PRACTICAL COLOR PHOTOGRAPHY

BY

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PREFACE

IN this little work historical and theoretical data have been as far as possible omitted. My endeavor has been to supply an elementary practical manual of the various processes of Color Photography, and no method or formula has been given that has not been personally tested in practice. This has naturally limited the scope of the work to some extent, but it has not entailed the omission of any information of practical value.

E. J. WALL.

Wollaston, Mass., May, 1922

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CHAPTER I

THE SPECTRUM — COLOR FORMATION

BEFORE considering the various processes of color photography, it is essential to explain the formation of color, and the difference between the additive and subtractive methods of color reproduction.

The source of all color is the spectrum or ribbon of colors formed by the dispersion of white light. When a narrow slice of white light is passed through a prism, it is spread out into a band of various colors, ranging from red through orange, yellow, green and blue to violet. This is nothing more than an artificially made rainbow, and while the colors enumerated above are the principal ones, they insensibly merge one into the other so that there are innumerable intermediate tints.

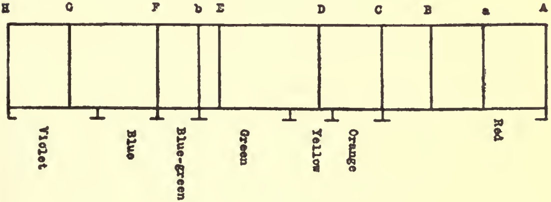


FIG. 1

In Fig. 1 is shown a normal spectrum, giving approximately the distribution of the colors. It will be seen that there are numerous transverse lines, designated by the letters of the alphabet, which always occur in the same places, that is to say in the same color regions, no matter what the method of spectrum production may be, for there are other ways of forming spectra besides the use of a prism, such as by means of diffraction gratings. These lines are called the Fraunhofer lines, from the physicist who first mapped them out, and who assigned to them the letters by which they are known. They may be looked upon as convenient milestones or data posts, which enable us to identify any color at once. For instance, the E line occurs in the middle of the green and if we were to designate the color of a dress material or a dye as similar in color or hue to the E line, there would be no question as to its exact shade; whereas the mere term "green" conveys no definite meaning. It is very common practice to define a position in the spectrum with regard to these lines, and we may meet with such terms as B $\frac{1}{2}$ C or E $\frac{2}{3}$ F, which also define the color, as one has merely to locate these particular points to determine at once the particular color designated.

All natural objects possess the property of absorbing more or less of white light and reflecting the remainder, and to this property their characteristic colors are due. The absorption may be general and equal for every part of the spectrum, when we obtain light of lowered luminosity or brightness which is called grey. If the absorption is complete, then obviously we have a total suppression of all color and light and the resultant is black. But if one region of the spectrum is absorbed more than another, that is to say, if the object selectively absorbs part of the spectrum, the sum of what is left is color.

A concrete example of the selective and absorptive power of objects is afforded by a very simple experiment.

Nearly fill a black vulcanite dish, such as is used for developing, with a solution of ammonio-sulphate of copper, which can be made by dissolving cupric sulphate in distilled water (about a ten per cent solution will do), and adding strong ammonia until the whitish precipitate which is formed at first is redissolved. A very rich blue solution is formed, and if this is poured into the dish to the depth of about three-quarters of an inch, it will appear quite black. But if a sheet of opal glass or white cardboard is placed in the solution at an angle, so that one end rests on the edge of the dish and the other on the bottom, it will be seen that the solution is actually colored and that the color shades off from the white of the opal glass through all shades of blue to almost black at the other end. This experiment proves in the first place that there must be some reflective surface capable of sending back to our eyes the incident light, and in the second place it also shows that the thicker the stratum of colored substance the deeper the color. In the case in point, the white light incident on the liquid penetrates to some depth, and, without the opal glass, reaches the black surface of the tray. As this reflects no light, the solution appears black; but on the insertion of the glass the incident light meets its surface, which reflects the whole of the light, except that absorbed or suppressed by the liquid. It is obvious that the light actually traverses a double thickness of the solution at any point, first through one distance to the glass and then through the same thickness to the surface again, so that the depth or intensity of color is due to a double absorption.

The processes involved in the above experiment are continually taking place with all objects. Light penetrates below their surfaces to a greater or less depth, and meets a reflective layer; if the substance possesses selective absorption, then the reflected light is colored.

The absorption or suppression of a particular spectral region gives color, and this is roughly shown in the accompanying diagram, Fig. 2. It will be seen that with the exception of green, all the colors are due to the suppression of one region only, while in this case there are two absorption bands, one at each end of the spectrum.

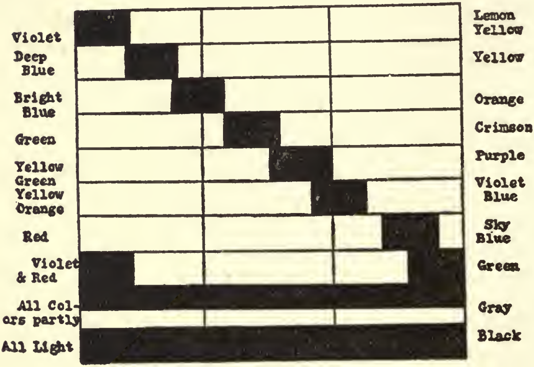


FIG. 2

On the left of the above diagram is given the color that is absorbed and on the right the residual color. It will at once be seen that while we are accustomed to talk of yellows, blues, crimsons, etc., these are not simple colors, but the sum of those spectral regions that are left when a certain band is cut out. It is also evident that if the right and left hand colors be added together the result must be white light, because we are merely restoring that which was temporarily removed. Two such colors, which, when mixed together, form white light, are said to be complementary colors. There are innumerable possible pairs of complementary colors, for it may be said that with the exception of the greens every line or point in the spectrum has its complementary. In the case of green the real complementary lies outside the spectrum, and can only be matched by assuming that instead of the spectrum being a straight line, it is actually a circle with the red and violet overlapping, forming the magentas or crimsons, in which lie the complementaries to green.

If we take two of the complementaries shown above, number II, in which blue is suppressed, with yellow as the resultant color, and number VI, which is violet-blue, and if we assume that we can match these in pigments with lemon chrome and ultramarine, and mix these pigments together, we shall find that we obtain, not white, but a more or less dirty olive-green. This seeming paradox leads us to another fundamental fact, which is that an admixture of pigments does not give the same results as an admixture of lights. Although this is a much misunderstood subject it is really very simple, but we will defer the complete explanation till we have cleared a little more ground.

The length and breadth of the spectrum are, like a camera image, dependent entirely on the instruments used. Everybody knows that the picture made with a vest-pocket camera may include as much of a given subject as a 10 x 12 print; the size of the result is determined by the focal length of the lens and the size of the plate or film, and is not dependent on the subject. It is obvious that if we ignore for the time being the Fraunhofer lines and divide our spectrum from the violet to the red end into equal steps, starting with wave length 4000 for the former and limiting the red to 7000, then we have 3000 different measurable steps which actually differ one from the other in color. Although our eyes are not sufficiently sensitive to differentiate between such fine gradations, yet they are capable of recognizing a great many, about 128 in all. This being the case, the question arises as to how we become conscious of color. Have we, as it were, 128 strings or wires in our eyes, each of which responds to one of these small spectrum steps, or is there some simpler system? Apparently the system that answers all theoretical requirements is a three-wire one. It has been established, principally by the researches of Young and Helmholtz, that we have but three nerve fibrils in the retina, the sensitive surface of the eye, which respond to all the colors of the spectrum. By the simultaneous and equal excitation of these three nerve fibrils we receive the sensation of white, and those of other colors by the action of two of them.

We may, therefore, say that there are three fundamental or primary colors in the spectrum, by the admixture of which we can form all intermediate colors and white. The positions of these fundamental colors are shown by the heavy vertical lines *R. G. B.*, in Fig. 3, and the curves show how the intermediate colors are formed. It will be seen from the diagram that the fundamental red is at about 6700, and this excites but the one sensation; but the green at 5180 not only excites the green-sensitive nerve fibril but also the red and the blue, while the blue at 4600 excites the green and red also, though but slightly. If we now take any intermediate color, such as orange at 6000, we only have to draw a vertical line through this point; the distances at which this cuts the two curves *R* and *G* give the relative amounts of red and green light required to match this particular color, and, as will be seen, this is about 70 red plus 35 green. There is another and very striking experiment, which can be performed by the aid of three projection lanterns; if these are arranged to throw three superimposed circles, the correctly colored red, green and blue-violet filters placed in them, and the three objectives fitted with iris diaphragms, it is easy to show every color of the spectrum. For instance, if we project the red disc, and cap the green and blue lenses, we have the fundamental red color sensation; now, after closing the diaphragm of the green lens to its smallest aperture, we can gradually mix green light with the red by slowly opening the green dia-

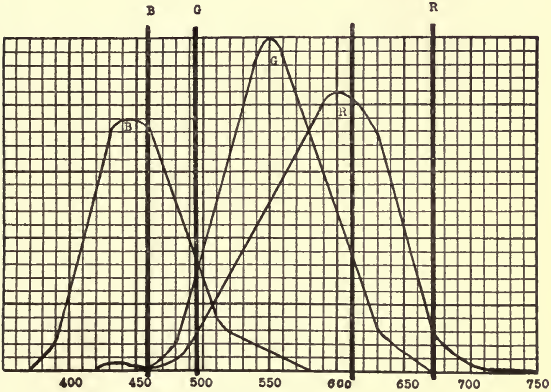


FIG. 3

phragm, when the red light on the screen will be seen to turn gradually more and more orange, until, when both lenses are at full aperture, we have practically a pure yellow. Now, by gradually closing the iris of the red lens, the light will become first yellowish-green, then greenish-yellow, and finally, when the red is completely cut off, pure green of the fundamental hue. In exactly the same way, by manipulating the blue lens diaphragm, we can show the gradual transition of the pure green through all the intermediate shades of greenish-blue and blue-green to pure blue. By manipulating the green diaphragm we can show the transition from pure blue to the fundamental blue-violet, which, for the sake of brevity, is generally called blue. By mixing with this the red, we can run through the whole gamut of crimsons, magentas, pinks or purples, for all these terms are used indiscriminately to designate these colors. Finally, if all three lenses are working at their full aperture, we obtain white, assuming that all three light-sources are of equal intensity; if this is not so, the white obtained will be more or less tinged with color, which may require slight adjustment of one or another of the diaphragms.

We have here the addition of light to light, for we start out with a black screen, that is one without illumination, project red light on it, then add the green and the blue-violet, with the final product of a white screen. It will now be easy to understand how we can show a picture in colors. Let us take the very simplest example, such as pieces of glass with opaque lantern-slide binding strips pasted thereon at different angles, and we can at once grasp the formation of the final colored pattern. Assuming that we have a white circular disc illuminated by the respective fundamental colors, we place in the red lantern a sheet of glass with a vertical stripe of opaque material. Obviously this shuts out the red light, so that we have a result such as shown in Fig. 4. At the sides all three lights are present and give us white; in the vertical stripe the red is cut out, only the green and blue-violet being present, therefore the result is a pure blue stripe on a white ground. Now let us insert in the green lantern an opaque cross with the arms at an angle of 45° to the vertical stripe; then, the green being cut out, the result is a mixture of the red and the blue-violet, which as we have seen is crimson or pink. In the center, where the image of the cross passes over the vertical stripe both the red and green are cut off and only the blue-violet shows. If we now insert a glass with a horizontal opaque stripe in the blue-violet lantern, where this

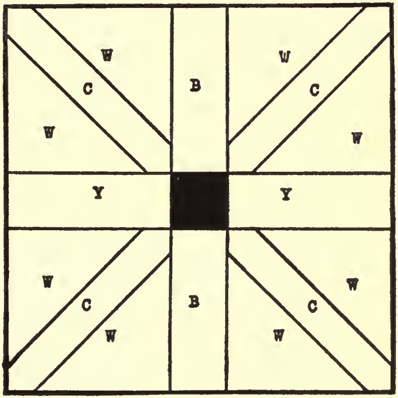


FIG. 4

cuts out this color we have the admixture of the red and green, that is, yellow, and in the center where all three strips cross one another all light is cut off and we have black. The final picture is a white ground with a blue vertical stripe, a yellow horizontal stripe and a crimson cross with a black center. If instead of using opaque strips we use lantern slides, which range in opacities from clear glass to complete blackness, and place one in each lantern, we shall so cut out the respective lights as to give us innumerable tints and shades of color as well as greys and blacks, and as the silver image gives the forms of the objects we have a picture in its natural colors. This is the theory of the additive process.

It is not always convenient to use a lantern or an instrument in which the three images can thus be seen, and we naturally desire to see the results on paper. We have then another proposition, but one which can be explained similarly. We start in this case with an illuminated white surface, and if we place a coating of red pigment, such as carmine, on this, the whole surface will be red. If a green pigment be now washed over the red, the color becomes a dirty indefinite shade, which might be called olive-brown; and if we use over this a blue-violet wash, the result will be black. It is obvious that our fundamental colors as used for the additive process are quite unsuitable for paper prints. But if on top of the red wash we place a yellow one, we obtain a more or less pure orange, and if we superimpose blue, not blue-violet, we shall obtain black, because the blue absorbs the orange made by the red and yellow. Blue on top of yellow gives us a more or less pure green, and in conjunction with red it gives us the crimsons. Therefore, the printing colors are red, yellow and blue.

magenta

The action of the individual colors ought to be clear from Fig. 2, but we can deal with it in another way. Let *A* (Fig. 5) represent the spectrum reflected from a red pigment, and *B* that of a yellow pigment: then if these spectra are superimposed the only colors reflected are shown in *C* from D ½ E to the red, and the sum of these is orange. In the formation of greens we have a similar case: let *D* represent the absorption of a blue pigment, and *E* that of a yellow, then, superimposing these, the only light common to both is the green shown in *F*.

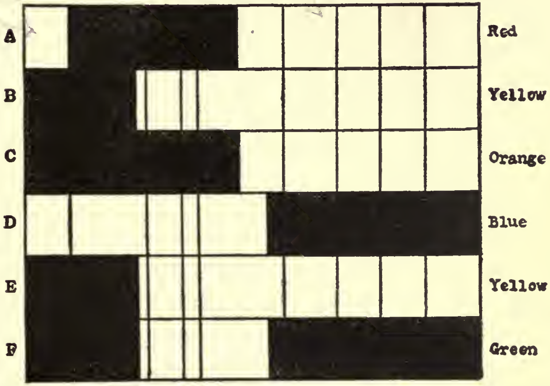


FIG. 5

From what has been said it should be clear that we obtain our colors in the case of prints, and lantern slides as well when they are colored with pigments, by subtracting colors from white light; therefore this process is generally known as the subtractive process.

CHAPTER II

THE SENSITIVE PLATES

EVERY photographer knows that the ordinary plate is practically color-blind, that is to say, it reproduces the violets and blues more or less like white, and the greens, yellows and reds more or less dark or black.

As in color photography we have to reproduce reds, greens and blues as of equal value, the plates used must be sensitive to these colors; therefore, we must use the so-called panchromatic plate. Any plate can be color-sensitized by bathing for a short time in certain dye solutions. While this is not a difficult operation and the resultant plates actually have a higher color-sensitiveness than commercial plates, which are made by the addition of the dye to the emulsion just before coating, it is not a process that can be recommended for the average worker. In the first place, the necessary dyes are very costly, and must be purchased in commercial quantities sufficient for a great many plates, although actually only a very small quantity is used; secondly, efficient drying arrangements must be installed; thirdly, control of results is extremely difficult, in consequence of the many factors involved; fourthly, bathed plates have not such a long life as commercial plates; lastly, sensitizing of plates can not be carried on successfully in a room that has been used for developing and fixing. The author's advice to beginners in color work is to adopt commercial panchromatic plates; quite enough troubles and failures will be met with in the ordinary manipulations without adding extra worries about the sensitive media.

If it is desired to experiment in this field, the following instructions will be helpful. In the first place, it is not advisable to select the fastest plates, as they have, as a rule, a greater tendency to fog than slower ones, and this tendency is always increased by bathing, particularly if the plates are to be kept some time. It is not advisable to bathe less than a dozen plates at a time. A medium plate, normally clean-working, should be chosen. Before entering upon the actual bathing process, it may be as well to point out that as the plates are rendered sensitive to red it is not advisable to use red light for the dark-room illumination. It can be used, but as one can see far better with a green light of equal power it is preferable to use one of those described later on (See P. 41). But the plates should not be unduly exposed even to one of these, and with a little experience it is astonishing how easy it becomes to work in total darkness, just switching on the green light as required.

While grooved troughs are the most convenient for bathing a dozen plates, they are very wasteful of solution, and so flat dishes should be used. If one sufficiently large to hold four plates at once be employed, it is almost as easy as using a trough. An interval timer, clock or watch, is an absolute essential. A grooved trough is preferable for washing. There is one extremely important detail, on which the author lays great stress, and that is that *the dish used for sensitizing should have been used for no other photographic operation and should be kept for this sole purpose*, particularly if of earthenware, as this soon acquires surface cracks into which the developing and fixing solutions enter, so that minute traces of these are extracted by the dye solutions and all sorts of curious markings and fog may be the result. Glass vessels are preferable to all others and they should be of the deep variety. In no case must metal dishes be used for sensitizing, as there seems to be some peculiar action that results in the formation of a characteristic coarse-grained fog, which increases somewhat rapidly with time.

As regards the drying apparatus, a proper drying cupboard with a constant supply of heated air is naturally the most convenient, but, failing this, the simplest arrangement is a light-tight, and as far as possible air-tight, box. This should be of generous size; 24 x 12 x 12 inches is not too large for a couple of dozen ¼ plates. The author used for a long time an ordinary metal deed box with draught-excluding rubber tape round the lid. In the center of the box should be placed a block of wood, which should be of a goodly size, for instance, for the above size box 9 x 6 inches, and of such a height as will permit a flat dish to be placed on top and yet allow the lid to be properly shut, with about an inch to spare above the top of the dish. This dish should be filled with desiccated calcium chloride, which can be obtained from any chemical house. It should not be in too large lumps nor in powder; about the size of small walnuts or chestnuts is right.

The plates should be arranged round the sides of the box with the sensitive surface facing the center; they must not be placed with this side towards the walls of the box or unequal drying will ensue with unequal sensitiveness and more or less fog. It is advisable to place on the bottom of the box two or three layers of clean stout blotting paper, which prevents the plates from slipping.

A far more convenient arrangement is the use of an electric dryer such as is used by hairdressers; this can be attached to any electric light socket, and if an endless box be used to confine the air currents, it will be found possible to dry a dozen plates in less than half an hour. This is a great advantage, as it may be accepted as an axiom that the more rapidly bathed plates are dried, the greater their keeping power and the greater their freedom from fog, with increased color-sensitiveness. The box should be about two feet long and sufficiently large to accomodate two wooden drying racks, placed one behind the other, but too much space must not be allowed around the ends of the racks. The dryer should be placed at such a distance from the end of the box that the temperature half way down the box should be from 33° to 35° C. (90° to 95° F.).

Many dyes have been suggested for panchromatizing and more formulas for sensitizing, but as simplicity and ease of attaining results are among the main features that have been kept in view throughout this work, but one formula will be given, which has proved to be entirely satisfactory in practice. The dye recommended is that known as sensitol violet, and this should be prepared in the form of a stock solution, which will keep in the dark indefinitely. The following directions, which might seem unnecessarily diffuse to the expert worker, are thus given for the benefit of those without experience. In a dry 500 ccm flask place 1 gram of the dye and add 100 ccm pure ethyl or methyl alcohol. Shake with a circular motion so as not to distribute particles of the dye on the upper parts of the flask; then place the flask in a water bath at about 30° C. (84° F.) and raise the temperature gradually to 65° C. (150° F.), giving the flask an occasional swirl round. Then add 400 ccm cold alcohol and after shaking gently pour into the stock bottle; measure another 200 ccm of cold alcohol into the flask and swirl round so as to wash off any adherent dye solution, then add this to the stock bottle; now pour 300 ccm distilled water into the flask and after shaking well add to the stock bottle. The result will be a 1 : 1000 stock solution of the dye, *which must be kept in the dark.* It may be as well to remark here that, owing to the difficulty of making up extremely dilute solutions to exact percentages by means of English weights and measures, the experimenter in color should accustom himself to work in the metric system, and acquire the necessary weights and measures. If this be impossible, a conversion table will be found at the end of the book.

Unfortunately all the isocyanin dyes, to which class this dye belongs, are more or less sensitive to acids and are more or less decolorized by them, and when in this bleached state they have little or no color-sensitizing power. They are so sensitive to acid that even the small amount of carbonic acid present in distilled water is sufficient to decolorize them, so that it is necessary to make the water for the actual bath alkaline. Ammonia is the alkali generally used, but while it is efficient it is dangerous, unless used in very minute quantities, that is, not more than one or two drops per 100 ccm of the bath, as it induces the rapid growth of fog. Borax is a far better alkali to use, as there is less likelihood of fog with keeping. The actual sensitizing bath is:

Stock dye solution	20 ccm
Borax, pure	2 g
Distilled water	1000 ccm

Dissolve the borax in the water first, then add the dye solution with constant shaking. The above quantity of solution is sufficient to sensitize about 500 square inches of plate surface, or thirty 4 x 5 plates.

