer Paper (EK# 145 5351) — 250 sh boxes only

Paper Conditioner (EK# 146 5814) — 32 ounce bottles to make
one gallon (1:3)

Acetic Acid — If you buy 28% acetic acid then, to get a 1%
solution, add 150ml's of 28% acid to 4,000ml's of distilled
water.

If you buy glacial acetic acid (100%) never forget
that it freezes at 60° F. I dilute it to 25% (1:3), always
adding the acid slowly to the water and not breathing the
fumes.   . To get a 1% solution add 200 ml's
of 25% acid to 4,800 ml's of distilled water. NEVER, but
never ADD WATER TO THE CONCENTRATED ACID BECAUSE THE
SUDDENNNESS OF THE REACTION WILL CAUSE THE WATER TO BOIL
IMMEDIATELY AND SPATTER CONCENTRATED ACID ALL OVER EVERYTHING.

Dyes — Cyan, Magenta, and Yellow, with their buffers, in sets
to make one gallon (EK# 146 5798) - $29.65

They are available separately in ½ gallon bottles to
make 5 gallons, much cheaper than five 1 gallon sets and
the dyes keep indefinitely, like many years.

Sodium Acetate

Calgon - Sodium Hexametaphosphate - Highlight Reducer

28% Ammonium Hydroxide - this is also used in the sniffers for
unconscious football players when they must be wide awake
for the next play

Kodak Anti-Calcium

Distilled water for everything

Equipment

Timer

16x20 glass transfer board - 1/4 or 3/8ths of an inch thick with
      ground edges and a Condit pin strip with high pins on
      9" centers

1 - 14x17 tray (Paper Conditioner)

3 - 14x17 trays (Dyes)

1 - 11x14 tray with a smooth bottom (1% acid rinses)

1 - 14x17 tray (Holding Bath)

1 - 14x17 tray (Water rinse at 100° F after the transfer)

1 - Plastic Storage Tank with a cover and a spigot (1% Acid Rinse)

1 - 1,000ml plastic graduate

2 - 150ml beakers (1% acid rinse)   - VWR# 13910-187

3 - 250ml Plastic Wash Bottles (Additives)   -   VWR# 16651-926

1 - 25ml graduated cylinder (measure 25% acid)

1 - 15ml graduate (Sodium Acetate in the 1st rinse)

     Sodium Acetate
     25% Acetic Acid
     Highlight Reducer (Calgon - Sodium Hetamexaphosphate)

Teaspoon

1 - EK Hard Rubber Squeegee (EK# 147 7249)

Sponge for the paper

Small tub for the acid hand rinse

1 - EK 17" Roller (EK# 147 7124)

1 - 250ml (8 oz) Graduate - VWR# 33040-044

3 - 1 Gallon Jugs (Dyes)

1 - 1 Gallon Jug   (Conditioner)

1 - 1 Gallon Jug   (25% Acetic Acid)

Filtering Equipment for the Dyes

1 - Pluro Stopper   VWR# 56387-029

1 - 2,000ml filtering flask   29415-143

1 - 4A Buchner Funnel (15 cm)   30310-200

1 box Whatman #3 filter papers (15 cm)   28456-123

1 Aspirator   28654-003

    In place of the aspirator, which goes onto a fawcet and the
    moving water creates a small vacuum, you can use the vacuum
    pump for the easel.

Preparations

See that the dyes, paper conditioner, holding bath (1% acetic
acid) and the 900 ml's of 1% acetic acid for the rinses
are at similar temperatures, between 70° and 80° F, or
more. This is uncritical, so long as they are all about
the same. Increases in temperature do not decrease the
transfer time, about 9 minutes for magenta which is the
longest. Cyan takes about 6 minutes and yellow, 4 minutes.

Soak one sheet of transfer paper in a tray of tap water at 70° F
until it is limp. Run your fingers around the edges to
remove any loose chunks of gelatin. Set the timer for
53 minutes and start it when you put the paper in the
conditioner, EMULSION (shiny) SIDE UP.