Slightly higher color-sensitiveness may be attained by using with the sensitol violet an admixture of orthochrom T. This dye should also be made up into a stock solution in the same way as the violet; but the sensitizing bath will then be:

Stock sensitol violet solution	10 ccm
Stock orthochrom solution	10 ccm
Borax	2 g
Distilled water	1000 ccm

The advantage of this batn is that a rather better green sensitiveness is secured, and also slightly general higher speed to white light, or, in other words, the exposures are slightly shorter. The difference, however, is but slight and in practice the plain sensitol violet bath will be found quite satisfactory.

From the data given above as to the area that may be sensitized with these baths, it will be seen that a dozen plates will require just 400 ccm of solution, so that the procedure is fairly obvious; place four plates in a dish and flood them with an even regular sweep with 133 ccm of the dye solution. Rock the dish gently first from side to side and then end for end for four minutes, pour off the solution into a waste bottle, set the dish up at an angle so as to allow the remains of the solution to drain down to one corner and off. Then pour on the plates 300 ccm alcohol (ethyl or methyl) and rock the dish for one minute. Remove the plates one by one, giving them a rinse up and down to make sure that the dye solution adherent to the back of the glass is rinsed off by the alcohol. Then place them in the draining rack, not more than four plates to the twelve-plate rack and push the rack into the farther end of the drying tunnel which has the hot air blowing through it. The rack should not be pushed more than about three inches into the tunnel.

The alcohol used for rinsing may be poured into a graduate, the dish stood on end to drain and four more plates treated in like manner with another 133 ccm of sensitizing solution. The same alcohol may be used for rinsing and again poured off for the third lot of plates, which are treated in like manner. The second batch of plates should be placed in another draining rack and pushed into the tunnel, thus pushing the first rack nearer the source of heat. The third lot of plates is treated in like manner and placed in the third rack, and by this time, the plates in the first rack should be quite dry.

The racks should be placed in the tunnel so that the surface of the plates is parallel with the current of air, and not at right angles to it; this ensures a complete change of air over the whole surface of the plates, whereas if they are placed at right angles to the air-travel, only the first plate gets the full benefit of the hot air and the others are more or less in dead air pockets.

This is not the cheapest method of working, but the author has proved it in practice to be one of the most reliable, and when one considers that the actual cost of the dye and drying alcohol is approximately $2.00 for thirty plates it is not a serious item.

There are, of course, all sorts of variations of this procedure. For instance the whole 400 ccm of dye may be put into the dish at once, and poured out into a graduate at the end of the time required to sensitize each batch of plates, and more alcohol may be used or a fresh batch each time; or the plates may be lifted out of the dye solution and placed in another dish for the alcohol bath; but the less the plates are handled the easier the work becomes. As already stated either ethyl or methyl alcohol may be used; denatured spirit is dangerous unless one knows what the denaturant is, and should be avoided. There is one point that has not been mentioned and it is extremely important. If the sensitizing and drying is carried on in a room that is used for ordinary work, such as developing and fixing, it may be taken as an axiom that it is impossible to prevent insensitive and other spots occurring. The drying fan draws the air from the room and any particle of hypo settling on the damp surface will cause an insensitive spot, while developer dust will give rise to black ones. The dimensions of the drying tunnel should be kept as small as possible, taking into consideration the size of the drying racks. These can, as a rule, be cut down considerably in height, as the legs can usually be shortened. The smaller the tunnel within reason, the more the air is confined and, therefore, the quicker the drying.

Taking all things into consideration, there can be no question that for the beginner in color work commercial plates are preferable. Their keeping power is certainly much greater, one is certain of having them free from drying spots and stains, and most of the makers issue with each box a card that not only tells one the correct ratio for the filters, but also the correct time of development to obtain a given degree of contrast. Above all things, one can obtain them backed, and thus there will be saved one of the worst jobs for the home worker. A backed plate gives much better results than an unbacked one, if the proper backing is used, and as the plate is sensitive to all colors it is obvious that the only efficient backing must be black. It is not a difficult matter to make a black backing, and one the author has used for years is:

Dextrine	100 g
Water	100 ccm

Heat till dissolved and then stir in:

Ivory black, water color paste	1000 g

Continue stirring until thoroughly incorporated. As this is sufficient for a large number of plates and it is apt to mould if kept, it is advisable to stir in about 10 ccm of phenol (carbolic acid).

There is no lack of commercial panchromatic plates, as Eastman Kodak Co. (Wratten & Wainwright), the Ilford Co. and the Cramer Dry Plate Co. all issue plates of excellent quality and color-sensitiveness, which may also be obtained backed on request. It would be invidious to single out one particular make as better than the others and also unfair; but naturally most workers have their own pet brand, as every smoker favors one particular tobacco. The author in no wise differs in this respect, but his favoritism is based on many years' use of one particular brand and while there is very little logical reason for it, he always thinks that he can obtain better results with this particular make. Plates certainly differ in their characteristics; assuming that they all have the same color-sensitiveness, the chief differences lie in the velocity constant of development, and increase of fog with time of development. The old advice that has so often been given for ordinary work applies with equal force to color work; that is, choose one plate and stick to it.

As regards the use of film for color separation work, the only plan that can be adopted is to use commercial panchromatic film and it must be in one piece. The author's experience has proved that to use three separate films is almost a hopeless task, in consequence of the unequal expansion and contraction of the celluloid making it practically impossible to obtain correct superposition of the images. On the other hand, if this must be used and the worker is determined to sensitize it himself, the same sensitizing baths may be used, but the alcohol bath must be omitted, or the film will either roll up into a tight spill that is utterly useless, or will be so distorted by partial solution of the celluloid as to be quite unworkable. The sensitizing bath can be somewhat improved by the replacement of 10 per cent of the water by the same volume of methyl alcohol, and after sensitizing, the film should be washed for ten minutes in frequent changes of distilled water to which 0.2 per cent of borax has been added.

CHAPTER III

COLOR FILTERS

TO explain the action of tri-color filters it is necessary to recall the statement that all colors can be formed from three fundamental colors. But while we have seen that these three fundamental colors give rise to the three color sensations, it must not be thought that there is any closer connection between the sensation curves, shown in Fig. 3, and color photography. The color sensation curves are quite useless for color photography, although this is actually founded on their physiological action, except when we use the additive process, when the illumination of the three positives should be made by the physiologically correct or fundamental colors. But for subtractive work, and for the making of the negatives for the additive processes, the color sensation curves are not of the slightest practical value.

The first essential is to split up the spectrum or any colored subject into three regions; the one representing all the red, another all the green, and the third all the blue. It has been found that the most satisfactory results are obtained when the spectrum is divided into three zones, shown in Fig. 6, in which *R* represents the region transmitted by the red filter, *G* that of the green filter and *B* that of the blue-violet filter. A comparison of the curves with the color sensation curves in Fig. 3 will at once show that there is but little similarity; in the former the curves are gradual and all three overlap one another at many points, whereas with the filters they cannot be legitimately called curves, but are abruptly ending regions with limited overlap at only two points, in the golden-yellow, at the D lines, from 5900 to 5800, and in the blue-green from 5000 to 4800.

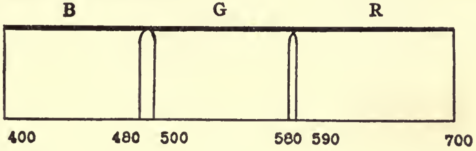


FIG. 6

If we separate these three curves we shall obtain a fairly clear idea of the action of the filters. In Fig. 7, *R* shows the action of the red and the blank portion is that which corresponds to the shadows of the negative. In *G* the action of the green filter is shown, again with the

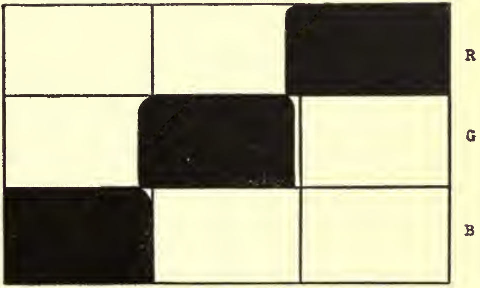


FIG. 7

blanks representing the shadows, and *B* represents the blue with the blank shadows. Now as it is the shadows of the negatives that print, the bare parts of the above diagram represent the parts that would print, therefore, positives or prints from the above would be represented by Fig. 8, in which the black parts show the parts that must not show in the additive process, that is when we project by colored lights; while in subtractive processes, that is in prints, they represent the colors that must be present. We may, therefore, tabulate these results as follows:

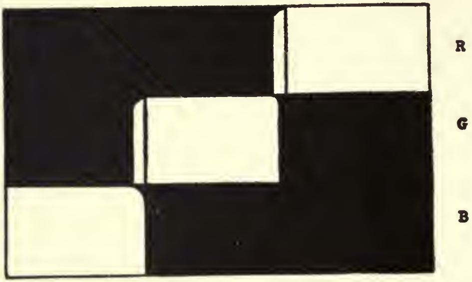


Fig. 8

Filter	*Additive process Projecting color*	*Subtractive process Printing color*	
Red	Red	Blue-green	Minus blue
Green	Green	Red	Minus red
Blue-violet	Blue-violet	Yellow	Minus yellow

It will thus be seen that one may assume that the subtractive printing colors are the complementaries of the filter colors, and for this reason the corresponding negatives are frequently referred to as the "minus color" plates, as shown in the fourth column.

As the limits of the transmission of the filters are set by the above statement, we have merely to make filters that will show these cuts. The most satisfactory method is by the use of aniline dyes, dissolved in gelatine and cemented between glasses to protect the stained film from damp and mechanical injury, for every photographer knows that gelatine readily absorbs moisture, and that it is easily damaged by dirty or damp fingers.

In the early days of color photography it was usual to employ glass-sided cells filled with colored solutions, and they are still employed sometimes in commercial establishments, such as photo-mechanical studios. But for the dilettante they are the most unsatisfactory form of filter that can be used, and also when of sufficiently good quality to allow large aperture lenses to be used, are very costly, so that we shall not take them into consideration at all. The preparation of the correct filters does not present insurmountable difficulties for the average worker, and it should be looked upon as part of the preliminary training for every worker to make a set of filters. Yet it must not be overlooked that it is actually much more expensive to make them and the results are rarely as satisfactory as the commercial filters. However, we will proceed to describe the preparation of a set.

The apparatus required will be a sheet of plate glass, not less than 10 x 12 inches in size and about half an inch thick; three leveling screws and a level; some sheets of plate glass about one-fourth inch thick and sufficiently large to allow a margin of at least one-fourth inch all round the largest filter that is required; a beaker of 500 ccm capacity, another of 100 ccm, and an accurate 10 ccm pipette. The materials required are some soft photographic gelatine, of which about 100 g will be ample, and small quantities of the following dyes; rose Bengal, tartrazin, patent blue, acid rhodamin, toluidin blue and naphthol green. About 10 g of each will be plenty. We also need some squares of patent white plate glass, about one-sixteenth inch thick and of the necessary size to cover the lens completely without cutting off any of the light from the plate, and some Canada balsam, dissolved in xylol, as used by microscopists, which can be obtained commercially; it should be noted that a chloroform solution of the balsam must not be used.

The large sheet of glass is merely used as a support for the gelatine-coated glass, so that the film shall set of an even thickness all over, and therefore, its actual size is not of real moment. It is frequently possible to pick up a fairly large piece from a glass dealer at a very reasonable price, because scratches and flaws will not matter. The smaller pieces of glass, one-quarter inch thick, are used to coat the dyed gelatine on, while the one-sixteenth inch pieces are used for the final filter. Both should have perfect surfaces. The reader may possibly wonder why the dyed gelatine cannot be coated directly on its final support; if this were done, the chances are that the filter would not be flat, for the gelatine contracts in drying and distorts the glass, that is bends it into a shallow curve, and the result would be that the filter would slightly alter the focus of the lens; as this filter curvature might not be equal in all three filters, the foci for the three colored images would differ and the images would be of unequal size, and possibly not equally sharp, and as we have to accurately superimpose the constituent positives, the outlines of the subject would not coincide and a confused jumble would be the result, or we would get color fringes.

For this reason also, it is important that the final filter glass be flat, and this is one of the difficulties in making filters, that is, to obtain six pieces of glass that are sufficiently flat to be serviceable. To test the glass for flatness, place it on a flat black support such as a focusing cloth or piece of velvet, this being placed at an angle of 45 degrees on a table about six feet from a window; then, on looking down on it, the image of the cross bars of the window will be seen reflected and usually a double image, one from the front and a fainter one from the back of the glass. If the glass or the eye be now moved so that the images are reflected from all over the surface, we can easily see whether the two surfaces are parallel, as then the two images will keep the same distance apart, whereas if lenticular they will either diverge or converge. Pieces showing this defect should be rejected. If the images are not straight, the glass is also curved. It has been assumed that the glass is bought cut to the required size; if it is bought in a large sheet it can be examined in the same way and the flat parts marked with a piece of soap and subsequently cut out; but this presumes knowledge of how to cut glass with a diamond or wheel. This, like everything else, is extremely easy when you know the trick, but it will probably be better to purchase the glass ready cut and select the good pieces.

The size of the filter is easily determined, and a rough and ready way is to measure the diameter of the lens hood, not the glass, and allow one-quarter inch beyond this; this is assuming that the filter is to be used on the lens, as it will be seen later that there are other positions. A more correct method is to use a diagram such as is shown in Fig. 9, in which *L* represents the lens racked out from the plate *PP*, to its equivalent focus; then, by drawing a line from the corner of the diagonal of the plate through the lens, the size of the filter can be at once determined by actual measurement, as the distance between the line from the corner of the plate to the straight line *A* which is a prolongation of the optical axis of the lens will give at once half of the necessary width of the filter. Obviously the further the filter is from the lens the larger it must be if it is not to curtail the field or the light.

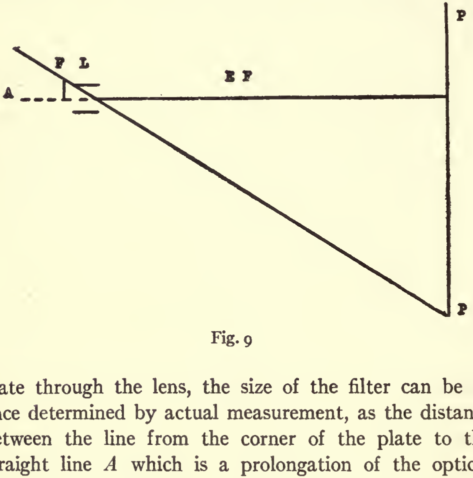


Fig. 9

The gelatine solution is prepared as follows: Distilled water must be used and it is well to make up a generous quantity of the solution, say about 400 ccm, as it is decidedly better to waste some than to run short. As a 10 per cent solution is required, we weigh out 40 g of gelatine, place in the 500 ccm beaker, cover with distilled water and stir it well for two or three minutes, then pour the water off and repeat the washing, allowing the gelatine to soak for ten minutes the second time and fifteen minutes the third, stirring it occasionally. Then as much water as possible should be pressed out by means of a glass rod and the beaker placed in hot water at 55° C. (130° F.), when the gelatine will gradually melt in the water that it has absorbed and enough more is added to make the bulk up to 400 ccm. The solution should now be filtered through a double thickness of well washed and wetted linen; an old handkerchief does well for this.

The dye solutions are preferably prepared in the form of stock solutions as follows: 1 g to 100 ccm for rose Bengal, patent blue, acid rhodamin and naphthol green; 2 g to 100 ccm for tartrazin and 0.5 g to 100 ccm for toluidin blue. These quantities should be placed in clean, well-dried bottles, 100 ccm of hot distilled water added, the bottles well shaken for half an hour and then allowed to stand so that the solutions may settle. The quantities of the dye (not solutions) needed for the average size of filter are very small and, therefore, the amounts for a square meter are given, from which it will be easy to calculate that for any given size:

For the red filter:	
Rose Bengal	1.25 g
Tartrazin	2.0 g

For the green filter:

Naphthol green	0.4 g
Patent blue	0.2 g
Tartrazin	1.0 g

For the blue filter:

Acid rhodamin	0.6 g
Toluidin blue	1.8 g

The usual quantity of gelatine solution employed is 700 ccm per square meter, which gives a dry filter thickness of about 0.4 mm; it is advisable to adhere always to a given volume of dyed gelatine for a given area.

We can now prepare the glass. This should be placed in a mixture prepared as follows. Make the following solution:

Potassium bichromate	50 g
Water	250 ccm

Then add gradually:

Sulphuric acid	25 ccm

Stir well and add:

Water to make	1000 ccm

Fill a developing tray with this solution and immerse the glasses, using a flat strip of wood to lift them, as the solution bites the skin. Really the best way to clean the glasses is to immerse one at a time and scrub the surface with an old tooth brush or a temporary mop, made by tying some old rags round the end of a short stick, then turn the glass over and scrub the other side, lift out with a stick and drop it into hot water, then start cleaning another glass and remove the first from the hot water, give it a rinse in distilled water and put in a rack to dry. Then put the second glass in the hot water and finish all in this way. It is possible to put six or more glasses into the cleaning liquid at one time, but in doing so there is a very great chance of scratching one or more of the glasses with a sharp edge or corner, and although cleaning them singly is more trouble and takes more time, it pays in the end.

When the glasses are dry they should be carefully polished with a clean rag. These glasses are used for the first coating and the dried dyed film has to be stripped from them, but unless they are perfectly clean it will not peel, and even then it is not always an easy matter. All sorts of dodges have been suggested, such as collodionizing the glass, waxing it, or polishing with talc; but we may be content with a very simple plan. Add about ten drops of almond or olive oil to 100 ccm of benzol, pour five or six drops of this on the glass and rub over with a tuft of absorbent cotton, and then polish with two pieces of clean dry linen. An old handkerchief again comes in handy, as it is usually fluffless; this will clean the surface and yet leave the merest trace of oil, which makes it easy to strip afterwards.

If the size of the finished filters were to be 5 x 5 cm, we would naturally choose the first glasses 12 x 12 cm, so as to get four filters from each sheet, which gives a chance to pick and choose. To cover 144 qcm at the rate of 700 ccm per square meter, we shall require 10 ccm of dyed gelatine and very small quantities of the dyes, for instance in the case of rose Bengal 0.018 g and 0.028 g tartrazin, which means 1.8 ccm of the first solution and 1.4 ccm of the second. While it is possible to measure these quantities with a good pipette, it is preferable to make at least 50 ccm of the dyed gelatine;

we, therefore, measure 34 ccm of the plain gelatine solution, mix 9 ccm of the rose Bengal solution and 7 ccm of the tartrazin, and add these to the gelatine solution; after stirring well, 10 ccm should be coated on the glass.

Every worker has his own particular method of working, and the author is addicted to the use of the pipette for coating, as it has been found easier to lead the gelatine over the surface of the glass with this than by pouring out of a small graduate, and there is less chance of bubbles. If these do occur they can very easily be led to the edge of the glass, where they will do no harm, and can be broken by touching with a spill of blotting or filter paper.

It is important that the room in which the coating is done be not too cold or the gelatine will set before it is possible to spread it over the glass, and the stock of dyed gelatine should be kept at a proper temperature. It is easy to do this with a water bath, and 45° C. (123° F.) is a comfortable temperature to work at, as the gelatine can then be easily spread, and it sets rather rapidly to an even surface. As soon as thoroughly set, the coated glass should be reared up on edge to dry and the method suggested for drying sensitized plates may be adopted, but dust must be carefully guarded against, and before commencing to coat, the working bench should be well washed down with water so as to ensure that no dust lies about. Rapid drying is not of such moment with filters as with sensitized plates, but it should be as even as possible; if it takes too long, the film may become pitted with small colonies of spots due to bacterial growth, particularly in hot weather.

When the gelatine is perfectly dry, it should be cut all round the edges, about 2 mm inside, with a sharp penknife, and usually it is possible to lift one edge with the knife and, by taking hold of the free edge, to strip the whole film; if not, it should be held for four or five minutes about two feet above a bowl of steaming water, when it should strip without trouble and without stretching. As soon as stripped, the film should be placed between tissue paper and stored between the leaves of a book. The used glasses can be freed from the narrow strip of dyed gelatine by scraping with the knife, repolished, and again coated with the second lot of dyed gelatine, but it is preferable to have at least six glasses and coat them one after the other, thus making one job of it. Naturally the pipette will be well scoured out with hot water.

It will be seen that the process is not such a difficult one and with a little practice it is easy to become so expert that a failure is rarely met with. But for years the author has given up coating his own filters, except for experimental purposes, and is content to buy commercial filters. The results are absolutely certain and the actual cost is so very little, that taking into consideration the difficulty of getting good glass and the fact that one has to buy much larger quantities of dyes than one needs, commercial filters actually work out cheaper in the end.

Commercial filters can be obtained in the form of film or cemented between glasses. Assuming that the worker has made his own filters or bought commercial film filters, we come to the operation of cementing them, which is not nice. The final glass must be carefully cleaned and the polished surfaces should be placed in contact, pair by pair. We now want to fasten these together like a book cover, and use for this purpose a piece of lantern-slide binding, making quite sure that the edges are even. This can easily be done by placing the wetted strip on a yielding surface, such as an open book; then, holding the two glasses together, lower them on to the strip with an equal margin on each side, press down, and rub the edges of the strip into contact with the sides of the glass. There is no need to let this get absolutely dry, but it should not be wet. The dyed film, cut to the same size as the glass, is slipped between the two glasses and all edges made to coincide. The filter should now be laid down on a sheet of hard card or paper, the top glass and the gelatine film lifted up together, and a pool of balsam poured on the lower glass near the hinge. Enough balsam should be used to cover about one-fourth of the surface of the glass. The gelatine film should then be carefully lowered down on the balsam, another pool of balsam poured on the gelatine and then the top glass lowered. Gentle pressure, starting from the hinge, will force the balsam out to all the edges without the least air bubble. If one does show, it can be chased to the edge by pressure of the fingers. A good sized metal bulldog clip should now be clipped on the glass at right angles to the hinge, as far in as it will go and then another applied opposite the first; the paper hinge should be scraped off the edge with a knife, paying no attention to that on the flat of the glass, and a clip placed here and then one on the fourth side. The filter may then be reared up on one corner to allow the balsam squeezed out from its edges to run down. When all the filters are cemented, begin with the first, wipe off the exuded balsam with filter paper or a bit of old rag, and leave the filters to dry.

They really require a warm place and should be left three weeks in a flat position, so that as soon as the first lot of exuded balsam has been wiped off they should be placed flat on a glass or shelf with a piece of paper underneath them, as the balsam that exudes will cement them to any thing that they touch. Balsam is one of the stickiest of all sticky substances and the best way to clean the fingers is to well wet newspaper with denatured alcohol and rub well, using as much clean paper as possible and then benzol and paper, followed by plenty of soap and hot water.

An alternative method is to leave the hinge on, place the filter on a thickness or two of blotting paper on a level surface and place a card on top with a good-sized weight, four pounds not being too heavy for a 12 x 12 cm filter. Direct heat cannot be used for drying, as this causes the edges to dry first and gives rise to distortion.

At the end of the three weeks the exuded balsam should be scraped off, and the glass cleaned with alcohol and newspaper, then with bits of cloth and finally polished. Do not try to be sparing with the cleaning cloth, or use one large cloth; little bits and each piece thrown away as soon as it gets sticky is the easiest way. The final polishing should be done with tissue paper and alcohol, following the same plan, that is, fresh pieces continually. Benzol, xylol or chloroform should not be used, as they are energetic solvents of balsam and will almost inevitably creep in between the edges, in which case the job will have to be done all over again.

Those who would like to make their own preparation of balsam may purchase some dried Canada balsam from a lens worker or optician. This should be roughly powdered, which is most easily done, though it is rather wasteful, by tying it up in a cloth and hammering it with a heavy hammer; a fine powder is not wanted but the big pieces should merely be broken up. Then place this in a wide mouthed bottle, place in the water bath and bring the latter slowly to a boil, stirring the balsam all the time; add about one fifth of its weight of xylol, stirring well and then letting it get cold in the water bath. This preparation requires a much higher temperature to melt and must be used hot. It then sets very quickly and at a pinch a filter thus cemented may be used the next day. The only difficulty likely to be met with is the setting of the balsam before an even film is obtained, but warming the glasses, or keeping them on a hot plate for some time under pressure will soon make the balsam spread out.

There are four possible positions for the filter; in front of the lens; between the combinations close to the diaphragm; behind the lens; and immediately in contact with the sensitive surface. Between the lenses is the very worst place to choose, although this requires the smallest filter, as is obvious. In the first place, it is very likely to upset the corrections of the lens, particularly with the later forms of anastigmatic lenses, and with these there is often not enough room to insert any other than a film filter. Secondly, it is not easy to change the filters in this position without some special fitting, so that we can dismiss this at once. Either in front of or behind the lens may be chosen, which one being a matter of indifference, provided focusing is always effected through the filter, a matter that we shall have to deal with later on when talking of screen plates (See Chapter XII). In either case some sort of sliding fitting is advisable, although this is not convenient in some cases inside the camera, as not only may the rear lens protrude beyond the lens board, but one has to have some means of shifting the filter between exposures, which necessitates a light-tight fitting.

It is possible in many cases to arrange a frame to slide over the camera front, and to fit the ordinary lens panel on this, so that the filters will be behind the lens. The sliding frame can be made on the same lines as the usual lantern slide carrier, and if velvet is used to line the outer frames there will be no trouble in making it light-tight. Or it may be possible to fit such a frame on the lens barrel itself, but here it must be so securely fastened that there is no chance of its slipping off. Really the simplest plan is to obtain one of the square slip-on cells, which, fitting on the lens hood or barrel, may be always retained in position and the filters merely lifted out and inserted as required. It is advisable, if possible, to remove the lens hood and fit the holder on the barrel, as this means not only slight reduction in size, but as a rule a firmer hold. In order to obtain the correct size of fitting, the diameter of the lens tube should be taken with a pair of sliding calipers. Failing these, the next best plan is to take a narrow strip of hard writing paper and wrap round the lens barrel so that the ends overlap by about half an inch, then with a sharp penknife cut right through both pieces of paper midway of the overlap, not at the end.

Placing the filter close to the plate means that the filter must be of the same size as the plate. Defects in the filter, such as want of absolute parallelism of the surfaces, are here of the least consequence; but local defects, such as coating striae or bubbles, are more apparent on the negative image, though only locally.

Special sliding backs can be obtained commercially, fitted with the three filters and made to take three plate-holders, or with some plate-holders, particularly of the English book-form pattern, the filter may be placed in actual contact with the sensitive surface; then naturally its thickness must be allowed for in focusing.

One important point in the choice of filter fittings, particularly metal ones, is that there should be no abnormal pressure on the glasses, as this may cause strain and consequent degradation of definition. It should be possible to turn the filter round, or shift it, with the lightest pressure of the fingers. Neither is it advisable to use cells screwing into the lens hood, as this is almost certain to shake the camera and there is much loss of time in changing.

For photomechanical work, in which long-focus lenses are nearly always used with half-tone screens, the glass must be optically worked, as carefully, in fact, as the lenses themselves. Such glasses are known commercially as "optical flats," and are very costly if of any size. They must all be absolutely the same thickness and be so arranged that they are always perpendicular to the axis of the lens.

The ordinary filters may be used for making the separation negatives for photomechanical work, as if there is not absolute coincidence of size, this can be corrected by the operator when making the screen negatives from the transparencies, though he will not be pleased at having to do this.

It may possibly be as well to interpolate here a note as to the making of the constituent negatives for photomechanical purposes. The use of the panchromatic gelatine plate for this work is largely on the increase, and in some cases the slow panchromatic plate is used for making the color separation and the screen negatives in one; but the usual practice is to make the separation negatives first, from these a set of transparencies, and then the screen negatives. It may be noted that the transparencies for such work should be as little like a lantern slide as possible. They should be fully exposed, quite "soft" in character, and with practically no bare glass except in the very deepest shadows. Full exposure should be given to the plates, and it is better to use slow negative rather than transparency plates for this work, as giving a longer range of gradation and less tendency to brilliancy. The exposure should be full and development not pushed too far, so that the highest densities are quite transparent.

In many commercial process establishments collodion emulsion, and even the wet plate process, still hold their own for the making of the separation negatives, and also the combined separation-screen negatives. Usually the emulsion is obtained commercially with its special sensitizers, and the makers issue instructions for the making of the filters, which are usually of the liquid cell type, for use with the same. On the other hand the method of sensitizing already advised may be adopted, or the dye may be added to the emulsion, and in this case 80 ccm of sensitol violet stock solution should be added to 1000 ccm of the plain emulsion, and the plates washed in running water or under a rose tap for fifteen minutes. The washing increases the sensitiveness of the plates about five times.

By some writers it has been proposed to use different plates for the different color separations, that is to say, an ordinary, non-color-sensitive plate for the minus yellow negative; an orthochromatic plate for the minus red negative; a panchromatic or red-sensitive one for the minus blue negative. This plan may at first sight appear to have certain advantages, but this method is not one that should be adopted. It is a well established fact that the degree of contrast, or gamma, differs with different kinds of plates, and in fact with different batches of the same kind of plate, to say nothing of the development velocity of the plates, and one of the most important essentials in making separation negatives is to have them of the same degree of contrast as far as possible. That is to say, in the three negatives the range of densities of a black and white scale should be the same; and with three totally different kinds of plates this is almost an impossibility. One kind of plate should be used for all three separation negatives, and they should be, as already pointed out, as far as convenient, developed together. The adoption of this plan will save no end of after manipulation and dodging in getting concordant results; and it may be taken as an axiom that hand work, except for the removal of purely mechanical defects, such as pinholes, etc., cannot be successfully executed with color negatives.

CHAPTER IV

THE DARKROOM

AS the plates used for color photography are sensitive to all colors, it is obvious that we cannot use the normal red light for illumination of the dark room, and if this were reduced, as it can be, so as to be safe for the panchromatic plate, the light would be so weak that it would be practically impossible to see anything. It is an established fact, however, that the eye is seven hundred times more sensitive to green light than to red, therefore, a deep green light is used for color work. But even with this it must not be forgotten that the plate is sensitive to green, hence undue exposure of the plate should be avoided, and it is advisable either to work in the shadow of the lamp, or to provide a cover for the dish; the former is preferable, as it enables one to rock the dish during development.

Green safelights can be obtained commercially and also green-stained papers, which can be placed between two glasses and used instead of the ordinary red screen. They can be also home-made, and as they do not require such a careful adjustment of the quantity of the dyes as taking filters, they are fairly easy to make. They require no other dyes than those used for the filters, that is, one can use naphthol green, patent blue and tartrazin, or instead of the patent blue, brilliant acid green may be used. A suitable formula is:

Patent blue	1.75 g
Naphthol green	1.75 g
Gelatine, 8 per cent solution	700 ccm

This is sufficient for 1 square meter. This screen should be bound up with another one prepared from:

Tartrazin	5.5 g
Gelatine, 8 per cent solution	700 ccm

When dry the two filters should be bound up together with a piece of tissue paper in between to diffuse the light. Only the two sides of this safelight should be bound; the top and bottom should be left free, so that any moisture, which might be driven out by the heat of the lamp, may escape. It is preferable to place the yellow-coated glass next the light source. The patent blue in the above formula may be replaced by brilliant acid green with equally satisfactory results.

It is possible, however, to make these safelights by merely soaking old plates in dye, or even old negatives may be used, provided the silver images be dissolved by the familiar hypo and ferricyanide reducer or potassium cyanide solution and the plate then well washed. The gelatinized glasses thus obtained should be soaked in either the patent blue and naphthol green solution or preferably in the following:

Brilliant acid green	5 g
Naphthol green	5 g
Water	1000 ccm

Soak for thirty minutes and then rinse and dry. A glass should also be soaked in 2 per cent solution of tartrazin for the same time, and when dry the two screens can be bound up together with paper in between as already advised. To make these lights safer still, the tissue paper may be soaked in the acid green solution, or one or two thicknesses of paper used, or even thin blotting paper employed.

To those unaccustomed to work by green light the room will at first appear very dark, almost black in fact, but as the eyes become accustomed to the light it will be found that the illumination is quite sufficient and actually it soon appears so bright that one may get the impression that it is unsafe. The time needed for the eye to become accustomed to the light depends a great deal on the outside illumination; if one enters the room from a room which is brightly lit, particularly by daylight, it may be twenty minutes or more before full vision is obtained. With use one becomes so accustomed to the green light that it will be found preferable even for ordinary negative work.

But now we are in a position to state that even this dim green light is unnecessary, as it has been discovered that certain of the aniline dyes possess the peculiar property of desensitizing the silver salts, so that one has only to soak the plate in a weak solution thereof or add some dye solution to the developer, to be able in about a minute to use a bright yellow light for development, and this process in no wise affects the image. The best dyes for this purpose are phenosafranin or the ammonium salt of aurantia; stock solutions of these dyes should be made up, of the phenosafranin 1 : 2000 and of the aurantia 1 : 1000. The former is rather more efficient, but it has the disadvantage of staining the gelatine deeply. It is also somewhat difficult to remove, but this will be dealt with presently. For the preliminary bath one part of the phenosafranin solution should be diluted with nine parts of water, while the aurantia solution should be used full strength. In either of the solutions the plate should be immersed for one minute and can then, without washing, be developed in the usual way. This preliminary soaking may be obviated by the addition of the dye solution to the developer, in the case of the phenosafranin at least. Ten per cent of its volume added to the developer is as efficient as the prior bath. As the dye has to penetrate the gelatine and its action is not instantaneous, it is obviously necessary to soak the plate in the dye solution, or if the dye-developer be used, allow it to act in a safelight for a minute or so. The soaking or initial development must be done first by the ordinary green light or in total darkness, and only after this can the bright light be used. Naturally also, as the silver salts are not completely deprived of all sensitiveness, this process must not be abused and the plate manipulated too near a very strong light.

Suitable safelights for this method may be made by soaking two gelatinized glasses in a three per cent solution of tartrazin for about fifteen minutes, rinsing and drying, and then binding up with tissue paper. It might be preferable to soak the paper in rose Bengal solution, as this makes a safer light, of a bright pleasant orange color.

One further advantage of this process is that it actually reduces the chemical fog on the negative, which is a very great assistance in practical work; for thus, in common parlance, it enables us to obtain more details in the shadows. It also completely alters the character of the normal hydrochinon developer which, as every practical worker knows, has a tendency to give hard, contrasty negatives, whereas with the addition of phenosafranin it works more like metol or paramidophenol, giving soft results. A suitable formula for this modification is:

A. Hydrochinon	12 g
Sodium sulphite, dry	50 g
Potassium bromide	1 g
Water to	1000 ccm

B. Potassium carbonate	50 g
Phenosafranin, 1 : 2000 solution	200 ccm
Water to	1000 ccm

Mix in equal volumes just before use.

As stated, the phenosafranin stains the gelatine rather deeply and this is not readily washed out with water, but it can be removed by treatment with either an acid alum solution or a nitrite bath. The former is made by adding 10 per cent of hydrochloric acid to a 2 per cent solution of ordinary alum, and the nitrite bath is made as follows:

Sodium nitrite	1 g
Hydrochloric acid	10 ccm
Water	1000 ccm

The best way of using this bath is to make up a 10 per cent solution of the nitrite; just before it is required for use add 1 part to 99 parts of water and then add the acid; the mixed solution cannot be kept in stock. It should be noted that the salt is nitr*ite* and not nitr*ate* of soda. The latter is useless, for the efficiency of this bath depends on the evolution of nitrous acid, which converts the dye into a nitrous compound, or diazotizes it. The rather deep red stain is thus converted into a bluish-violet compound which washes out from the gelatine more readily. Naturally, as probably everyone knows, an acid bath should not be used immediately after fixing or the hypo is decomposed, giving rise to various sulphur compounds, with the possible deposition of sulphur in the gelatine. Therefore, the above baths should only be used after the negatives have been washed. The one disadvantage of the nitrite bath is the evolution of nitrous acid, which has a rather unpleasant smell and in any quantity causes coughing and irritation of the eyes. As the negatives have already been fixed, the bath can easily be used in full daylight, so that one need not be cooped up in a small dark room with it.

This desensitizing process is an extremely valuable one and is applicable to all sensitive silver materials. With bromide or development papers, aurantia is the only dye that should be used, as the phenosafranin stains the paper very deeply, while the aurantia can be readily washed out.

It may be as well to add that for the bright light not more than an 8-candle power lamp should be used, though of course if the work is carried out at some distance from the lamp or an opaque screen be temporarily interposed between the developing dish and the light, the power of the lamp may be increased.

As regards developers for panchromatic plates in general, it is probable that every worker has his own pet formula, and there is no reason to alter it or adopt a new one. The two points to be kept in view in the selection of a developer are that the negatives should be what are usually called "soft," that is, without extreme contrasts, and that they should as far as possible be free from fog. Metol-hydrochinon appears to be the favorite and the following is a standard formula:

Metol	4 g
Sodium sulphite, dry	50 g
Sodium carbonate, dry	20 g

Hydrochinon	2 g
Potassium bromide	0.1 g
Distilled water to	1000 ccm

For use mix 1 part with an equal volume of water. The temperature of the developer should be 18° C. (65° F.), and the duration of development three to four minutes. The author's favorite developer is the following:

A. Paramidophenol hydrochloride	30 g
Sodium sulphite, dry	90 g
Distilled water to	1000 ccm
B. Potassium carbonate	140 g
Distilled water to	1000 ccm

For use mix in equal volumes. Temperature 18° C. (65° F.), and duration of development three and one half minutes.

Presumably everyone knows that the correct method of mixing the first formula, or any metol developer, is to dissolve the metol in the water and then add the other ingredients in the order named. In making the second developer, the paramidophenol should be dissolved in some of the water, the sulphite in the remainder, and the two solutions mixed. The paramidophenol base is thereby thrown out of solution, therefore it is essential to thoroughly shake the bottle before measuring a quantity for use. The suspended base immediately dissolves on the addition of the alkali. It will be noted that there is no bromide in this formula, and none is required, as the hydrochloride combines with some of the potash, forming potassium chloride, which is a mild restrainer and fog preventer. Should the paramidophenol base itself be used instead of the hydrochloride, and it can be, of course, with equally good results, 0.05 per cent of potassium bromide should be added. Too much should not be used, as it actually slows the plate with normal time of development, that is, it holds back the shadow detail, the most important part of the negative; if development be prolonged sufficiently to bring this out, the negatives are, as a rule, too hard. It may be said that if the pure paramidophenol base be chosen, one fourth less should be used, that is, seventy-five parts of paramidophenol will do as much work as one hundred of the hydrochloride.

The temperature given above for the developer is important and should be strictly adhered to. If the solution is cold, the development is prolonged and, conversely, if it is too warm the duration is curtailed and there is a much greater chance of chemical fog. Also with strict adherence to a given temperature and time of development, the character of all negatives will be alike.

Other developers may be used, but enough has been said to enable the reader to adapt his own pet formula to the work. There is one very important point, which must be rigidly observed, and that is that the developer must not be used a second time. If the plates are so large that they cannot be developed together, which is the ideal method, then fresh solution should be used for each plate; obviously there are more possibilities of variation in the negatives by separate development than by developing all together.

The reason why great stress is laid upon this matter of fresh solution for each batch or each plate, is that in development the bromine set free from the silver salt by the reducing agent combines with the alkali and forms a bromide, and this, naturally, in quantities varying with the amount of metallic silver deposited to form the image; so that one has, after development, a solution of unknown and variable bromide content, and constancy of results is impossible. This may seem a wasteful and expensive method of working; but when one considers the importance of perfect results, the cost of the fresh developer becomes negligible.

But little need be said about the fixing bath. Any formula may be adopted, though an acid chrome bath of the following constitution gives excellent results; it fixes very rapidly in about five minutes, and hardens the gelatine:

Sodium sulphite, dry	45 g
Water	100 ccm

Stir well and add:

Glacial acetic acid	20 ccm

Then add to the following, when the hypo is dissolved:

Hypo	400 g
Hot water	600 ccm

Finally add:

Chrome alum	20 g
Hot water	50 g

and make the total bulk up to 1000 ccm.

The washing of the negatives follows the usual course. It is unnecessary to deal with intensification and reduction, as these also can be carried out as usual; but these operations should be avoided as far as possible by correct exposure and development, as the gradations are apt to be altered by them, with consequent false color-rendering.

CHAPTER V

THE CAMERA AND EXPOSURE

UNFORTUNATELY there is no reasonably priced three-color camera on the market. So, unless one is prepared to make a camera, the only alternative is a sliding back, and this limits the work in the main to subjects in which there is no movement, as obviously three successive and not simultaneous exposures must be given.

Many complicated forms of cameras have been devised, with costly optical arrangements for obtaining the three constituent negatives with one exposure, but these we can ignore. Possibly the simplest form of one-exposure camera is the two-step, of which the best constructive details were given by C. E. K. Mees, and his instructions are here followed. The camera was originally devised by E. T. Butler, on the lines of the photochromoscope suggested by Cros in 1871. The camera takes a seven-inch lens, but can be used with any lens that has not a shorter focus than this. The size of the plate determines the extension of the camera, and also decides as to whether the longer or shorter axis of the plate is vertical or horizontal. The lens should be one of the newer anastigmats and work at as large an aperture as possible, for the filters prolong the time of exposure. A reflector is placed behind the lens at an angle of 45 degrees to the axis of the lens. Part of the light is reflected and passes through a filter to the plate, while the remainder which passes through the first reflector meets a second reflector placed parallel with the first. Here the light is again divided; the reflected part passes to the second plate through another filter, while the rest of the beam goes onward to the third plate behind the second reflector. It is necessary to use the three filters, and the images must be of identical size; in addition, the reflectors must not give two images, so that they must be so constructed that the second image, due to reflection from the back of the glass, is rendered harmless.

All the images have to be in focus at the same time, and if a black and white object be taken it must be rendered of the same value in all three negatives Only one kind of plate must be used, that is, one cannot use a panchromatic plate for the red exposure, an orthochromatic for the green and an ordinary for the blue. As regards the nullification of the double image this can be attained by using colored reflectors, and obviously this can be most satisfactorily done by coating the back of the glass with colored gelatine. This coloration must be the minus color of the taking filter; for instance, in the diagram (Fig. 10) it will be seen that the first reflector, which gives the red record, is designated as a "minus red reflector," and a minus red must be blue-green. In like manner a minus blue must be yellow. It will be found that the arrangement suggested in the diagram will be the most satisfactory, though the red and green sensitive plates may change places. Then, of course, the colors of the back coatings of the reflectors must also be changed, and that for the first reflector would be a minus green, or crimson. Identity of size of the images can be secured by altering the angle of the reflectors, as if they are raised the central beam of light is shortened. The reflectors must be separately adjusted so that the focus of the reflected images is the same in each case, which means that the length of the optical path in glass must be equal for each plate. For this purpose, the thickness of the filters must be adjusted so that the length of glass through which each beam travels is equal. The length of the glass through which the direct beam travels is equal to the thickness of the two reflectors taken at an angle of 45 degrees to the axis of the lens. That is to say, it is 1.41 times the actual thickness of the filters. The thickness of the red filter is, therefore, equal to 1.41 times the thickness of the two reflectors, while the thickness of the blue filter will be 1.41 times the thickness of the yellow reflector.