Mix the sodium acetate if you think you'll want it. It is a
5% solution, or to make life easier a level teaspoon and
100 ml's of distilled water. So long as you always do it
this way, the solution will be a constant.

Mix the Highlight Reducer (Calgon). It is a 0.1% solution, or
a level quarter teaspoon and 750 ml's of distilled water.

Make up the Holding Bath, 1,000 ml's of 1% acetic acid.

Give the tray of paper conditioner a couple of tilts ...

Be sure there is 1% acid rinse in the tub by the transfer block.
Old holding bath (when it begins to turn color) is fine.
Anytime you have handled anything with paper conditioner
on it, rinse your hands in this tub — NOT THE HOLDING BATH.

Fill two trays half-full with water at 100° F to soak the cyan
and magenta matrices, EMULSION UP, for three minutes. This
swells the emulsion, so the temperature should be somewhat
constant, remembering that the emulsion shrinks as the
temperature stabilizes in the dyes.

After a 3 minute soak, let the cyan matrix drain (don't shake it)
for 15 seconds then put it into the cyan dye, EMULSION UP.
Tilt the cyan tray a few times, then drain the magenta
matrix.

Refill the 14x17 tray with water at 100° F and soak the yellow
    matrix for 3 minutes. This tray will be the water rinse
    for the matrices after they have been transferred.

If you get a matrix in the wrong dye, pull it immediately and
    wash it in water at 100° F going back and forth between
    two trays until there is no color in the water, then put
    it in the right tray. This will take about 4 minutes.
    When the print has been rolled, clean all three matrices
    in the Matrix Clearing Bath.

From time to time, when you're not doing anything else, give
    each tray a couple of tilts

Measure 140 ml's of 1% acetic acid with the small beaker. Using
    the 25ml graduated cylinder or the 15ml graduate, measure
    any additives that you want (25% acetic acid, 5% sodium
    acetate, or 0.1% Calgon - Highlight Reducer) and add it to
    the beaker.

If you are going to roll more than one print, soak the next sheet
    of transfer paper in the water rinse tray at 70° F.

The cyan matrix needs at least 6 minutes soaking in the dye.

        Give the trays a couple of tilts ...

Pour the 140 ml's of 1st acid rinse into the 11x14 tray which has
    a smooth bottom and refill the beaker with 140 ml's of 1%
    acid rinse.

        Tilt the trays, making the dyes go back and forth ...

Rinsing the Matrix

Lift the cyan matrix from the dye. Let it drain until the dye
begins to form droplets, then lift the bottom edge to stop
the drain.

If you are using 25% acetic acid in the 1st rinse,
don't let it drain at all: the rinse is effectively
adding dye to the lower mid-tones.

If you have a 5% sodium acetate addition to the
1st rinse, let the matrix completely drain, because you
are taking dye out of the matrix.

If you are using Highlight Reducer, let the matrix
drain until it begins to form droplets.

The 1st rinse is exactly 1 minute. The matrix goes in EMULSION UP
and the agitation is continuous. The purpose is to remove
all the excess dye from the surface of the emulsion and the
support, but it also (to some extent) disturbs the dye in
the relief - even without additives.

It is always best to handle the dyed matrices with dry fingers,
especially when you are picking them up in the rinses. Water
on your fingers will drain onto the relief and cause streaks
in the finished print.

The 1st rinse is followed with a 30 second drain.
During this time rinse the tray and refill it with the
1% acetic acid in the beaker.

The 30 second drain is followed by the 2nd acid rinse — 30 seconds.
This removes the 1st rinse. There are never any additives
in this rinse.

The 2nd acid rinse is followed by a 30 second drain.

After 30 seconds, put the matrix, EMULSION UP, in the holding bath.

Give the trays a couple of tilts ...

Putting the Paper on the Transfer Board

Before you reach for the receiving sheet, rinse your fingers in the jug of acid then with fresh water, Ajax if necessary, then more acid and fresh water. Any dye on your fingers will transfer into the paper.

Lift the paper from the conditioner and let it drain. With glass or polished aluminum the receiving sheet should not be sloppy wet. If you are using a granite block, it doesn't need much conditioner unless it is dry. With granite the paper is held to the tooth in the granite during the actual transfer with a wet-wet bond. The paper cannot move. With glass it is just cohension and the paper will move if you aren't careful, or if it is either too wet or too dry.

Lay the receiving sheet on the block with the shiny (emulsion) side up and position it so the pins are not only centered but also with a half-inch gap between the edge of the paper and the pins. If the matrix is not punched symmetrically, then set the paper with the proper offset for the way the matrix was punched. Remember that the matrix goes on, EMULSION DOWN, and in the holding bath you are looking at it EMULSION UP.

With the squeegee start at the center and work with some pressure, but not a lot, out to the corners. This is pressing the paper against the block and also removing the excess conditioner. The purpose is to make certain that the paper is in contact with the block. If there is any grit between the paper and the glass you will see it: it must be removed. Wipe the squeegee blade with the sponge, then sponge up the puddles of conditioner on the glass. Wring out the sponge and go over the paper once again with the squeegee for small puddles. Small amounts of conditioner will be neutralized by the acid that comes over with the matrix.

Rinse the squeegee, the sponge, and your fingers thoroughly in the box of 1% acetic acid, then rinse them in fresh water, and dry your fingers. If the conditioner gets into the matrix, the dyes won't transfer.

Rolling the Matrix

During the 30 seconds which the matrix must stay in the holding bath, lift it out twice and let it drain briefly. This is an extra precaution. Also the mat can sit in the holding bath for several minutes and not get into any big trouble, like losing a lot of dye.

When you are ready to transfer, the matrix is EMULSION UP in the holding bath and you want it in the tray with the holes for the registration pins away from you. Pick it up by the far end (with the holes) in your right hand, then with your left hand take the bottom of the mat and lift it away from you so no more acid drains. Too much acid is better than not enough. The emulsion is now down and the holes for the registration pins are next to your stomach.

Fit the small registration hole on its pin and hold it while you get the other hole on the aligning pin. The excess acid will form a bead in the gap between the edge of the receiving sheet and the pins. Adjust the curvature of the mat till the tension keeps the holes jammed against the sides of the pins and, at the same time, keep the image area off the receiving sheet. If you don't, it will start transferring.

With your right hand get the roller and set it on the mat with the backside of the roller against the pins. If the mat has slipped off the pins, you'll feel that there's nothing stopping the roller as you pull it back. This is more of a problem with low pins and, to my way of thinking, it is a good reason for high pins: there is more to hold the mat.

As soon as you know the mat is on the pins, move the roller, with the handle level, across the mat. Let the weight of the roller take the mat from your left hand; don't drop the mat, let the roller take it and it only needs a gentle push. If you do push down on the roller, there will be small colored dots (complementary to the color of the dye) where no transfer happened. These tend to cluster and are a nuisance to spot.

Timetable

53'	Paper in the conditioner - clock starts
48'	Cyan and magenta matrices soaking at 100° for 3 minutes
45'	Cyan and magenta matrices into their dyes
	Start the 3 minute soak for the yellow matrix
42'	Yellow matrix into the dye

If you are making more than 1 print, start the ~~water~~ *paper in* the water soak.

Get the 1st rinse ready

34' + 15"	Drain the cyan matrix
34'	Cyan mat in the 1st rinse
33'	Cyan mat out of the 1st rinse
	Start 30 second drain
32' + 30"	Cyan mat in the 2nd rinse
32'	Cyan mat out of the 2nd rinse
	Start the 30 second drain
31' + 30"	Cyan mat in the holding bath
	Put the paper on the transfer board
30'	Roll the cyan matrix

If you are making more than 1 print, the paper goes into the conditioner.