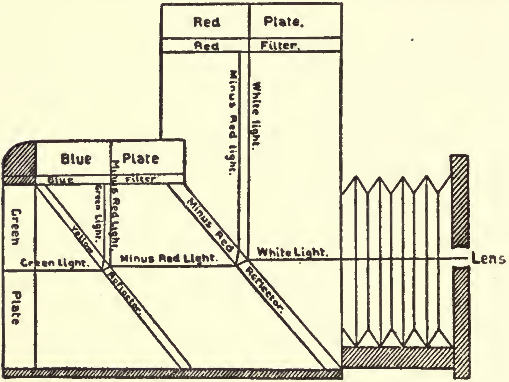


FIG. 10

In order to adjust the color of the filters so that the correct ratio may be obtained, pieces of film should be placed between the glasses and a black and white chart photographed till equal density results are obtained on all three plates. It will be seen that the adjustments are rather delicate and involve a considerable amount of work by trial and error, but this should not deter anyone from attempting to make such an instrument, as it is the cheapest and most convenient camera for a single exposure that can be devised. It is quite possible also that a camera constructed on the line of the chromoscope, described on p. 125, would be simpler, though not quite so compact. The dimensions are given there, so one can adapt it for negative work, but as the depth of the instrument is 10⅝ inches, it obviously entails the use of a lens of focal length not less than this, though this depth can obviously be cut down.

As an alternative to the above described camera, the following may be adopted. This has some advantages, particularly as regards the evenness of illumination of the reflected images, which is frequently faulty with parallel reflectors. This type was patented in 1896, and some changes in the disposition of the filters have been recently suggested by H. E. Rendall. The internal construction is shown in the accompanying diagram (Fig. 11), in which L is the lens in a focusing jacket, or obviously a short length of bellows could be placed here. A, the first filter, of a mauve color, that is, one transmitting red and violet, is placed at an angle of 45 degrees to the optical axis of the lens, and from it some of the light is reflected to a plate at P_1, in front of which is a green filter G. The remainder of the light passes through A and some is reflected from B, a blue filter at right angles to A, to the second plate P_2, in front of which is an orange filter O. The remainder of the light passes through *B* to P_3, in front of which there is no filter, the reflector *B* acting as filter.

The adjustment of the filter absorptions is rather a delicate matter; but a suitable filter for *A* can be made from rose Bengal 0.8 g per square meter, or phenosafranin 0.48 g, or a Wratten & Wainwright No. 31, minus green 1, may be used. The *G* filter should be the normal tri-color green filter, as previously advised. *O* may be made with tartrazin 4 g, or naphthol orange 3 g per square meter; or a Wratten & Wrainwright No. 21, monobromofluorescein, may be used. For *B* a Wratten No. 49b, C 4 dark, should be used. Probably this filter could be matched with crystal violet 1 g and patent blue 1.6 g per square meter; but as these dyes cannot be mixed they must be coated on separate glasses and cemented together. Methylene blue 0.8 g, or toluidin blue 2 g, might take the place of the patent blue; but

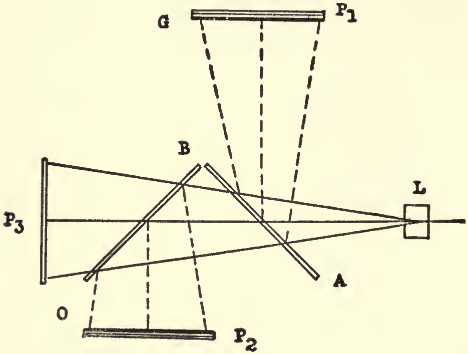


FIG. 11

these do not absorb as much violet as patent blue, which has a marked absorption band commencing at $G\frac{1}{2}H$ and extending into the ultra-violet.

In this, as in the other camera, the optical paths through glass must be equal, therefore, filter *G* must be 1.41 times the thickness of *A* plus 1.41 times the thickness of *B*, and filter *O* must be 1.41 times the thickness of *A*. A compensating filter must be used on the lens to equalize exposures and probably that suggested for autochrome plates on p. 143 will be very close to the ideal.

One advantage of this arrangement of filters is that it gives the yellow image direct from P_3, and this forms the basis for the constituent pictures, which is advantageous, as opaque yellow pigments may be used for prints. The special advantage of the dark blue filter is that it cuts out some of the violet and therefore, gives a more brilliant negative for the yellow. Naturally the same arrangement of filters as advised for the previously described camera may be adopted.

The distances of the filters from their respective plates must be controlled in the same way, that is, by making negatives of geometrical figures and superposing them. An expansion of the figures in one negative will show that it is too far from the plate, and *vice versâ*.

The simplest form of camera is undoubtedly the semi-dialyte. This is dealt with elsewhere (see p. 222), and also the objections to this system.

With regard to the lens that should be used for color work, no special instructions need be given, as any lens may be used, but some are more suitable than others. The newer anastigmats are preferable, as they cover sharply a given size plate at a larger aperture than the older types, and this is a consideration in consequence of the increase of exposure incident to the use of filters.

Every plate maker gives, as a rule, the ratio of exposures for his plates with a given set of filters; but this can always be determined by experiment and the best method is to use a scale of greys, made by exposing a piece of bromide paper, in geometrical ratios, to white light and then developing. It is only necessary to place the edge of the bromide paper between the edges of a book, and expose to white light for say one second, then push the paper in about half an inch and give another second exposure, then push the paper further in and give two seconds exposure, doubling the exposure in each case so that the result will actually be as follows:

First exposure 1 second = 1
Second exposure 1 second + (1 already given) = 2
Third exposure 2 + (1 + 1) = 4
Fourth exposure 4 + (2 + 1 + 1) = 8
Fifth exposure 8 + (4 + 2 + 1 + 1) = 16
Sixth exposure 16 + (8 + 4 + 2 + 1 + 1) = 32

This should give six steps of varying density, which will be quite sufficient to determine the filter ratios, for one has merely to make three exposures through the three filters with this graduated strip as the object, to obtain three negatives. A comparison of the images will give one a very good idea whether the ratios adopted are correct or not, for if they are, the scale of greys will be alike in all three negatives. If one strip of the bromide paper is shielded from all light, and the other end quite black, it is easy to determine how the exposure ratios must be altered to attain equality.

Theoretically, one ought to determine the filter ratios before each exposure, as the color composition of daylight varies considerably, being very much richer in red and green in sunlight than in shadow or in cloudy weather. But if the filter ratios have been determined, one may ignore this factor, at any rate at first. The actual exposure required without a filter should be determined by means of one of the exposure meters that actually measure the chemical intensity of the light by the darkening of a paper to a standard tint. These are much more reliable than those in which the brightness of an object is determined by visual comparison with a standard; and all tables based on latitude and classification of subjects are misleading for color photography.

It is extremely difficult to tell from a set of negatives which filter was used for a particular negative. One might imagine that this would be an easy matter, but it is not, and even after long experience it is easy to be misled. It is, therefore, always well to make the exposure automatically record the filter. If the filters are used in contact with the sensitive surface this is very easy, for one has but to affix to the face of each filter, placed next to the sensitive plate, an opaque letter designating the color. When the filters are used on the lens, some little device should be thought out which can be permanently affixed to the plateholders and which will be automatically recorded by the light. Several of these will at once suggest themselves, such as distinct file cuts in one edge. The author has been in the habit of using small triangular pieces of metal driven into the corners of the front of the plateholders, one piece in one, two pieces in opposite corners of another, and none in the third. There is no difficulty in at once picking out the negative recording each color, provided the same holders are always used for the same filters, that is, the one without any corner piece for the blue, that with one for the green, and that with two for the red, or any other order that is decided upon. The corner pieces need not be very large; a right-angled triangular piece measuring about 5 mm from the apex to the base is quite large enough. This leads to the suggestion that order is a capital essential in color work, and that exposures should always be made with the filters in one particular order, which should be rigidly adhered to for all time, as then one does not have to think as to whether one filter or the other has been used.

This particularly applies when separate exposure work is undertaken, and while it may be extremely nice to be able to tackle any and every subject that comes up from portraits to landscapes and bric-a-brac, yet some of the most valuable work may be done with an ordinary camera, three separate plateholders and three exposures, confining one's work to subjects that will not move, or which at least give one time enough for three separate exposures. As illustrative of this may be mentioned the case of a certain worker, who happened to see the author at work on some color prints and wanted to know how "the job was done." His photographic experience was probably like that of many another amateur; he had dabbled in black and white work and had shot at everything and anything, and then gotten rather tired of it because he had no purpose in his work. He decided to attempt color work, using his old camera, with three plateholders and three separate exposures, and his first filters as well as the plates were borrowed from the author. The only subject that he could find which was sufficiently brightly colored to satisfy him and would certainly not move, was a somewhat brilliantly colored old china vase. Curiously enough, possibly another example of beginner's luck, an exceedingly good result was obtained. Succeeding failures with landscapes induced our friend to "stick to his pots," as he expressed it, with the result that now he has the finest collection of color prints and slides of old china in the world and has become one of the leading experts in that field, as he was led to learn all that could be learned about his pots.

CHAPTER VI

SUBTRACTIVE PROCESSES. SUPERIMPOSED CARBON PRINTS

PROBABLY everyone knows the fundamental basis of the carbon process, a name that has clung since its first inception, although carbon is no longer the pigment used. Briefly, some water-insoluble pigment is suspended in gelatine and coated on paper somewhat thickly; this is then sensitized with a bichromate and, after drying, exposed to light under a negative. Where the light acts, the gelatine is rendered insoluble in warm water, so that on treatment of such a print with hot water the insolubilized gelatine, being undissolved, remains to form the image in varying thicknesses of gelatine imprisoning the coloring matter. There is, however, one unfortunate fact, that, the exposure being from the front of the tissue, as the pigmented gelatine is called, the insolubilizing action proceeds from the surface downwards, so that the underlying strata, those nearest the paper, are still soluble, and will wash away in the hot water, leaving the surface image or picture more or less without support. This action is made clear from Fig. 12, which represents the tissue exposed under a strip negative; *P* is the paper and *G* the exposed gelatine, the amount of light action being shown in black. It is obvious that only the patch I on the extreme left of the diagram is anchored to the paper, where the light action has penetrated right through to the support; in the remaining patches there is still an underlying stratum of soluble gelatine varying in thickness from II to VI. If the tissues be now immersed in hot water, this soluble gelatine will be liquefied, dissolve in the water, and leave

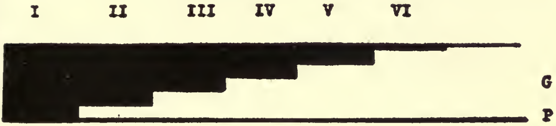


FIG. 12

the last five patches unsupported in anyway, except where they are attached to one another. Possibly two or more might be strong enough to hold thus, but the lighter patches, say V and VI, would break off, and these represent the details in the highlights of the picture.

To overcome this trouble, it is necessary to use a temporary support, and squeegee the exposed tissue to this for development. The condition in this stage is shown in Fig. 13, in which *P* as before is the paper, *G* the gelatine

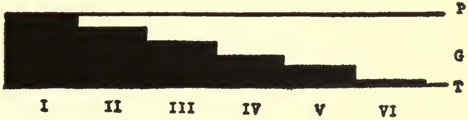


FIG. 13

and *T* the temporary support. It is obvious that the patches II to VI are now supported and will not be lost in development.

Three-color tissues can be obtained commercially and it is not wise for the amateur to attempt to make his own, as, while the actual making of the pigmented gelatine is quite easy, to obtain an even thickness of coating is not so. The tissue has to be sensitized with bichromate, and the following is an excellent formula:

Potassium bichromate	25 g
Citric acid	7 g
Ammonia	30 ccm
Water to	1000 ccm

This should make a lemon-yellow solution, smelling distinctly of ammonia. If it does not smell, a little more ammonia should be added. The tissue should be immersed in this for three minutes, and the temperature of the solution should preferably be 15° C. (60° F.); then the tissue should be placed between two sheets of filter or fluffless blotting paper, lightly rubbed with the hand to remove excess solution, and hung up in the dark to dry. It does not become light-sensitive till dry.

While the time required for this drying is not a serious matter, as tissue sensitized in the evening will be ready for use the next morning, yet by the use of an alcoholic or acetone bath it can be dried in half an hour. For this bath, however, it is advisable to use ammonium bichromate, and, as the alcohol or acetone mixture will not keep, it is as well to make a stock of the ammonium solution as follows:

Ammonium bichromate	25 g
Distilled water to	400 ccm

When required for use, mix ten volumes of this with fifteen volumes of methyl or denatured alcohol, or acetone. Then pin the tissue on a board by the four corners and paint the surface with a broad flat brush saturated with the spirituous liquid. Use the brush first lengthwise and then across; leave for five minutes, and then paint again and allow to dry. The brush should not be bound with metal.

No matter how the tissue has been sensitized, it will not keep longer than a week or ten days, and it is advisable to use it within three days.

The exposure has to be judged by an actinometer, which can be obtained from any large dealer.

Possibly it may be helpful to describe the making of an actinometer, or print meter as it is sometimes called. Procure a pill box from a drugstore — a one ounce box is quite large enough — place the lid, top side down, on a piece of wood, and with a sharp penknife cut two parallel slits half an inch long and about a quarter of an inch apart. Pass the knife blade through these slits with a little sideways pressure so as to widen them sufficiently to allow a strip of paper to pass freely. Procure some gelatino-chloride printing-out paper, Solio or the like, about 4 x 5 or larger, and cut into strips just wide enough to pass through the slits. Expose the paper between the slits to diffused daylight until of rather a deep color, then paint the top of the lid with water colors which when dry will match the color of the paper. A slit must also be cut in the side of the lid, parallel to and in line with the top slits, and through this the end of the paper is brought, forming a little tag, which enables one to shift the paper after exposure.

To use this actinometer, the box is placed by the side of the printing frame containing the tissue and the negative, and as soon as the small exposed strip of paper darkens to the standard tint, a fresh piece is pulled into place and the action of light watched until the standard tint is again reached. This operation is repeated as many times as necessary. It is usual to classify negatives according to the number of tints they require; thus one speaks of a 2-, 4-, or 7-tint negative. Trial and error will alone give an idea as to the number of tints required; but the average negative will usually need about five tints. By using the long strips of paper, the unexposed part can be coiled up in the box.

Even more convenient than this is a paper actinometer of the so-called terrace pattern. To make this, procure a strip of glass; a bit of an old negative answers admirably. This should be one inch wide and about six inches long. Procure also some typewriting paper; the thin "onion skin" variety is excellent. Cut this into strips slightly, say one-sixteenth of an inch, narrower than the glass and of the same length. Then arrange these strips in step or terrace fashion, as shown in the diagram (Fig. 14) in which *G* represents the glass, and *P P* a few of the paper strips. The width of the steps is not of much importance; about three-eighths of an inch will be plenty. This entails cutting a piece off each strip and if these are laid one on top of the other, the result will be about sixteen steps, each one increasing the density by one thickness of paper.

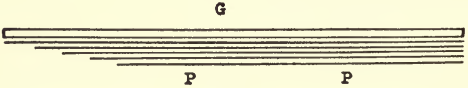


FIG. 14

The steps should preferably be numbered or lettered, and the numbers can be written on a piece of fixed-out negative film with waterproof drawing ink, or may be similarly written on the paper itself. Small figures or letters of ready-gummed black paper may be obtained commercially. This figuring or lettering is not absolutely essential, but it facilitates the reading of the tint in practice. Finally a strip of clear celluloid should be cut the same length and width as the glass, placed over the papers, and the whole bound up with narrow lantern slide binding strips, the papers being pressed into as close contact with the glass as possible.

Printing-out paper may be used with this as with the other form; or plain white paper may be sensitized with the bichromate bath and used instead, and then the numbers or letters will appear yellow on a brown tinted ground. Such a meter can be used in a printing frame, but another strip of glass may be hinged to it with cloth or lantern slide binding strip along its length on one side, thus forming a little frame. A couple of metal clips serve to keep the paper in close contact with the celluloid while printing. Again, trial and error must be resorted to, to ascertain the necessary exposure; but, as a rule, from five to ten steps will be sufficient under the above conditions. Of course, if the paper selected be thicker, then it will naturally stop more light and not so many steps will be required.

Practically the carbon tissue is about the same speed as a print-out gelatino-chloride paper; or one can take the yellow print as a guide, as the image can be seen on this, and when all the details are visible in the highlights of this print, the printing may be interrupted. It is as well to expose all three tissues at once, and actual sunlight must not be allowed to fall on the negatives. The negatives must be provided with a safe-edge, and the easiest way is to use black lantern-slide binding strips.

Stick them to about half their width on the gelatine of each negative all round, and, when the strip is quite dry, shave off the projecting part with a knife. The safe-edge prevents the tissue from washing up at the edges during development.

As the carbon prints are to be developed on a temporary support and subsequently superimposed in register, it is necessary for this support to be transparent, or sufficiently translucent to enable the outlines of the images to be seen. Such temporary supports are obtainable commercially, or celluloid sheets ten one-thousandths of an inch thick may be used. The temporary support should be polished with a solution of beeswax in turpentine, such as:

Beeswax	20 g
Resin	20 g
Turpentine	1000 ccm

Melt the wax in a pot in a water bath, add the resin, preferably in powder, and finally add the turpentine slowly with constant stirring. Make a pad of absorbent cotton, wrapped in a piece of linen cloth, pour a little of the wax solution on the pad and rub over the surface of the celluloid, which can be pinned to a board by the corners; then polish off the wax with a cloth. It is as well to use two or three clean pads, as but the merest trace of wax is required. Then hang up the prepared sheets for twenty-four hours to dry. Sheet celluloid of the given thickness can be obtained from any dealer, either with polished surfaces, or one side polished and the the other matt. As the final print assumes the same surface as the temporary support, it is thus possible to obtain either matt or glossy pictures. The celluloid sheets should be obtained an inch larger each way than the tissue, as this facilitates handling.

The exposed tissue must not be left too long between exposure and development, as the insolubilizing action, initially set up by light, proceeds in the dark; so that if the exposed tissue be allowed to lie undeveloped for some hours, the final prints will be actually darker than they should be, becoming obviously overexposed. The exposed tissue should be immersed in a bath of cold water (15° C. or 60° F.), and care taken that no air-bells adhere to the surface, which can easily be done by carefully passing the fingers over the surface both back and front. At first the tissue will have a tendency to roll itself up into a spill with the gelatine side inside; then it will gradually straighten itself out, and then the edges will turn back with the paper inside. This is the psychological moment to take advantage of. The waxed celluloid sheet should be slipped into the dish with the waxed side toward the gelatine of the tissue, the two brought into contact under water, and the print shifted until it is fairly central; then both should be lifted out, being held in contact by the thumbs. The two should then be placed on a pile of paper, preferably stout blotting paper; a sheet of blotting paper should be placed over the print, then a sheet of ordinary hard paper, and the two thoroughly squeegeed into contact; the flat squeegees are better than the roller type for this. The print should then be placed between two sheets of blotting paper and under a moderate weight, such as a pile of big and heavy books, for about fifteen minutes, and it is then ready for development.

The developer is nothing but hot water, and it is preferable to work at as low a temperature as possible. A dish should be filled with water at 38° C. (100° F.), and it is advisable to have a kettle or saucepan with water at a higher temperature, which can be added if the temperature in the dish sinks. After about five minutes the temperature of the water in the dish should be taken with a thermometer, and if it has cooled down too much, which it may do if a thick stoneware dish be used, add more hot water. Immerse the print, on its temporary support, in the hot water, and if any air bubbles adhere, break them with the fingers. If the print has been properly exposed, it will be seen in about two or three minutes that some of the pigmented gelatine will begin to ooze out from under the paper. Then one edge of the paper should be gently lifted with the finger nail and the paper pulled off with a gentle steady pull; this paper can be thrown away, as it has done its work. There will be no sign of a picture; the face of the celluloid will be covered with a smeary mess, but if the celluloid be gently moved about, to and fro and up and down, the soluble gelatine will dissolve and the picture gradually make its appearance.

An alternative method of working is, after removal of the paper, to slip a sheet of glass under the celluloid, fasten it at two sides by means of metal clips, and immerse it face down, supporting it by two glass or metal blocks at each end, when the soluble gelatine will sink away from the face of the print by its own weight. Another method is to place one edge of the glass bearing the celluloid face downwards in the side of the dish and holding the other in the fingers move the celluloid gently up and down. Or, if a large dish be used, the glass and the print may be supported by one hand at an angle of about 30 degrees from the horizontal, and the hot water splashed on it with the other hand. It is easy to see whether development is proceeding as it should do, and provided that the exposure is correct and the temperature of the water kept up, in about five minutes the print should be finished. It may then be placed face up in a dish of cold water, or a very gentle stream of cold water allowed to run over it from the tap, so as to remove any trace of soluble gelatine that may adhere. It should then be immersed in a 5 per cent solution of ordinary alum for fifteen minutes and then put to wash in cold and frequently changed water, or gently running water may be used, and twenty minutes is long enough for this. It should then be hung up to dry.