Get the 1st rinse for the magenta mat ready

Fill the 14x17 tray half full with water at 100° to rinse the cyan mat when it comes off - 3 minutes.

Give the trays a tilt from time to time

23' + 15"	Drain the magenta matrix for 15 seconds
23'	Magenta matrix into the 1st rinse
22'	Magenta matrix out of the 1st rinse
	Start the 30 second drain
21' + 30"	Magenta matrix into the 2nd rinse - 30 seconds
21'	Magenta matrix out of the 2nd rinse
	Start 30 second drain
20' + 30"	Magenta matrix into the Holding Bath

Remove the cyan matrix from the receiving sheet by lifting one corner and peeling it back gently. If you are making another print it goes into the 100° soak for 3 minutes - otherwise hang it up to dry. A rinse before you store it won't hurt, but it isn't really necessary either.

20'	Roll the magenta matrix
17'	Cyan matrix out of the 100° rinse and into the dye

Get the 1st rinse for the yellow ready
Get the 100° rinse for the magenta matrix ready

13' + 15"	Drain the yellow matrix for 15 seconds
13'	Yellow matrix into the 1st rinse
12'	Yellow matrix out of the 1st rinse
	Start 30 second drain
11' + 30"	Yellow matrix into the 2nd rinse - 30 seconds
11'	Yellow matrix out of the 2nd rinse
	Start 30 second drain
10' + 30"	Yellow matrix into the Holding Bath
	Magenta matrix off the pins and into the 100° rinse
10'	Roll the yellow matrix
5'	Yellow matrix off the pins and into the 100° rinse

Wipe the print off with the sponge and put it in a flip dryer at low to medium heat for 5 minutes. It will be damp dry.

If you are making another print, reset the timer for 35 minutes and get ready to rinse the cyan matrix.

Additives in the First Rinse

By adding 25% or 28% acetic acid to the first rinse and not draining the matrix at all when it comes out of the dye soak then the first rinse not only removes the excess dye on the surface but also, due to the increase in acidity, the gelatin in the relief will take up more dye in the lower mid-tones from the rinse than it accepted in the dye bath. Gelatin is affected by the acidity and acetic acid in particular, but the chemistry of this is quite unknown. This increase in density will appear in the Zone III and IV areas and has little or no effect above Zone V. 25ml's per 150ml's of 1st rinse is the upper limit and beyond this there is no change. This is a minor adjustment which can make a lovely print glorious, but it won't save an underexposed matrix.

By adding a 5% solution of sodium acetate —— 3, 5, maybe 8 ml's —— to the 1st rinse it is possible to remove dyes from the mid-tones of the matrix. Beyond 8 ml's it becomes a general cutter. Drain the matrix thoroughly before putting it into the rinse tray. Sodium acetate can really cut, but too much will remove the detail from the upper mid-tones. It is not the solution for an overexposed matrix.

Highlight Reducer is a 0.1% solution of sodium hexameta-phosphate (Calgon) — 1 gram per 1,000 ml's of distilled water. In small amounts it will take all the color out of Zone VIII and correct for color shifts in the highlights. If you are not using distilled water for the rinses you will need this to remove the small and very noticeable shifts in the whites. It, like sodium acetate, is also used as a cutter for overexposed matrices. This is radical and like using a ferricyanide bleach in black & white to save a lousy print — it will always show.

Matrix Clearing Bath

Stock Solution

Kodak Anti-Calcium	120 grams
Amonium Hydroxide, 28%	48 mls
Water to make (90° F)	1,000 mls

For use this is diluted 1:11 with water at 68° F, like 100 ml's of stock and 1,000 mls of tap water in an 11x14 tray. When the matrix is removed from the receiving sheet, soak it as usual for 3 minutes in water at 100° F, then into the Clearing Bath for 30 seconds with constant agitation and a three minute wash - back and forth between two trays with fresh water, three times - then into the holding bath for thirty seconds. The matrix should be resoaked in water at 100° for three minutes before it is returned to the dyes.