The developing dish should now be well cleaned out and the second and third prints developed in precisely the same way as the first. If, as soon as the first print is placed in the cold water, the second is developed, and then the third dealt with in the same way, all three prints can be finished and in the alum bath well within an hour. One caution must not be omitted, and that is that the print, until it has dried, is very easily damaged; therefore, placing all three prints in the same dish of cold water or alum solution should be avoided, otherwise some rough edge may dig a piece out of the tender gelatine.

When the prints are dry we can proceed to transfer them to their final support in superposition. Specially prepared final supports are obtainable commercially in various tints, thicknesses and surfaces, but only white should be used, any tint naturally affecting the color of the final picture. If the operator is desirous of making his own final support, a sheet of bromide or developing paper should be fixed, well washed, and immersed in 10 per cent solution of formaldehyde for ten minutes and hung up to dry without washing. At first rough papers should not be used, as they are much more difficult to handle than the smooth kinds.

The three prints on their celluloid supports can be temporarily superimposed, when dry, to see whether anything like satisfactory color-rendering has been obtained. If it is sufficiently pleasing, the surface of each print should be gently rubbed over with a pad soaked in benzol to remove any possible traces of wax and again hung up to dry. As the benzol is very volatile, this will only take a few minutes. Meanwhile immerse a sheet of the final support, which should always be larger than the print, in a dish of cold water and allow it to soak for at least half an hour (an hour is not too long); this is to give the paper fibers a chance to fully expand.

A cement is required to make the prints stick together; a plain 6 per cent solution of gelatine may be used, or the following may be made up and will keep well in a corked bottle:

Soft gelatine	10 g
Glacial acetic acid	10 ccm
Distilled water	480 ccm

Allow to soak for about half an hour and then melt in a water bath and add:

Methyl or denatured alcohol	500 ccm
Phenol (carbolic acid)	10 ccm

This cement must be melted by heat each time before using and should be applied rather thinly with a broad flat brush.

The yellow print should be immersed in cold water for ten minutes, then brought into contact with the soaked final paper, lifted out together with this, thoroughly squeegeed, and hung up to dry. When quite dry the temporary support of celluloid may be stripped off, leaving the print on the paper. This print should now be pinned to a board by the corners, and the blue print on its support, which may have the corners cut off to allow room for the pins of the yellow print, should be placed on top and the two shifted about until accurate register is obtained, and two more pins driven through the two supports; the top support bearing the blue impression should then be lifted up and the yellow print quickly painted with the cement, which must not be too hot, and the blue print then lowered into place. Possibly some little shift may be necessary, but it should not be; anyway, one can examine the register with a magnifying glass. When satisfactory, the two should be hung up to dry and the celluloid stripped as before. The third, the red impression, is superimposed in the same way. It should be noted that the pins referred to above are the glass headed push-pins, and if these be driven with steady straight pressure through the supports, there is very little tendency for the prints to shift.

Another process, which while actually a carbon process, employs no light for the insolubilization of the gelatin, relying upon the action of finely divided silver on the bichromates, which causes insolubilization of gelatine in which the silver is imbedded, is known as the Raydex process. This peculiar action of silver on the bichromates was discovered by Howard Farmer in 1889, and for years lay dormant, no practical application of it being made. Briefly the process is as follows; the three constituent negatives are obtained in the usual way and, from these, prints are made on a special bromide paper. These prints are immersed in water and brought into contact with the colored pigmented tissue which has been previously soaked in some special solutions, where they are left for a short time. The print is then separated from the tissue, which is squeegeed to a temporary support, developed with warm water and then superimposed in register as described above for straight carbon work. The actual formula for the solution has never been published, but in all probability it is a compound of cupric sulphate and bichromate. The instructions issued by the Raydex Company may be summarized as follows: from the three constituent negatives three prints must be made on the special bromide paper, giving the same exposure to each; to get the correct exposure, make a trial print from the negative taken through the green filter. The exposure required to obtain a rich black, with clear highlights, and which will develop out, that is, to a point where on continuing development no apparent further action takes place, is the correct exposure for the three negatives. Development should not be too rapid, as this gives weak colors. Wet the three exposed prints and develop side by side with any good metol-hydrochinon developer. After development, transfer without washing to an acid fixing bath for at least ten minutes and then wash thoroughly and dry, or use at once for making the color prints.

Three transparent supports must be waxed at least half an hour before use. Soak the bromide prints in water and when limp place them face upwards on clean glasses (old negative glasses are suitable). The prints should be trimmed smaller than the color sheets. The back of the yellow color sheet is slightly damped and then immersed for two minutes in a special solution, then rinsed and placed on top of the correct bromide print under the surface of water, lifted out and squeegeed into contact, and set aside for twenty minutes, when the action is complete. The same procedure is gone through with the blue and the red. The color sheets should be trimmed to within about one-eighth of an inch of the size of the bromide prints and then the pairs pulled apart. Squeegee the color sheets into contact with the dry waxed supports and allow to remain for ten minutes, develop in water from 43° to 49° C. (100° to 110° F.), and when development is complete rinse in clean water at 38° C. (90° F.), and hang up to dry. The bromide prints after washing can be redeveloped and again used. Single transfer paper is soaked in water for half an hour, and the yellow print squeegeed thereon and dried. The blue and red prints are painted with a special liquid cement and dried. When the paper and the yellow print are perfectly dry the paper is stripped, and the surface freed from wax by treatment with benzol. The blue print on its transparent support should be soaked in water for a few minutes with the yellow print and the two brought into contact, lifted out and lightly squeegeed into contact and dried. When dry treat with benzol and transfer the red print in the same way. The prints are reversed but for many purposes this will be of no moment. An alternative process is given, in which the prints are produced on glass and stripped with hydrofluoric acid, but this seems rather tedious. It will be seen that the process is in its essentials the carbon process pure and simple, with the important modification that the light exposure is eliminated. Some excellent results are possible by this method. The fact of being able to make the carbon prints at night is a great advantage, and also that having once gotten good bromide prints almost any number of duplicate color prints can be made from them.

CHAPTER VII

THE IMBIBITION PROCESS

THIS process is the transfer of a dye image to a gelatine film; as the result, prints are formed consisting only of transparent aniline dyes in a single layer of gelatine. The finished pictures are very luminous and rich in coloring. There are various methods by which this result can be obtained; either by using a primary gelatine relief, staining this up, and using as the dye matrix, or by using the property that hardened gelatine possesses of not absorbing certain dyes, and the fact that these dyes will migrate or wander into another gelatine film.

Practically, one may liken the relief processes to the use of a rubber stamp, which temporarily takes up the coloring matter, only to give it up when pressed against an absorbing support.

The pinatype process was originally suggested by Edwards in 1875, and independently by Cros in 1881, and was introduced commercially by Meister, Lucius & Brüning in 1906. The original process, as suggested by the last-named firm, required the three original negatives, three transparencies from the same and three print-plates, which were prepared from the transparencies by exposure of bichromated gelatine plates; it will thus be seen that, exclusive of the negatives, six plates were required before a single print was possible. But equally good results can be obtained by using the transparencies themselves as print-plates, thus saving one step in the process; this modification was suggested by Didier, the actual inventor of the process.

The following is the method of making the bichromated print-plates. It is assumed that the three constituent negatives have been secured and that ordinary silver transparencies have been made from them. As regards these last, the only comment necessary is that they should not be too hard and should partake rather of the character of negatives than of brilliant lantern slides. The bichromated plates can be prepared with:

Hard gelatine	50 g
Ammonium bichromate	20 g
Water	1000 ccm

The gelatine should be cut up into small pieces and soaked in the water for about thirty minutes and then melted by the aid of heat, the bichromate added and the mixture filtered, while hot, through Canton flannel or two or three thicknesses of linen. The quantity of this mixture should be 400 to 500 ccm for every square meter of glass. The preparation of the solution and the coating of the glass can be performed by weak daylight or artificial light. The glass can be old negative glasses, well cleaned and polished. They should be placed on a leveled slab and the requisite quantity of the gelatine mixture poured on them and coaxed out to the edges. It will be found that a pipette is the most handy tool for this, and the temperature of the solution may be about 55° C. (130° F.). As soon as the gelatine has firmly set, the plates can be racked for drying, and the remarks already made as to this operation in the case of filters and plate sensitizing apply here also. The plates must be dried in the dark. A possible variation of this process, and one that may commend itself, is to omit the bichromate salt from the above formula and coat a stock of glass with plain gelatine solution; sensitize this as required by immersion in plain bichromate solution, about 5 per cent, then rinse and dry. By this method there is naturally less chance of the plates spoiling.

In either case the bichromated plates are exposed under the transparencies to daylight, and as in the carbon process, an actinometer should be used; but it will be possible to do without this, as the image is easily seen in a brown color against the bright yellow ground. The exposure should be such that the image is visible in all its details, even in the high-lights. After exposure, the plates are soaked in cold water until the drainings are colorless, or, if time is a consideration, the plates may be immersed in a 10 per cent solution of sodium bisulphite until colorless and then washed. Though not absolutely necessary, it is advisable to let them dry then, but before this they should be immersed, just for a minute or two, in their respective dye baths, as this enables one to tell which plate is which. Otherwise it is extremely difficult to distinguish them, as the image is almost invisible.

The alternative process, in which the silver transparencies are used as the print-plates, is to be preferred, as the films are actually harder. The transparencies must be somewhat denser than for the last process and have absolutely clean whites, and it is important not to use any developer that has a tanning action on the gelatine. The transparency for the yellow impression should be sensitized in:

Ammonium bichromate	12.5 g
Ammonia	100 ccm
Distilled water	1000 ccm

Those for the blue and red are bathed in:

Ammonium bichromate	20 g
Ammonia	200 ccm
Distilled water	1000 ccm

The plates should be immersed for five minutes and then dried. Before exposure, the backs of the plates must be thoroughly cleaned, as any dirt would show in the result as a darker patch. They are placed in an ordinary printing frame, gelatine side inside, and in contact with the gelatine should be placed a sheet of printing-out paper, which acts as an actinometer. The insolation is carried on until the details appear in the shadows, and naturally this image is a negative; the yellow plate requires about double the exposure of the others. After exposure, the plates should be well washed, or, to shorten the time, may be immersed in the bisulphite solution recommended above, or in a 5 per cent ammonia solution.

The transparencies are then ready for staining up, but as the presence of the black silver image makes it difficult to see the dye image in the subsequent superposition, it is advisable to dissolve the silver with weak hypo and ferricyanide. This process not only presents the advantage of cutting out the making of the print-plates, but the correct exposure can be easily determined. The plates are very hard, and will stand subsequent treatment without damage. In consequence of the feeble relief, the prints show a most delicate detail; and the successive prints are very regular owing to the superficial film being backed up by the insoluble film caused by the exposure through the back.

The dyes that should be used for this process are natural carmine or lanafuchsin BB or SL for the red impression, indulin blue for the blue, and acid yellow, mikado yellow, or quinoline yellow for the yellow. The dyes are made up in three per cent solutions in distilled water; but if the carmine be used, then 4 g should be rubbed up into a paste with a little water, and ammonia added drop by drop until a perfectly clear deep red solution is obtained. About 5 ccm of the ammonia will be required, and then water should be added to make the solution up to 100 ccm and it will be ready for use.

As was pointed out, the printing colors are the complementaries of the filter colors, and this applies to all subtractive processes, so no further mention of this will be made. The first time of staining, the plates will require about twenty minutes to attain full intensity; but in subsequent staining only about ten minutes. The print-plates may be used for an almost indefinite number of pulls; exactly how many has never been determined, this naturally being dependent on the care with which they are used.

It is actually immaterial in what order they are pulled; but it will be found easier to make the order blue, red, yellow or red, blue, yellow. The reason for this is that it is much easier to obtain registration of the outlines of objects in one of these series than if the yellow be put down first, for this looks so faint against the white paper that it is not easy to secure accurate registration of the outlines. After repeated use, the print-plates become deeply stained even in the whites, and while this is no disadvantage in practice as regards the dyes transferring, it is a great disadvantage from the point of view of easy registration, as it makes it difficult to discern the outlines of the objects. When this occurs, the plate should be immersed in a bath of:

Potassium permanganate	2 g
Sulphuric acid, 10 per cent solution	10 ccm
Distilled water	1000 ccm

As soon as the dye has bleached out, the plate should be immersed in a five per cent solution of sodium bisulphite until all brown stain disappears, and then well washed.

The paper to which the dye image is transferred is plain gelatine-coated paper, and this gives one a wide choice of surfaces. One can easily obtain a suitable paper by fixing out bromide or developing paper, washing and treating with five per cent solution of formaldehyde for ten minutes, and drying without washing. After the print-plate has been soaked in the dye solution for a sufficient time, it should be rinsed with water until the drainings are practically colorless. A sheet of paper should be soaked in water for about five minutes, left for half a minute after the surface moisture has been blotted off, then the print-plate squeegeed down and the two left in contact. The paper should be uppermost, a thin piece of wax paper placed over it and the squeegee used well, stroking from the middle of the print out to the sides; roller squeegees are not so suitable for this as the old fashioned flat ones. The paper and plate should be left in contact for about fifteen minutes, and then a small corner of the paper turned back and the image examined to see if it is deep enough. Naturally, a little experience is required to tell this, but one soon becomes expert enough. If the pull is not thought sufficiently intense, the corner must be squeegeed down again and the whole left a little longer, and again examined.

The next plate is treated as described for the first, but as at first one is a little awkward in obtaining register, a piece of thin celluloid is placed over the first pull. The thinnest celluloid that can be obtained should be used, and creases or folds in this should be avoided; the celluloid should be cut about an inch longer than the print, as this gives one a convenient handle to catch hold of, and it should be placed over the first print so that a little space is left at the top of the print with no celluloid. The idea is that this space enables one to temporarily clip or hold the second plate in contact with the print, after registration has been obtained, and then withdraw the celluloid without shifting the relative positions of the second print-plate and the paper. The easiest way to work is to form a temporary desk by supporting a piece of thick glass on two piles of books or blocks of wood, and place under this a mirror or white card that will reflect the light through the paper and the second plate. Then, with a magnifying glass, it will be found fairly easy to obtain coincidence of the outlines. Then, if the plate and the paper are firmly held at the top, the celluloid may be slipped out and the two well squeegeed together.

The third print is obtained in exactly the same way as just described. Under no circumstances must the one pull be allowed to dry before the next impression is superimposed. Therefore, it may be as well to place the print-plate with the adherent paper between sheets of stout blotting paper well dampened with water.

Working in this way, particularly if the gelatined paper has been well hardened with formaldehyde, there is but little danger of want of exact register from expansion or shrinkage of the paper. Only in the case of very soft paper stock is there any danger. In such cases, the paper should be soaked in water for at least half an hour before making the first pull. A still more radical remedy is to pin the paper with the gelatine side down on a board, and paint the back with a celluloid varnish, such as:

Scrap celluloid	20 g
Amyl acetate	50 ccm
Acetone	450 ccm
Methyl alcohol to	1000 ccm

Two or three coats of this thinly applied will prevent any expansion or contraction. The paper, after this treatment, must be left at least twenty-four hours to thoroughly dry.

If, when the three impressions are pulled in superposition, it is found that one or other color predominates, and of course the depth of the staining is dependent on the time of contact between the paper and the plates, one of the plates may be again soaked in the dye solution and again superimposed in register and left for a short time. Thus the excess of red may be killed by a second staining up with blue, and excess of blue by a second staining up with yellow or red. If the whole picture is too weak, all three plates may be reapplied. If it is too dark, it may be moistened in water and squeegeed in contact with a gelatine coated plate for a short time, and some of the excess dye will migrate into this plate. A negative must not be used for this, as the silver image prevents the even transfer of the dye, but naturally a plate with the silver removed can be used, and by careful and frequent examination of the corner of the print as already advised, one can soon tell when the reduction has proceeded far enough.

The prints thus obtained are sufficiently permanent to withstand months of exposure to any daylight that may be met with in an ordinary room; but they may be made more permanent by five minutes immersion in a three per cent solution of cupric sulphate. This turns the reds into a more violet hue, and it is hardly necessary.

CHAPTER VIII

RELIEF PROCESSES

HOWARD FARMER discovered that if a silver image imbedded in gelatine was immersed in a solution of a bichromate a reaction took place and the bichromate was reduced, so that the gelatine surrounding each minute particle of silver became insoluble in hot water. On this has been based a process for obtaining a gelatine relief, which can be stained up and used as the matrix for the transfer of dyes to gelatined paper. This is obviously the same principle as that involved in the carbon process, with the added advantage of being independent of daylight. Obviously it suffers from exactly the same disadvantage, that is, if we expose from the front in the usual way, the delicate details and half tones will be unsupported and will wash away in the development. We must, therefore, print through the back of the support. In the case of celluloid this is, of course, of no moment, as the thickness of the celluloid is not sufficient to make the image markedly diffuse; but if it is desired to use glass plates, the thickness of the glass causes want of sharpness in the print. This may not be sufficient to be objectionable to some people, but unless the glass of all three plates is of exactly the same thickness, the diffusion of the images will differ and the individual pulls be unequally sharp. This trouble in using glass plates may be gotten over by making the positives in the camera by copying, as is done when making lantern slides, only the transparency plate must be placed with its glass towards the lens and allowance for its thickness made in focusing the image.

In the case of celluloid films, while the same procedure may be adopted, one can print by contact, using an electric lamp. An opaque card with an aperture about one inch in diameter cut in it may be placed over the bulb, with a ground glass covering the hole, so as to obtain diffused light. The lamp should be placed four or five feet from the printing frame. The exposure under these conditions is naturally longer than in contact printing, but it is not unduly prolonged.

Any slow transparency plate may be used, but contrast or photomechanical plates should be avoided, as they readily give too much contrast. Any developer except pyrogallol may be used, and this should be avoided on account of its tanning action and staining. The images should not be too dense, otherwise the pull from the matrix may be wanting in details in the highlights. Naturally the positive must also be free from fog, for as the gelatine is rendered insoluble wherever there is silver, and fog is nothing but silver generally distributed, it might happen that the fog is sufficiently bad to give insoluble gelatine and consequently color where it is not wanted.

The positive should preferably be fixed and washed as usual, though this is not absolutely essential, and then immersed in one of the following baths:

Chromic acid	5 g
Potassium bromide	20 g
Water	1000 ccm

or:

Potassium bichromate	6 g
Hydrochloric acid	10 ccm
Water	1000 ccm

These may be used over and over again, in fact until their action gets too slow; they should, however, be kept in the dark, when not in use.

The positive should be immersed in the solution in a dish, and the dish rocked until it is seen that it is bleached quite through to the back, on looking through the glass. Prolonging the immersion does no harm, but as a rule ten minutes is sufficient for any positive, no matter how dense it may be. The bleached positive is then immersed in water at about 40° C. (105° F.), when the gelatine will be seen to gradually dissolve away, leaving the whitened silver image, which is either the bromide or chloride. Should the gelatine not dissolve easily, the temperature of the water may be raised two or three degrees; but it is not advisable to force development, as otherwise some of the isolated patches and the fine details may be washed away. The plate should then be rinsed in cold water to remove any adherent soluble gelatine, washed to remove any traces of the bichromate-acid bath, which would decompose the fixing bath, and immersed in a hypo bath until the white silver salt is dissolved. After this it requires but a brief washing, and can be dried or immediately stained up.

The author has a fancy for immediately staining up lightly, as this prevents any subsequent mistake as to which plate is which, as otherwise when dry the relief is so slight that it is difficult to distinguish between the various plates. The dyes used may be the same as those suggested for the pinatype process, the final transfer paper may be treated in the same way, and the method of superposition of the images also followed.

Exactly how many pulls may be taken from these matrices the author has never determined, but with reasonable care at least a couple of dozen may be made. This is probably as many as the average worker will require, but the life of the matrices may be prolonged by treating them with an alum solution; in this case, the primary development of the silver image must be pushed a little farther than usual. The alum bath, a ten per cent solution of ordinary alum or five per cent of chrome alum, should be applied to the reliefs after they are freed from hypo. They may then be washed for ten minutes and treated as suggested.

The advantage of this and similar processes over the pinatype process is that there is nothing but the gelatine image to stain up, so that no dye can be transferred to places where it should not be. Also, as all acid dyes readily stain the gelatine, and most of them transfer well, there is a much wider choice of dyes. Thus, one may use for the red picture, in addition to those already given, fuchsin, erythrosin, rhodamin G, various sorts of ponceau; for the yellow, acid yellow, naphthol yellow; and for the blue, diamine pure blue 3B, carmine blue and alizarine cyanol. In fact one can try out the various dyes sold for dyeing household materials, and these are very cheap.

If the final dye impression is weak, or wanting in details in the high-lights, the original positive was underexposed or underdeveloped, and conversely if the highlights show too much color, particularly in portraits, the positive was overexposed or overdeveloped. If the relative coloring is good, but too weak generally, the dyed matrix was not left long enough in contact with the paper. As with the pinatype process, corrections can be made by subsequent transfers from one or all of the plates.

It will be found advisable to dye up the matrix each time before transfer, and it is actually immaterial how long it is left in the dye solution, as the gelatine can only take up a certain amount of dye, and the only point to observe is that, the more dye it has absorbed, the more rapid the transfer to the gelatinized paper.

THE ETCHING PROCESS

Another process, which is quite as simple as that already described, and which is actually simpler if the original negatives are used as the printing matrices, is the so-called etching process. In this the gelatine in contact with the metallic silver of the image, instead of being insolubilized, is chemically etched or dissolved away.

This process is founded on an observation made originally by Liesegang in 1897, and was improved upon by Andresen in the following year. The former noticed that when a negative was immersed in a solution of ammonium persulphate, the gelatine surrounding the silver image was so softened that it became soluble in hot water. Andresen improved the idea by using hydrogen peroxide, and this is actually the etching agent in this process, that is, it gives up oxygen when reacting with the silver and the nascent oxygen attacks the colloid.

The etching fluid is:

Hydrogen peroxide	30.0 ccm
Cupric sulphate	20.0 g
Nitric acid	5.0 ccm
Potassium bromide	0.5 g
Water to	1000.0 ccm

This is used at normal or room temperature, preferably 18° C. (70° F.) If the temperature rises, the action is apt to be too violent in the deep shadows.

If one elects to use the original negatives, it is apparent that it obviates the making of a set of transparencies and second negatives. There is no real objection to this use of the primary negatives, except that the gelatine may become damaged in the course of time and one has then no reserve negatives to fall back upon, from which to make further matrices. It is as well, therefore, to make transparencies from the original negatives and keep these in reserve. It may be emphasized here (because, although we are considering one special process, this recommendation is applicable to every case in which transparencies are made for the purpose of reproduction of negatives) that they should not be like lantern slides, that is, brilliant and hard, but rather of a soft character, fully exposed without dense shadows. In fact the best type of reproduction transparency is that in which there are no patches of clear glass and no dense shadows that one cannot easily read print through. One can, in making the second negative from such plates, obtain any desired degree of contrast by the use of contrast plates, slight underexposure or the liberal use of bromide in the developer. Whereas, if the transparency is wanting in detail, there is no method of obtaining it.

If one elects not to use the original negatives, one must make transparencies from them and duplicate negatives from these. Obviously with all these processes, in which either negatives or positives are used as print-plates, one is not tied to the original size of the negatives, as they may be enlarged or reduced in the camera, and thus any size of picture secured.

It is advisable to soak the negatives to be used in five per cent chrome alum solution for about fifteen minutes, and then wash and dry; but if films are used, and these are the most satisfactory because of their pliability, it is not necessary to use the alum bath.

The negatives should be immersed in the etching solution and allowed to soak for about five minutes, and then the dish gently rocked, and it will be seen that the image will begin to gradually disappear and dissolve off. If the solution is properly made up, the image does not change color at all, but comes away with the gelatine in its original black color. The solution becomes opaque from this suspended silver and turns milky, because the bromide gradually converts it into silver bromide. If, after use, the solution is allowed to stand, the bromide settles down to the bottom of the dish and the supernatant liquid can be poured off and used again if thought necessary; but as the cost of the solution is really very small, this is hardly worth while.

The action of the bath is allowed to continue until, after rinsing the plate or film with water, no black image is seen, which is best observed against a white surface. The image will not be quite invisible, but when there is no black silver visible the action is complete. It is always advisable to manipulate all three negatives at once, or each one with fresh solution, as this means regularity of results. As the etching action is due to the evolution of oxygen from the peroxide, and commercial peroxide may be used, it is clear that the more the solution is used the longer it will take to etch. If the solution has been used and allowed to stand, and it is thought worth while to use it again, it will probably be unnecessary to add more peroxide; but more bromide should be added, because really the quantity of bromide controls the rapidity of the solvent action, and if it be entirely used up, the silver may be dissolved without the gelatine, though this is not likely if the above ratios are adhered to. Naturally, also, increase in temperature increases the rapidity of the action, but there is no particular advantage in rapid action, and if the rise in temperature is about ten degrees, some of the gelatine not in contact with the silver may dissolve; of course, a rise of one or two degrees is of no moment.

As soon as all the black silver image has dissolved, the plate should be washed for about fifteen minutes and preferably fixed in a chrome alum fixing bath; this is not actually necessary, but as there is always a slight residue of silver bromide left in the image, the hypo removes it. Then, after washing out the hypo, which takes but a short time, the plates should be immersed in five per cent solution of formaldehyde for fifteen minutes, rinsed, and dried. This drying hardens the gelatine so that the image is less liable to damage in the subsequent operations.

The dyes that can be used and the various manipulations are exactly as described in the previous processes, so that there is no necessity to repeat the directions. The print-plates may be repeatedly used, staining up afresh each time.

Developed Relief Process

This is another inverse process, that is, one in which a positive is used for the print-plate, which must be exposed through the back. The directions already given for the bichromate relief process also apply to this, and, as in that, warm water is used to dissolve the gelatine. The basis of the process is the tanning action of oxidized pyrogallol on gelatine, and this is so great that the latter actually becomes insoluble in warm water, as was pointed out by Warnerke in 1881.

It is a well-known fact that the oxidation of pyrogallol, and all developing agents, is prevented by the addition of sodium sulphite and, therefore, by the addition of more or less of this the height of the relief obtained, or the quantity of gelatine rendered insoluble, can be varied. It is possible to use a plain solution of pyro with soda or ammonia, but there is danger of superficial tanning, and as one also wants freedom from fog, it is advisable to use some sulphite and some bromide. A suitable developer may be made on the following lines:

Pyrogallol	5 g
Sodium sulphite, dry	10 to 20 g
Sodium carbonate, dry	25 g
Potassium bromide	1 g
Distilled water to	1000 ccm

The sulphite should be dissolved in 100 ccm of the water, the pyro added, and the solution at once bottled. The carbonate and the bromide should be dissolved in 900 ccm water, and when required for use the two solutions should be mixed. Obviously, any quantity of stock solution of the carbonate can be made up; but it is not advisable to make up any quantity of the pyrogallol in stock, as every time the bottle is opened the pyro becomes more or less oxidized, as the amount of the sulphite is so small that it is not an efficient preservative, and consequently tanning of the gelatine, where it is not wanted, might take place. Unless the three transparencies are developed together, fresh solution must be used for each one, as otherwise if the developer be used for two or three plates in succession, one meets with precisely the same trouble again, because the developer oxidizes much more rapidly in an open dish in the presence of the carbonate than in the bottle with the plain sulphite solution.

It seems unnecessary to repeat what has already been said when describing the other processes, as to the necessity of avoiding underexposure, but as this developer contains a fair proportion of bromide and this delays the appearance of fine detail, it is as well to give a generous exposure so as to avoid too bare high-lights.

As soon as development is complete, the plates should be at once washed in water to stop development. There is no necessity to fix. They can then be treated with warm water at about 38° to 40° C. (100° to 105° F.), in which the gelatine not in contact with the silver will dissolve, leaving a relief containing silver. It is advisable to remove this, as it renders the later registration more difficult, and naturally any silver solvent may be used. While thoroughly efficient, the least satisfactory from a practical point of view is Howard Farmer's hypo and ferricyanide, as it will not keep. The following reducer, known as Belitski's, is just as efficient, keeps well in the dark, and may be used repeatedly:

Potassium ferric oxalate	50 g
Distilled water	200 ccm

Dissolve and add:

Sodium sulphite, dry	20 g
Water	100 ccm

This at once forms a blood-red solution and to it should be added:

Oxalic acid, dry crystals	15 g

Shake the solution until it turns a fine green, without any tinge of yellow; if this latter persists, and all the oxalic acid has dissolved, a few more crystals of the acid must be added, and the solution well shaken; but if the solution is green and there is some undissolved acid, the mixture should be poured off from the crystals. To this solution should be added:

Hypo	250 g
Water to make	1000 ccm

When the hypo is dissolved the solution is ready for use.

Possibly some little difficulty may be experienced in obtaining the potassium ferric oxalate, and it should be noted that this is not ferric oxalate; but there is no difficulty in making it by dissolving 35 g of ferric chloride (not the anhydrous salt) in 50 ccm water and adding 64 g of neutral potassium oxalate dissolved in 150 ccm warm water. This introduces a little potassium chloride into the solution, which does no harm. After fixing, the relief should be washed to remove the hypo and dried. The other steps in the process are as already outlined for previously described methods.

CHAPTER IX

MORDANTING AND TONING PROCESSES

IN the processes now to be described the silver image is converted into some salt which exerts an absorptive action on basic dyes. There is no relief formation and the dyed image is imbedded in the original thickness of the gelatine, so that the whole film has to be transferred to the final support. Consequently it will be found that films give the least trouble.

The first process is the diachrome or iodide process, which was first described by Traube in 1907. The constituent positives are made in the usual way, and after fixing and washing are immersed in the following solution until the image is seen to be completely bleached:

Iodine	15 g
Potassium iodide	50 g
Glacial acetic acid	25 ccm
Distilled water to	1000 ccm

It may be as well to give the best method of making the above solution. Add the iodide to 100 ccm of water, then stir in the iodine and stir until completely dissolved, then add the remainder of the water and the acid to make the required volume. If the iodine and the iodide are added to the full quantity of water, it takes a very long time for the iodine to dissolve.

As a variant of this bath, the image may first be bleached with cupric chloride, by the action of:

Cupric sulphate	50 g
Sodium chloride	20 g
Water	1000 ccm

Wash after bleaching, immerse in a two per cent solution of potassium iodide for fifteen minutes, and wash again. The first bath converts the metallic silver into a complex silver-copper chloride, which is then converted by the second bath into the corresponding iodide. Possibly an easier method, in which copper iodide is at once deposited on the image, is by the use of the following:

Cupric sulphate	50 g
Water	500 ccm

Dissolve and add:

Potassium iodide	33 g
Water	100 ccm

A heavy precipitate is at once formed, and strong ammonia should be added till a perfectly clear dark blue solution is obtained, when the volume should be brought up to 1000 ccm by adding more water.

Whichever bath is used, the bleached image should be immersed in a five per cent solution of sodium bisulphite for five minutes. The acid lye can be obtained commercially and can also be made as follows:

Sodium sulphite, dry	500 g
Water	750 ccm

Stir well and add, with constant stirring, and slowly:

Sulphuric acid	100 ccm

This practically forms a 40 per cent solution of bisulphite, which is used as a decolorizing bath, as it instantly attacks the free iodine that is very tenaciously held by the gelatine, and decolorizes it. The bleached positives should be well washed and can then be dyed up.

In all these mordanting processes basic dyes must be used, whereas with the relief processes acid dyes are employed. The terms "acid" and "basic" do not refer to the acidity or alkalinity of the dye solutions. An acid dye is one in which the actual coloring matter is a color-acid, and usually it is combined with an alkaline base such as ammonium, sodium, potassium or calcium. Such dyes are, therefore, salts of color-acids. The color element in a basic dye is a color base combined with an acid, such as hydrochloric, etc.

The fact of having to use basic dyes rather limits one's choice and for the red we have fuchsin, rhodamin G and 3G, which are the best, then Janus red B and pyronin G. For the yellow, auramin, vesuvin, chrysoidin Y, thioflavin and safranin Y. For the blue, Victoria blue B, night blue, methylene and thionin blues.

The actual dye bath should not be strong, certainly not more than 2.5 : 1000, and it is advisable to add about five per cent of glacial acetic acid. The stronger the bath the more rapidly will it act, but the results may be rather flat and wanting in contrast; whereas with a weaker bath, although it takes a longer time, more brilliant prints are obtained. As soon as the pictures are sufficiently stained, they should be rinsed to free them from excess dye on the surface. The image will now consist of silver, plus copper or silver iodide, and the dye, and as a rule, unless rather thin images were obtained in the first place, which is preferable, they will look too opaque and muddy because of the silver iodide. To remove this they have to be fixed, and it is here that one is apt to strike trouble, as, on treatment with an ordinary hypo bath, the dye is apt to diffuse into the surrounding gelatine, or, as it is technically termed, bleed. To prevent this the following bath should be used:

Hypo	150 g
Sodium acetate	50 g
Tannin	50 g
Water to	1000 ccm

The prints should only be left in this until the images are sufficiently transparent, and then immediately washed.

The positives should not be dense for this process, should be well exposed and rather thin, and must be quite free from fog. An acid chrome-alum fixing bath should be used, and after washing they should be immersed for fifteen minutes in a 10 per cent solution of formaldehyde, and dried without washing.

THE COPPER MORDANTING PROCESS

This is somewhat easier to work than the iodide process, as there is less chance of the dyes bleeding; but it is more particularly suitable for the red and yellow constituent pictures, though it can be used for the blue as well; it was first suggested by Traube in 1916.

The process is as follows: the silver image is treated with a solution that converts it into a mixture of silver and cuprous ferrocyanides, both of which are insoluble in water: the copper salt is the mordanting agent, the silver ferrocyanide having but little power in this respect.

It is possible, therefore, to fix out the silver ferrocyanide, leaving the copper salt and the dye. As the former is very transparent, it gives but little trouble in the superposition of the pictures. As stated, the only objection to it is that it has a reddish tinge and this dulls the blues and makes the yellows more of an orange shade, though this last causes but little trouble.

Copper toning processes for bromide prints have been known for a great many years and any of the old formulas may be used, but the following is particularly suitable:

Cupric sulphate	20 g
Potassium ferricyanide	15 g
Potassium citrate	120 g
Ammonium carbonate	10 g
Water to	1000 ccm

In the first place the ferricyanide must be in clear ruby crystals, without any adherent yellow powder, which is the ferrocyanide. The commercial salt is rarely sufficiently clean, and the best thing to do is to weigh out a little more than the correct quantity, say 15.5 g, place this in a small beaker and add about 100 ccm distilled water, stir twice and pour off the water. The clean copper salt and the citrate should be dissolved in half the water, which may be used warm with advantage, the ferricyanide dissolved in 250 ccm, and the ammonium salt in the remainder. Warm water must not be used for the latter. Mix the ferricyanide and the ammonium solutions and add to the copper. The positives should be immersed in the complete solution until there is not the slightest sign of a black image to be seen when examined through the glass. This may take from fifteen to twenty minutes. They should then be washed well and may be immersed in a 20 per cent solution of hypo for ten minutes and well washed. After toning they are of a somewhat opaque reddish brown color when examined by transmitted light; but after fixing they should be a clear transparent red. After being freed from hypo, they should be immersed in the dye solutions, with glacial acetic acid, as recommended for the iodide process, and should be left therein till sufficiently stained up. If at this stage the image appears too opaque, or the blue too dull, as it may, the positive should be immersed in a 10 per cent solution of sodium acetate plus the same quantity of tannin for ten minutes, then rinsed and dipped into a 2 per cent solution of caustic soda, which dissolves the cuprous ferrocyanide, leaving nothing but the dye image.

THE VANADIUM MORDANTING PROCESS

This is actually an old process, but its use as a mordant was proposed by Namias. We have here the same basic reactions as in the copper process, that is, the precipitation of insoluble vanadium ferrocyanide *in situ*, with the formation of silver ferrocyanide; the former salt is yellow, while the silver ferrocyanide is white, and again it is the other ferrocyanide that acts as the mordant and not the silver. The usual vanadium salt employed is the chloride, an expensive salt that is so hard to crystallize that it is sold in syrupy form. It has the great disadvantage that it forms silver chloride, which is very opaque. The author has worked out a method of making vanadium oxalate which is comparatively cheap, and much more satisfactory in use, as it gives images so transparent that it is rarely necessary to fix them. The following is the method advised: place in a porcelain evaporating dish 100 g ammonium vanadate and 460 g pure oxalic acid, then add gradually 500 ccm distilled water, and heat. The thick cream, which is white, gradually becomes more fluid and turns first yellow and then green and the vanadium goes into solution; continue the heat till the solution turns blue, then make up the bulk with distilled water to 1477 ccm. This will be a 20 per cent solution of vanadium oxalate with a slight excess of acid. The sulphate may be made in the same way, substituting 197 ccm of pure sulphuric acid for the oxalic; this should form a blue solution, but if not it may be heated, and the bulk in this case also made up to the same as before. Both solutions contain the same ratio of vanadium and they will keep indefinitely in the dark, and it is immaterial which is used. The actual bath is:

Vanadium oxalate solution	50 ccm
Oxalic acid, saturated solution	50 ccm
Ammonium alum, saturated solution	50 ccm
Glycerine	50 ccm
Potassium ferricyanide, 10 per cent solution	10 ccm
Distilled water to	1000 ccm

The vanadium, oxalic acid and alum should be added to half the water, the glycerine and ferricyanide added to the remainder, and the two solutions mixed. The previous comments as to the ferricyanide apply equally in this case.

The positives should be immersed in the bath until all signs of a black image have disappeared when examined from the glass side, and they can then be washed and dyed up. After treatment with the above bath, the positives will be found to be of a yellowish-orange color and are as a rule sufficiently transparent without fixing.

THE CHEMICAL TONING PROCESSES

These are given rather with the idea of making the subject complete than for their practical value, as in nearly all cases the images are too opaque to be of any value. The iron toning process, however, which gives a blue, has been frequently used as the foundation image for the other colors, and the yellow mercury image may be used in the same way.

The best way of obtaining the blue-toned image, which actually gives a very satisfactory foundation for the other images, is by a modification of the bath given for vanadium, using ferric oxalate instead. As commercial ferric oxalate is rarely suitable for the work, the following method should be adopted for making it: add 520 g of ammonium iron alum to 200 ccm distilled water, and heat until dissolved. Then cool, add 200 ccm strong ammonia, and allow to stand for fifteen minutes with an occasional stir. Now transfer to a tall 1000 ccm graduate, and rinse the first vessel out with repeated lots of distilled water and add to the graduate till full. Allow to stand until the precipitate has settled somewhat, then syphon off the supernatant liquid, fill up the graduate again with distilled water, shake well, again allow to settle, and again syphon off the liquid; repeat this operation until the water no longer smells of ammonia. Then allow the graduate to stand until the precipitate and the water together measure not more than 850 ccm. Add 215 g pure oxalic acid, stir well, and allow to stand for a short time. The precipitate will gradually dissolve and form a bright green solution; when all the red ferric hydroxide has dissolved, filter the solution and add distilled water to make the bulk up to 1000 ccm. This will be a 20 per cent solution of ferric oxalate with an excess of 1.2 per cent of oxalic acid. The addition of the oxalic acid must be made by artificial light, and the solution must be kept in the dark. The toning bath is made up exactly like the vanadium bath, merely substituting the iron for the former.

The blue image given by this bath is known generally as a cyanotype or Prussian blue image, and it may be used as the foundation for the red and yellow images, as any silver image, whether on paper or on glass, is toned blue by it. It is thus possible to make the print from the minus-blue negative, on bromide or development paper, or on a transparency plate, and superimpose the other images.

The yellow-toned image is obtained by treating the black silver image with mercuric-potassium iodide, which is made as follows:

Mercuric chloride	11 g
Distilled water	500 ccm

Heat until dissolved, and add the following solution:

Potassium iodide	27 g
Distilled water	500 ccm

Shake the mixture well and filter. The print or transparency is immersed in this solution for fifteen minutes and then thoroughly washed. The image turns brown, and only after washing does the yellow color appear. Another variation of the above is the following:

Mercuric chloride	50 g
Distilled water	900 ccm

When dissolved, add slowly with constant stirring:

Potassium iodide	2.5 g
Distilled water	100 ccm

In this the image turns yellow at once.

There is no satisfactory method of obtaining a good red image by direct toning. There are several methods of obtaining colored images by the use of lead salts, but these are so opaque that the resulting pictures are so dirty and muddy as to be valueless. The blue toning process described above is satisfactory for both transparencies and prints; but the yellow toning process can only be used to make the foundation print, as it is too opaque for lantern slides.

The Combination of Processes

We have dealt so far with the various processes as totally distinct, but it will frequently be found that a combination of one or more of these processes will give excellent results. For instance, suppose the blue constituent picture is made by blue toning of a bromide print, then the red and yellow images may be made by transfer by the imbibition method.

There is only one disadvantage in using bromide paper for one of the prints, and that is, its unequal expansion, which may cause some trouble in registration. This may be overcome to a great extent by soaking the paper in water for half an hour before exposure, which gives it opportunity to fully expand. If a piece of thin celluloid be placed between the negative and paper, the latter may be squeegeed down to the celluloid and the loss of sharpness is so slight as to be negligible. Or, the negative may be given two coats of celluloid varnish and the paper squeegeed direct to it, and if the paper be stripped immediately after exposure and the negative wiped dry no harm will ensue. The paper may be treated before exposure with celluloid varnish, the back being painted rather thickly, which can be easily done if the paper is placed in a printing frame with a glass behind it to hold it flat, the sensitive side being inside, of course. Old celluloid films, freed from their gelatine, and dissolved in methyl alcohol with acetone and a little amyl acetate, make an excellent varnish.

If the constituent pictures have been formed by one of the mordanting processes, and are thus carried by the original thickness of gelatine, the best plan to adopt is to strip the films, and while this may at first sight seem a ticklish matter, it really becomes very easy with a little practice. The great danger is, of course, expansion of the gelatine and consequent lack of registration; but, if the following directions are carefully followed, there is little chance of this.