I tend to clear matrix only when I see a change in the prints, say eight or ten. From what I've heard it is much more important to clear matrices when the dyes are made with tap water and not with distilled water. With distilled water the problem does not exist.

Chapter 9.   CONCLUSION

This handbook is not the system for dye transfer printing.
In itself it is a system, but it's really an attempt to approach
the problem systematically. There is no one way to make dye
prints because everybody making dye prints will find their own
way and make their own prints. No print is a replica of anything;
consequently every print is an interpretation of something.
People learn to print by printing and looking at prints, all the
time thinking about what they are trying to make.

Dye printing from transparencies is the only way to control
the contrast in a color photograph. If you want more contrast
in the print, develop the separations in straight DK-50 or
possibly D-11 and adjust the exposure times for Zone III. Make
the separations on Kodalith. If you want less contrast,
pre-expose the red and green separations (blue doesn't matter)
which will reduce the gamma between Zones III and VII by
flattening the lower mid-tones without changing the upper
mid-tones.

This cannot be done with color negative because it is
developed to D(max) and the contrast is fixed, whether or not
the negative is printed on photographic paper or as a dye with
Pan Matrix film. If you do use Pan Matrix , make a step tablet
with the color negative film which you'll print and use it to
balance the Pan Matrix for neutrality. If you have shot the
photograph both ways, positive and negative, print both and you
will see the difference which comes of making separations. This
difference is the advantage of making separations. The disadvantage
is the specialized equipment and the extra work. The finished
print is the benefit which makes it all worth while.

Appendix —— SPECIALIZED EQUIPMENT & MATERIALS

Tri-Level Point Source Light Unit
120 watt Voltage Regulator

> K & M Mfg. Co., Inc.
> 4931 73rd Ave North
> Pinellas Park, Florida 33565

4x5 Film Punch
✓4x5 Registration Printing Frame
      Extra pin glass
✓4x5 Registration Carrier for Omega D series enlarger
      Extra glass (top and bottom)
1 - 12" Telescoping Brace w/ brackets
1 - 16" Telescoping Brace w/ brackets

1 - Vacuum easel with 2 channels (10x12 and $11\frac{1}{2}$x$15\frac{1}{4}$ - actual size),
      two valves and high pins on 9" centers

1 - Gast Vacuum Pump with relief valve

2 - 24" Easel Tracks w/ clamps and Spin Tite

1 - 9" Pin Strip with High Pins

> Condit Mfg. Co., Inc.
> Philo Curtis Road
> Sandy Hook, Conn 06482
> (203) 426 4119

✓1 - Kodak Registration Punch   (EK# 147 6969)
1 - Kodak 17" Print Roller   (EK# 147 7124)
1 - Kodak Squeegee   (EK# 147 7249)

Miscellaneous Glass and Chemicals

> VWR Scientific
> PO Box 1050
> Rochester, NY 14603
> (716) 288 5881

Light Source for Omega Enlarger

> Aristo Grid Lamp Co., Inc.
> 65 Harbor Road
> Port Washington, NY 11050
> (516) 767 6575

Materials

4x5 Pan Masking Film (EK# 153 4304)
4x5 Separation Negative Film, Type 1   (EK# 153 9485)

$11\frac{1}{2}$ x $15\frac{1}{4}$ Matrix Film   (EK# 140 4276)
10x12 Matrix Film   (140 4433)

Tanning Developer A   (169 1971)
Tanning Developer B   (146 8571)
Color Liq Film Fix   (153 2274)

Dye Transfer Paper
        11x14   (145 5385)
        10x12   (145 5351)
Paper Conditioner   (146 5814)

Dye Set to make 1 gallon (146 5798)

Distilled Water
Acetic Acid
Sodium Acetate

3" Gelatin Filters & Frames

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