Place the plates to be stripped on a flat surface, and, with a straight edge and a sharp penknife, cut through the gelatine film right down to the glass, about an eighth of an inch from the edge all round; this considerably facilitates later operations. The actual stripping solution is:

Glycerine	37.5 ccm
Water	37.5 ccm
Hydrofluoric acid	37.5 ccm
Denatured alcohol to	1000 ccm

Care must be exercised in the use of the acid, as it readily attacks the finger nails and skin even in this dilute strength, and when strong it causes the most painful and persistent burns. As the solution attacks glass and enamel, it must be used in papier-maché or vulcanite dishes; on this property of attacking glass is based its stripping action, as it practically dissolves the surface of the glass and thus loosens the adhesion of the gelatine to the latter. It will be found advantageous to make up a stock solution of the above without the acid, and only add this just before use. Still more desirable is the abandonment of the acid altogether and its replacement by an alkaline fluoride. The commercial hydrofluoric acid is a 40 per cent solution, therefore, in the above quantity there will be actually 15 parts of acid. As we can set free the acid from an alkaline fluoride by the action of an acid, such as sulphuric or nitric, we may use either 30 g of sodium fluoride or 44 g potassium fluoride and 75 ccm pure nitric acid to obtain the same result. Therefore, the procedure would be to make a stock solution of the glycerine and alcohol and add the fluoride and acid just before use.

The positive should be placed on a level plate and a little of the stripping fluid poured on its surface and spread with a flat brush; this is more convenient than using a dish. In about five minutes the film will begin to loosen, and this can be easily determined by trying to lift one of the narrow margins of the film with the penknife.

If this comes away freely then one may proceed to strip the film; if not, a little longer time should be allowed. In no case must any force be used to lift the film; it is better to allow double or treble the time for the solution to act naturally, as any force will distort it and cause trouble in subsequent registration. When the film seems loose, gently lift the glass and allow the mixture to drain off slowly so as not to give the film a chance to slip; then pour on a little of the stock solution without the fluoride, leave for two or three minutes, and then drain this off in turn.

One may now use either waxed paper or celluloid as the transfer medium. If the latter is used, it should be thin and preferably rubbed over with a little vaseline; it requires very little of the latter, the merest dab just rubbed all over the surface and then well polished with a clean rag or two. Waxed paper will be found the easier of the two, but it must be smooth and free from folds, and larger than the film. It should be laid down on the surface of the plate and very lightly squeegeed, and then the paper may be lifted and it will bring the film with it away from the glass.

An alternative method, which obviates the use of the fluorides, is to use an alkaline formaldehyde solution, such as:

Potassium carbonate	100 g
Formaldehyde	100 ccm
Glycerine	100 ccm
Denatured alcohol	300 ccm
Water to	1000 ccm

The carbonate should be dissolved in the glycerine and water and then the other ingredients added. The film should be cut round as before, immersed in this solution in a dish, and left therein for from twenty to thirty minutes. The progress of the stripping action is tested by the edges, as previously suggested. When the film proves to be loosened, lift the plates from the solution, drain, and immerse in a mixture of 400 ccm alcohol and 600 ccm water for five or ten minutes, then lift out, drain, and lightly squeegee down on the waxed paper.

It is advisable to treat all three plates in this way simultaneously, so that there may be no delay in the final transfer. For the final support gelatinized paper is required, which has already been dealt with. The paper should be larger than the picture. Having all three images on the waxed papers, the first may be laid down on the dampened final support, lightly squeegeed, and after about half a minute the wax paper may be stripped, and then the other images transferred in the same way. Instead of using the waxed papers, the final support may be squeegeed direct to the plates, and there is even less chance of non-registration.

A cement is not actually necessary, but the final result is stronger if one is used and there is less likelihood of the films separating. Either of those already suggested may be used, but they must not be too freely applied. If the cement is used, it is advisable so to arrange the work that each print may be left for about ten minutes before the next is applied; but the paper must not be allowed to dry, and should be placed face up on a pile of wet blotting or filter papers.

Another alternative is to make two pictures on glass, and the third on thin celluloid, printing through the back to obtain a reversed picture and then cement this down to the other two transferred prints, when the celluloid acts as a protection to the picture. For experienced workers coating the constituent pictures with collodion will naturally suggest itself as a good preventive against expansion, but for the novice, coating with collodion is not such an easy matter, and if this be used more time must be allowed for the stripping fluid to penetrate. If three celluloid films are used, and this is possibly the easiest plan, though there is slight modification of the colors, especially in the more delicate tints, because of the color of the celluloid, then, as we shall have celluloid applied to gelatine, a cement must be used which will act on both, which can be made on the following lines:

Gelatine	2 g
Pyroxyline	5 g
Glacial acetic acid	50 ccm
Methyl alcohol	100 ccm
Amyl acetate	20 ccm

Soak the gelatine in the acid and melt by heat, dissolve the pyroxyline in the alcohol and amyl acetate and add to the gelatine solution, stirring well, and, if any gelatine is thrown out, heat a little more.

CHAPTER X

THE THREE-COLOR GUM-BICHROMATE PROCESS

THIS is essentially a carbon process, and is usually known as the "bi-gum" process. It is purposely described separately, as it is impossible to obtain the paper commercially and one has to prepare it. After one impression is obtained, it is necessary to recoat the print with the second sensitive mixture, print, develop, and recoat for the third print. It requires some little experience to carry this to a successful conclusion, and it is more time-consuming than straight carbon printing.

One meets again in this process the trouble of expansion of the paper, and it is possibly more accentuated. The following methods in addition to those already given may be useful. As there is no sensitive surface to take care of, one has greater latitude in treatment. The most radical treatment is to soak the paper in water for twenty-four hours and then squeegee down to a sheet of glass, the edges of which have been coated with a 10 per cent solution of gelatine, to which has been added 1.5 per cent of chrome alum. The edging should be about half an inch in width. The wet paper will adhere to this edging and on drying contracts and becomes as tight as a drumhead. It can, when dry, be painted with celluloid solution, such as:

Celluloid	12 g
Methyl alcohol	750 ccm
Acetone or ether	250 ccm
Castor oil	10 ccm

Two or three coats may be applied to the dry paper, but there should be no glaze formed; if there is, more alcohol should be added. When the solvents have completely evaporated, the surface should be freely painted with a five per cent solution of gelatine containing one per cent of chrome alum, and this must be applied warm and allowed to dry. Or, instead of the chrome alum, the paper, after having been painted with the plain gelatine solution, may be painted with 25 per cent formaldehyde solution as soon as surface dry, and then dried. If a glazed surface is required, the commercial final transfer paper for carbon work should be used, and as this can be obtained in various surfaces it saves any preliminary preparation.

The sensitive surface is prepared with gum arabic or fish glue and gum, with which the colored pigments are incorporated, then sensitized with bichromate, dried and exposed. The development is effected with cold, not hot, water, and the print is merely allowed to lie face down on the surface of the water, as both the gum and fish glue are soluble in cold water. The print is then immersed in alum solution, washed, and dried.

The pigments used are preferably those prepared for water-color painting and should be obtained from an artist's supply store, as these are ground up specially fine in water and are free from lumps or gritty particles. The preparation of the pigments is a time-consuming and laborious job; but if anyone wants to do it, the following is the correct way to set about it. A glass muller and a good sized sheet of plate glass will be required. A small heap of the powdered pigment should be placed in the middle of the glass, a few drops of water added, and the whole worked with the muller, water being added gradually, until a thick cream is obtained. Grinding with circular strokes is kept up for about half an hour, a few drops of water being occasionally added to prevent the mass getting too dry. Then the pigment should be scraped up with a palette knife and put into a wide-mouthed bottle or preserving jar, and fresh pigment ground up in this way until the stock is finished. Care must, of course, be taken not to mix the pigments. Add to the pastes in the jars about ten times their volume of water, stir or shake well, allow to stand for about ten minutes to allow the large particles to settle, and then pour off the supernatant fluid and allow to stand a week or ten days for the fine pigment to settle.

The colors used should be chrome yellow, alizarine crimson and a mixture of Prussian blue and ultramarine blue in the ratio of 4 : 6. The gum solution is prepared from good clean lump gum arabic (powdered gum should not be used); 200 g of the gum should be placed in the center of a piece of fine muslin, the ends of the latter gathered together so as to make a bag and tied round with a string; this is then suspended in a wide-mouthed bottle or jar, by the aid of a piece of wood across the mouth, so that the muslin bag dips sufficiently far into 600 ccm of distilled water to completely cover the gum. This should be placed in a fairly warm place and left for two or three days for the gum to dissolve. One can, of course, merely add the gum to warm water and stir untill dissolved, but as the gum nearly always contains some dirt, the method described obviates having to filter or strain the gum solution.

There are two methods of preparing the paper; one in which the sensitizer is mixed with the pigmented gum, and the other in which the latter is applied to the paper and the bichromate only applied as one wants to print; the latter is preferable, as one can prepare a reasonable stock of the pigmented paper and it will keep indefinitely, whereas with the sensitizer incorporated it will only keep a few days. If the sensitizer is to be mixed with the gum, the following is a suitable mixture:

Pigment	25 g
Gum solution	50 ccm

Rub up well so as to obtain a smooth mixture, using either a mortar or a large sheet of glass and a palette knife; in the latter case transfer to a tea-cup or wide-mouthed jar and add with constant stirring:

Ammonium bichromate	3 g
Citric acid	2 g
Water	25 ccm

If the sensitizer is to be applied afterwards, this latter solution may be omitted, and it will then be possible to prepare quite a stock of the pigmented gum, though to prevent it from moulding a few drops of phenol (carbolic acid) should be added. This may also be added to the stock of plain gum solution with advantage, though if the latter goes sour and becomes more fluid it is still fit for use.

There are two methods of sensitizing the coated paper, either by floating or by painting the solution on, and the latter is far preferable. If the floating method be adopted, the back of the paper, not the coated surface, must be floated on:

Ammonium bichromate	30 g
Citric acid	15 g
Water	1000 ccm

Float for about five minutes and then hang up to dry. For painting on, half the water in the above formula should be replaced with denatured or methyl alcohol, and the solution may be freely painted on the back of the paper.

Applying the pigmented gum to the paper is somewhat of a trick, which can be easily learned with a little practice, and that is one reason why the use of the non-sensitized mixture is preferable. It is impossible to state exactly how much mixture should be used per unit area, but one soon learns from the appearance of the paper; for when finished it should present an even coating of color and it should not be possible to see the white surface through the pigment. Two brushes will be required, a camel's hair mop, with which the pigment is applied freely with circular strokes, and a hog's hair softener, which should be used first with vertical strokes and then with horizontal ones until an even coat is obtained, when the paper may be hung up to dry. The brushes must not be used too vigorously or a plentiful crop of minute bubbles will result, and this particularly applies to the use of the second brush.

Exposure is gauged with an actinometer as in ordinary carbon printing, and the paper is rather more sensitive than printing-out paper. Development, as already stated, is effected by floating the print face down on water, and although this means more time it is the best; twenty to thirty minutes should be allowed, and the print may be lifted up and examined from time to time. A spray, as from a scent diffuser, may be used, but the use of a rose tap or pouring water direct on to the surface from a vessel is not advisable, as some of the finer details are sure to be washed away. On the completion of development the print should be immersed in five per cent alum solution for ten minutes, washed by repeated changes of water, and dried. While wet the image is extremely tender.

The second pigment is applied over the first print in the manner described, and the sensitizer also used in the same way, but allowance must be made for the slower penetration of the latter, due to the greater thickness on account of the presence of the first print.

We now come to the crux of the whole process, the registration of the images, because it is impossible to see the outlines of the objects through the pigment coat. The first thing to do is to see whether the negatives themselves can be registered by their edges or corners. For this purpose they should be placed on a sheet of glass, which should be at least an inch narrower than the negatives, so that both ends of the latter protrude beyond the glass. The latter should be supported on piles of books or in any convenient way, and have a white card under it to reflect the light. Then two diagonally opposite corners should be brought into coincidence and the images examined. Care should be taken to look straight down on them and the use of a magnifying glass is advisable. If two of the negatives are thus found to coincide, the third may be compared with either in the same way. If they all agree, further printing is much facilitated as one has merely to mark the corners of the plates on the paper, or preferably use a printing frame larger than the negatives, cut cardboard corner pieces, and fit these into the frame so that the glasses will automatically drop into register.

If the corners and images do not coincide one has a much more difficult job. Six corner pieces of card must be cut, two of the negatives registered, the corner pieces applied at opposite diagonal corners and stout needles driven through both, taking care that the glasses do not shift. The third negative must now be registered in the same way, one of those already fitted with the corner pieces being on top, and the needle must be driven through the hole already made and through the second card. The corner pieces should be numbered 1, 2, 3, to correspond to the negatives, and if they are butted into the corners of the frame and registered by the needles, the negatives will be in register. It is safer, after having once made one hole, which should not be on the extension of the diagonal of the plate, but to one side, to drive a second needle through the three cards, on the other side of the diagonal, as this prevents any possible shift.

Naturally one may use paper with any surface for the support, but, except for large prints, smooth papers are preferable, as with really rough papers the irregularities of the paper cause irregularities in the depth of the pigment film.

CHAPTER XI

THREE-COLOR LANTERN SLIDES

HAVING obtained a set of tri-color negatives it is obvious that one can as readily make lantern slides or transparencies as prints, and almost all the processes described for the latter are applicable to slide making.

The easiest method is by the use of celluloid film sensitized with bichromate and exposed through the back. While roll film is not ideal, because of the back non-curling coating, it is superior to the cut sheet film as it has only one-third the thickness. Those who like to make their own materials will find it possible to coat even the thinnest celluloid evenly by a little trick; the difficulty in doing this is that the celluloid instantly curls up on the application of a warm solution. But by the use of the following plan there will be found no difficulty from this. Clean some old negative glasses, of a goodly size, and level them carefully. Prepare the following mixture:

Gelatine	53 g
Golden syrup	53 g
Glycerine	65 ccm
Chrome alum	1 g
Water to	1000 ccm

Soak the gelatine in 750 ccm of water with the syrup and the glycerine for half an hour, then melt by heat at 50° C. (120° F.), add the chrome alum dissolved in 100 ccm water, and make up to the quantity given. It should be noted that the syrup is cane sugar syrup, not corn syrup, though probably the latter will serve the purpose. Coat 65 ccm of the mixture on every 100 square inches of glass and allow to set, and then dry; this may take twenty-four hours, and one must not be misled by the feel of the film, as it actually never dries because the syrup and the glycerine are hygroscopic. The result will be a fairly thick tacky film that will hold anything. If the thinnest celluloid be rolled down to this, it will stick for weeks unless pulled off. Thus it will remain perfectly flat while coated with the various solutions. As soon as these coatings have dried the celluloid may be stripped by lifting two corners and one edge; one of the best things to do this is to use a flat bone paper knife run carefully along the edge so as not to damage the tacky coat; then a straight steady pull will detach the celluloid. The tacky glass may be used over and over again; exactly how many times, will depend on the care with which it is handled, but at least a couple of dozen times is easily possible.

To prepare the gelatine for the sensitive coating there is nothing better than the following:

Carpenter's fine glue	55 g
Water	500 ccm

The glue is the best and palest carpenter's glue that can be obtained, and it should be allowed to soak in the water for twelve hours. The correct method of working is to weigh a beaker or jar empty, then weigh in the glue and measure the water; at the end of the time pour off as much water as possible and weigh the jar again. Add enough water to make the weight 660 gm and add:

Gelatine	55 g

Allow to soak for half an hour, then raise the temperature to 50° C. (120° F.), and stir until all is dissolved, then add:

Alcohol	40 ccm

To this should be added some emulsion of silver bromide, and this is made as follows:

Gelatine	10 g
Potassium bromide	6 g
Water	100 ccm

Allow the gelatine to soak for ten minutes, melt by heat at 50° C. (120° F.), and add slowly with constant stirring:

Silver nitrate	5 g
Water	50 ccm

This can be made by artificial light, as the silver salt merely plays the part of an inert pigment and prevents too high a relief; its light-sensitiveness is not used. Keep the emulsion at 50° C. (120° F.), for about fifteen minutes, and then pour the emulsion out into a flat dish to set, and leave all night; if one has a refrigerator, the dish should be put in it so as to thoroughly chill the gelatine. The next morning score the emulsion with a *silver* fork first lengthwise and then across, so as to cut it up into small nodules. Collect these in a clean cloth, tie the ends of the latter into a bag and suspend in water; change this six times in the course of half an hour, giving the bag a good squeeze each time, so as to express as much water as possible. Then leave the bag to drain for an hour, for preference opening it and spreading the shreds out so as to give them a chance to drain well. Melt at 50° C. (120° F.), and add 75 ccm alcohol.

This should be stirred into the hot gelatine-glue mixture, and the result should be about 1000 ccm of a milky emulsion, which should be made up to that quantity; if on the other hand it measures a little more it will not matter.

There are now two methods open, the one to sensitize this, the other to coat as it is and sensitize as wanted. The last plan is preferable, as one can thus prepare enough celluloid at one sitting to last a year; whereas if sensitized with bichromate it will not keep more than two or three days. To sensitize, 30 g of ammonium bichromate should be added to the 1000 ccm, and it can be made to keep better by the addition of 10 g of potassium citrate. If the gelatine-coated celluloid is prepared, then the normal bichromate sensitizer should be used as already advised on p. 113.

Printing is effected through the back and, therefore, this must be polished well. The printing frame should preferably be placed at the bottom of a lidless box, about eighteen inches deep, so as to prevent the access of side light as far as possible. The films are very sensitive, and from two to four minutes will be about correct exposure in bright diffused light. An actinometer is hardly required, as the image can be easily seen on the white emulsion. Printing should be carried on until all but the details in the highest lights are visible on the back of the film, that is, on the celluloid side. Care must be taken in examining the progress of printing not to expose the film to too bright a light, or more or less general insolubility will be caused. After exposure, the films are developed in warm water at a temperature not exceeding 45° C. (113° F.), and the progress of development is easily seen, as the silver bromide acts as a pigment. As soon as the picture is developed, immerse in cold water. One now has a carbon or gelatine picture with the silver bromide as pigment, and as this is now valueless, having done its work, it must be removed, either by using a hypo bath, or what is preferable, hypo and ferricyanide or the reducer given on p. 93. The reason for advising the use of these is that the silver salt may be so far reduced by the exposure as to be actually darkened and as this means metallic silver it darkens the colors. A good wash should follow, and the reliefs may be dyed up, or dried and subsequently dyed.

Any of the relief processes already described for prints may be used here, and for this work the best film to use is motion picture positive film, which can be usually obtained to order. This is on celluloid only 0.005 inch thick and has no back coating; the emulsion is excellent for positive making, though rather faster than the usual run of transparency plates.

As regards the dyes for staining up, one has a fairly wide range, as acid dyes are the best. The following baths were suggested by Lumière, and their only disadvantage is that the dyeing is very slow. On the other hand, it must be recognized that the most brilliant results are obtained with slow dyeing, that is, in weak solutions; strong solutions and rapid dyeing always give flat pictures.

For the red:

Erythrosin	1.5 g
Water	1000 ccm

Time of dyeing from one to five hours. Rinse with water and immerse for five minutes in five per cent solution of cupric sulphate.

For the yellow:

Chrysophenin (aurophenin)	2 g
Water	1000 ccm

Dissolve by heat and add:

Alcohol	200 ccm

The great disadvantage of this dye is that it must be used in the form of the ammonium salt, and forms insoluble muddy brownish colors with calcium salts; therefore the relief must be immersed in a 1 per cent solution of hydrochloric acid for five minutes and then washed in distilled water, before staining; it is as well, therefore, not to use this.

For the blue:

Pure diamine blue FF	2 g
Fish glue	12 ccm
Water	1000 ccm

Dyeing takes from two to ten hours. The glue causes a slower and more even dyeing. This picture should be immersed in the copper bath after rinsing, but this treatment is not necessary for the yellow.

Von Hübl recommended the following, which do not take so long as the previous baths. For the red:

Erythrosin	0.25 g
Alcohol	100 ccm
Water to	1000 ccm

For the yellow:

Naphthol yellow S	0.5 g
Alcohol	100 ccm
Glacial acetic acid	5 ccm
Chrome alum, saturated solution	50 ccm
Water to	1000 ccm

For the blue:

Bluish fast green	0.1 g
Alcohol	100 ccm
Glacial acetic acid	5 ccm
Water to	1000 ccm

Other dyes as suggested for prints may be used; for the red, rhodamine B, or better still xylene red B, are good, for the blue, patent blue V, and for the yellow, mikado yellow.

One of the best methods of working is to use acid and basic dyes, as this gives one a much greater range and power over the colors and it is extraordinary what deep colors can be obtained. This method of working is based on the fact that the acid and basic dyes mutually precipitate one another, so that it is possible to faintly stain up with an acid dye and then by treatment with a basic dye to obtain a very deep result, or the order of the dyes may be reversed. This method was originally suggested by J. H. Powrie, and elaborated by A. E. Bawtree, whose choice of dyes is followed. For blue, soluble blue 5 per cent, oxalic acid 5 per cent; for peacock blue, which gives the best colors, soluble blue 5 per cent, naphthol green 1 per cent, malachite green 5 per cent. For yellow, aurantia 2 per cent, auramin 0.3 per cent. For red, rose Bengal 10 per cent, auramin 0.1 per cent. The method of using these is to immerse the picture in the first named dye for a short time, then wash and immerse in the second; for instance for yellow immerse in the aurantia first, then in the auramin. This alternation of the baths can be repeated, with intermediate slight washings, till sufficient depth is obtained; this in fact may be likened to a species of dye intensification.

The pinatype process gives very brilliant transparencies, but it is a little trouble. Glass should be coated with 5 per cent solution of hard gelatine containing 2 per cent of ammonium bichromate, and 30 ccm should be allowed for every 100 square inches. Weak daylight or artificial light may be used, but the plates must be dried in the dark. They will keep for about fourteen days, but it is better to coat the glass with plain gelatine solution and sensitize as wanted. Transparencies must be used to print from, and it is advisable to print from the minus red one first, that is, from the transparency taken through the green filter. It is then washed with water until free from bichromate, or to save time it may be immersed in a 2 per cent solution of sodium bisulphite, and washed and dyed up. It must now be dried, placed on a leveled stand, coated again with the bichromated gelatine and dried. The minus blue transparency, taken through the red filter, should be placed over the film and registration secured by the aid of a magnifier; the two plates are kept from shifting by two strong metal clips, or a printing frame can be used. The exposure is about twice as long as for the red impression, because some of the bichromate penetrates into the red image, so that the sensitiveness is reduced, and an increase of the bichromate is not advisable. After printing, the plate is washed or treated with the bisulphite, and dyed up. The yellow impression is obtained in the same way; but it is easier to make the yellow picture on another glass and reverse it, so that it can be used as the cover glass for the red-plus-blue image.

In all these processes, the blue constituent may be obtained by the aid of a silver image, and this toned with the cyanotype mixture as already described. A combination of processes can also be used, excellent results being obtained by making a blue-toned picture and transferring the red and yellow to it by the imbibition method. Enough has probably been said to lead the beginner in the right road to making successful lantern slides, for after all a slide or transparency is nothing more than a print with glass as a support instead of paper. Attention to details and extreme cleanliness in working are essential, and above all things absolute freedom from dust, as this shows up most distinctly when projected on a large scale on the screen.

The Photochromoscope

Instead of using superposed subtractive pictures it is possible to make use of the additive superposition of the pictures, by means of an instrument called the photochromoscope or chromoscope.

Then, instead of each individual constituent positive being colored in the subtractive or complementary color, ordinary black and white transparencies are used, which are illuminated by the three fundamental colors and are optically superposed, giving the impression of a complete colored picture. The results obtained by this method are extremely pleasing, especially when seen stereoscopically, but, as in the stereoscope, only one person can examine the results at one time.

The following instructions should enable anyone to make one of these instruments; these have been taken from König's work, as they are the only working instructions that have been published. The instrument is shown in section and plan in the accompanying diagrams. Fig. 15 shows a section of the chromoscope; the box is made with steps with apertures at L, L', L'' for the light filters and transparencies. *M* and *M′* are two transparent mirrors at an angle of 45 degrees to the bottom of the box. *R* is a mirror or white card or preferably a sheet of opal glass, which is hinged so as to allow of adjustment to obtain the best illumination of the aperture *L″*. The transparencies are placed on top of the filters. The eye

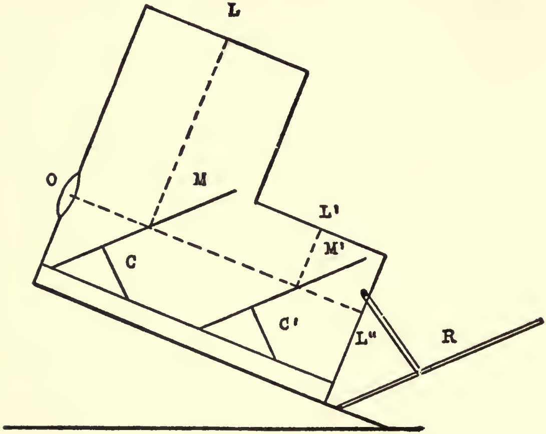


FIG. 15

sees through *O* the transparency placed at *L″* through the mirrors *M* and *M′*. The picture at *L′* is reflected by the mirror *M′* and passes through *M* to the eye. The picture at *L* is reflected by the mirror *M* to the eye at *O*. The last two pictures are thus seen in an inverted and upright position at *L″* and combine with the picture which actually is at this plane. The measurements are so adjusted that the three pictures fuse into one.

As the image of a mirrored object appears to be as far behind a mirror as the object itself is in front of the mirror, LM must be equal to ML'', and $L'M'$ equal to $M'L''$. Therefore, $LM - L'M'$ must equal $ML'' - M'L''$, or the distance of the mirrors M and M' from one another must be equal to the distance of L from L'.

The wood may be any well-dried kind, about 1 cm thick, which will not warp. For 9 x 12 cm pictures, or practically, with suitable-sized apertures, for $3\frac{1}{4}$ x $4\frac{1}{4}$ or 4 x 5 plates, the outside measurements should be about as follows:

AB	285 mm	$11\frac{1}{5}$ in.
CD, *AF*	165 mm	$6\frac{1}{2}$ in.
BC	265 mm	$10\frac{2}{5}$ in.
AG	135 mm	$5\frac{3}{5}$ in.
HG	125 mm	$4\frac{9}{10}$ in.
CJ	160 mm	$6\frac{3}{10}$ in.
HJ	130 mm	$5\frac{1}{10}$ in.

The horizontal surfaces *AGKF* and *HJEM* have an aperture of about 10 x 13 cm exactly in the middle; the vertical surface *CDEJ* also has a similar size aperture, the upper edge of which is exactly as far from *JE* as the nearest edge of the aperture *HJEM* is from *JE*. One side wall carries a flap which is provided with hinges and turn-buckle, which is just large enough for the reflector *R* with the base that carries it to be stored away inside the box.

On a board of exactly the size of the inner bottom surface of the box the two mirrors M and M' (Fig. 15) are fastened. These mirrors should measure about 135 x 135 mm, and are placed with their lower edges screwed on two metal angle plates which should be screwed to the board. The shorter side of these plates should slope about 5 mm above the board. The longer side should have a slit about 25 mm long, through which passes the binding-screw. This slit enables one to shift the position of the mirrors slightly. The mirrors are supported behind by two screws *C* and *C′*, by means of which the angle of the mirrors can be slightly altered. These screws should be perpendicular to the surface of the mirrors, that is, at an angle of 45 degrees to the bottom of the box. In order to support the mirrors they may have on their upper edges a narrow metal strip, to which may be soldered a hard brass or steel spring, which may be hooked to the baseboard, or to little blocks of wood projecting from the sides of the box.

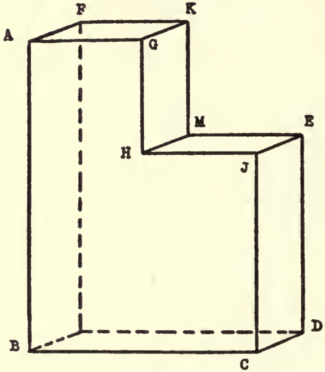


FIG. 16

The distance of the two mirrors from one another is the same as *GH* (Fig. 16), that is, 125 mm. The rear mirror should almost touch the back wall *CDEJ* at the top. The transparency, placed at *L″* (Fig. 15), should be illuminated by the mirror or reflector *R*, which should be adjustable, so as to enable the best illumination to be obtained. The whole apparatus should be fastened to a stout baseboard, so that it may be directed to the sky or any illuminant that is used.

An aperture should be cut in the front wall *ABF*, like the lens-board of a camera front, and the piece again fitted in with screws and turn-buckles. In this cut-out piece should be fastened an ordinary bi-convex or reading glass of from 35 to 40 cm focus, so that its center or optical axis should be exactly level with the middle of the aperture *CDEJ*. This lens need not be achromatic; one of the ordinary reading glasses is quite satisfactory. As large a lens as possible should be chosen, so that both eyes may be used; and the lens should be blocked out with black paper or a metal frame so that only a horizontal slit remains for the eyes to look through. The inside of the apparatus should be painted dead black, so that no white light is reflected to the eye. An ordinary shellac varnish, thinned with alcohol, and mixed with lampblack, so as to give a dead surface, may be used, or the wood may be chemically stained.

As pointed out on page 24 we must, as this is an additive process, use the fundamental colors for the filters, which are placed in the three apertures *L*, *L′*, *L″*, and which illuminate the three transparencies. The latter must be placed on filters of the same color as was used to make the negatives, that is, the transparency from the negative taken through the red filter must be illuminated by red light, the green transparency by green and the blue by blue-violet light. The filters for this purpose may be those suggested on pages 171, 173 for screen-plate printing, or may be made from the following stock solutions of dyes. As these filters are merely used as light absorbers, or screens, and are not required to give accurate images, there is no need to be so careful in their preparation as with taking filters, that is to say, they need not be cemented nor need the glass be optically so perfect as in the latter case; old negative glasses, free from bubbles and scratches, may be used with satisfactory results. But it is important that the coatings should be as even as possible. Two colored screens should be placed film to film for each color, as it is thus possible to obtain more even results.

It is advisable to make up stock solutions of the dyes and add these to plain gelatine solution. The stock solution for the blue filter is made from:

Crystal violet	3 g
Methylene blue	1 g
Glacial acetic acid	5 to 6 drops
Warm water	100 ccm

A 6 per cent solution of plain gelatine will also be required. The actual dyed gelatine should be:

Gelatine solution	747 ccm
Dye solution	23 ccm

This is sufficient for 1 square meter of filter surface.

For the green filter the following stock solution should be prepared:

Tartrazin	6 g
Patent blue	1 g
Naphthol green	2 g
Warm water	180 ccm

The green filter is the one that gives the most trouble and requires the most adjustment so as to obtain white light, for the three filters must give white light at the eyehole *O*. It is as well, therefore, to make about five filters of different depths of coloring, which can be done by adding varying quantities of the dye solution to the plain gelatine:

Gelatine solution	690 ccm
Dye solution	8 to 16 ccm

It is as well to start with 8 ccm of the dye solution, and then make other mixtures with 10, 12, 14 and 16 ccm of dye solution, so that five different depths of filters will be obtained. The above quantity is sufficient for 1 square meter of filter surface.

The red filter should be made with the following stock solution:

Tartrazin	4 g
Rose Bengal	3·5 g
Water	150 ccm

The actual dyed gelatine will be:

Gelatine solution	432 ccm
Dye solution	38 ccm

This is sufficient for 1 square meter of surface.

As the mirrors M and M' must not only reflect the pictures at L and L', but also transmit that at L'', ordinary mirrors are not suitable. Half silvered or platinized mirrors may be used, but these are costly and easily tarnish, so that plate glass should be used, and as they should not reflect the pictures from the back surfaces they ought to be colored. The easiest way to make these is to coat them with dye solutions, and they should be cemented to plain glasses with Canada balsam.

The dyed gelatine for the green mirror should be made from the following stock solution:

Tartrazin	0.5 g
Naphthol green	0.8 g
Patent blue	1.2 g
Water	250 ccm

To every 100 ccm of the plain gelatine solution should be added 8 ccm of the dye solution, and the mixture filtered. For a mirror 135 x 135 mm, 13 ccm of the dyed gelatine should be used.

For the blue mirror use the following:

Patent blue	1 g
Warm water	100 ccm

To every 100 ccm of gelatine solution allow 4 ccm of the dye solution and coat the same quantity as above, namely 13 ccm, on the same size mirror.

These colored mirrors should now be fastened in the box at an angle of 45 degrees with the base. The blue mirror should be placed under the red filter, and the green mirror under the blue filter.

The instrument should be inclined towards the sky and the inclination of the mirrors altered until the images of the filter apertures are seen as far as possible in coincidence. It is advisable to cover one of the apertures and adjust one mirror first, and then, having obtained satisfactory agreement (narrow colored fringes at the margins can be ignored), cover up the aperture just brought into coincidence and use the third aperture in the same way.

If the filters are correct, the field of view should be whitish and very bright; but care must be taken to use the reflector, as if this is not done one or other of the colors will predominate. If the field is too red the green filter is too dark; with a greenish field the green filter is too bright. And it is here that the use of the extra filters comes into play, as one can substitute one for the other till a good white is obtained. If the field is yellowish, the blue filter is too dark; if it is blue the red filter is too dark or the blue filter is too bright. As a rule if the filters are prepared as advised above it is only the green filter that will require adjustment. An absolute white is extremely difficult to obtain, but a great preponderance of one or the other color can be avoided.

As soon as the correct filters have been found they should be permanently fixed in the apertures. To hold the transparency at *L″*, two wooden or metal grooves should be provided. At *L* and *L′* spring metal clips can be used.

The green filter should be placed at *L″*, the red may be either at *L* or *L′*, and the transparency from the green-filter negative should be placed here. The red-filter transparency should be placed on the red filter and the blue on the blue filter. The latter should be temporarily covered with an opaque card, and the red transparency shifted till the outlines of the images coincide, and then the card removed from the blue picture and this adjusted in register.

If the measurements of the instrument are not exactly correct, the three images may coincide but may not lie in the same plane; for instance, the red image may be in front or behind the green.

If the red image is in front of the green transparency, the distance *LM* is too small; if it lies behind, *LM* is too great. This may be remedied by shifting the mirror M backwards, or by altering the distance *LM* or *GH*. It is as well to bear this in mind when making the apparatus and arrange so that the heights *GH* and *CJ* may be slightly altered by inserting a wooden frame or planing off a little. This regulation requires to be done only once, while the focusing of the images must be done each time. To avoid adjusting it each time, the following plan may be adopted: the red and blue transparencies should be provided with narrow card margins, which should be stuck on. On the edges *GK* and *JE* should be fastened a T-square of wood or metal, only a few millimeters long, against which the picture edge should be laid. It will now be easy by careful and gradual paring away of the card to so arrange that the transparencies at once coincide, and they will then only have to be pressed up against the T-square to fall in register.

Frequently great improvement may be effected by placing over the green filter other green glasses of faint tint, which can be prepared by coating glasses with varying amounts of the green-dyed gelatine. These compensate for the varying composition of daylight. It is not possible to use artificial lights with this instrument, unless the composition of the light is brought to approximately the same as daylight. The instructions given for the preparation of the viewing filters for screen-plates on page 165 may be followed.

With such an instrument one may perform many interesting experiments, which, although not color photography, are well worth trying. For instance, by placing the transparencies in the wrong apertures all sorts of colored results may be obtained. Negatives may be used and then images in the complementary colors will be seen. And obviously by covering up any aperture the complementary color is at once seen from the admixture of the other two. By using cut out patterns, too, some wonderful color effects can be obtained.

CHAPTER XII

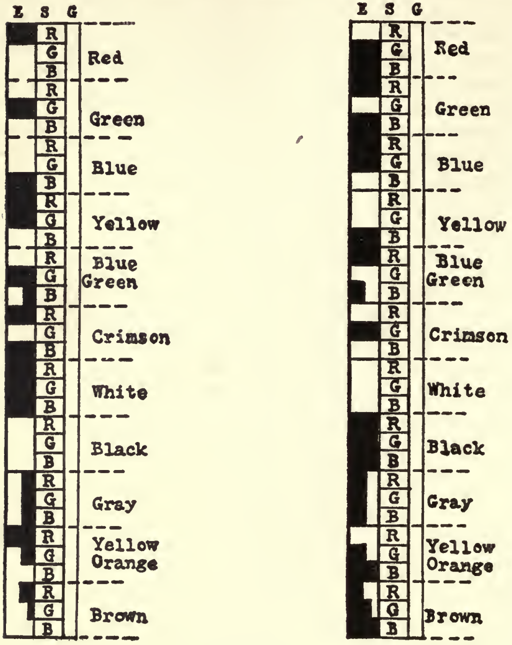
SCREEN-PLATES

THE fundamental idea of the screen-plate was conceived by Ducos du Hauron in 1867. It belongs to the additive processes, and the principle is similar to a particular school of painting, in which small areas of pure pigments are juxtaposed to produce a given color effect, when seen at a certain distance. Thus, if we wash paper with rose Bengal, which is a bright crimson aniline dye, and then apply a wash of malachite green, the result will be a dirty brown; but if instead of superimposing the colors we use them in small areas side by side, the result when examined at a little distance is a yellow. Exactly in the same way blue-violet and green on top of one another would give a dirty olive, but juxtaposed in minute dots we obtain a pure blue; and the violet and red in the dotted form will give a pure crimson.

The idea of Ducos du Hauron lay dormant for many years, until in 1892 J. Joly, of Dublin, and J. W. McDonough, of Chicago, conceived methods of putting it into practice, and for this purpose ruled glasses with fine red, green and blue lines, about 200 to 300 to the inch. Such a screen was placed in contact with a panchromatic plate, exposed, and developed. From the line negative thus obtained ordinary silver transparencies were made and bound up in register with similarly ruled screens, and the results were excellent in color. Commercially, the process was a failure, because of the cost of ruling the plates, and the want of a really satisfactory panchromatic plate. In 1907 the Lumière Co., of Lyons, France, introduced the autochrome plate, in which the small color elements were obtained by sifting potato starch to obtain grains of approximately the same size, staining up three portions with the necessary dyes, then mixing and sifting over tacky glass until a grey surface was obtained, any little interstices between the starch grains being filled up with a black powder. This film was protected with an insulating varnish and then a panchromatic emulsion applied. A great many patents have been taken out for the preparation of similar plates and a few have been introduced commercially, but so far as the author is aware the autochrome and the Paget plate are the only two that survive.

Before dealing with the practical working of the process, it may be as well to explain how the colors are formed, and for this purpose a greatly enlarged and purely schematic section of a screen-plate is shown in Fig. 17. On the extreme right are the colors, or the colored lights reflected from the object, which meet first the glass plate *G*, then pass through the screen elements *S*, to the emulsion film *E*.

It will be seen that red light can pass through the red element *R* only, so that the emulsion is affected by it at this point only and is reduced by the developer, giving the black patch shown. The same argument applies to the green and the blue elements; in each case we obtain the black silver deposit only under the corresponding screen element. In the case of yellow, the light passes through both the red and green elements, therefore, we have these blackened in the negative emulsion. The blue-green and crimson likewise pass light of two colors. White light passes through all three elements, therefore the emulsion is completely and equally reduced



A. Negative B. Positive

FIG. 17

under the three. In the case of black, that is, no light, there can be no action, hence there is no silver deposit, and in the case of grey, which is a mixture of black and white, we again have equal action but in a lesser degree. It would be possible to take any number of colors and treat them in the same way, but it will be sufficient to take two other colors, yellowish-orange and brown. In the former case, the red is in full strength mixed with some green, therefore, there is full action under the red and some under the green element; in the case of brown, which is actually nothing more than reddish-orange mixed with black, there is also action under the corresponding elements. Assuming that our diagram thus represents the result of exposure and development, if we should immerse the plate in a fixing bath, it is obvious that we would actually have a negative in the complementary colors of the subject; thus, reading down, the colors shown would be blue-green, crimson, red, green, black, white, grey, bluish-green and a pale greenish-blue. If in any way we should make a positive from this negative and place it in contact with the same screen elements, we should obtain the same colors as those of the object, as shown on the left of Fig. 17. It is unnecessary to follow out the formation of the colors in the positive, as it is obvious from the diagram. This is the whole theory of the screen-plate process.

Everyone knows that it is extremely easy to distinguish small objects as distinct when one is fairly close to them. As one of the very simplest examples, we may take the case of three trees; standing within about twenty feet, we can not only distinguish each branch but also each leaf, and can tell from the shape of the latter whether they (the trees) are elms, oaks or beeches. But at a distance of a mile we no longer see anything but a general green mass, and it would probably be difficult to name the trees. Exactly the same applies to small objects: at the distance of normal vision, about ten inches, one can distinguish quite plainly dots of black and white of a diameter of about $\frac{1}{50}$ inch. At a distance of ten feet the dots appear to be merely a grey mass, and as we reduce the size of the dots, or elements, as we have called them, the shorter becomes the distance at which they can be separated, until they become so small that a microscope is required to separate them. In order, therefore, for a patch of color to appear uniform on a screen-plate, the elements have to be very small and in the case of the autochrome they are about 0.015 mm (0.0024 inch), therefore they are not visible at the distance of normal vision.

There are two distinct methods of using this process. If the screen elements are of a regular geometrical pattern, regularly recurring, then one may use the screen-plate pressed into contact with a separate panchromatic plate, and on development obtain a negative the image of which is broken up into the geometrical pattern. From this we can make any number of positives and by binding them up with similar screens in correct register, we shall obtain a colored result. This method is known as the separate method. But with an irregular haphazard mosaic, such as is formed in the autochrome plate, and with elements of such a fineness, it is an almost hopeless task to fit the positive to the screen-plate; therefore, the emulsion is coated on the plate itself, and, after development, the negative image is dissolved away, leaving the unexposed and undeveloped emulsion *in situ.* This is then developed and gives us a positive in colors. This will be easily grasped from Fig. 17A, which shows the negative image with the black silver behind the appropriate color elements; if we imagine all the white spaces there shown to be covered by undeveloped silver bromide, we have an exact picture of the developed autochrome or any other screen-plate by what is known as the combined method, that is, one in which the emulsion is coated on the screen-plate itself. If now we dissolve the primary negative image, it is clear that we still have our silver bromide under the other elements, and if this be exposed to light and developed we shall obtain the result shown in Fig. 17B, and there is no trouble in registration.

There are advantages and disadvantages in both methods. In the combined method, if we want more than one copy of a subject we must obviously make more than one exposure, whereas, with the separate process, having once obtained the matrix negative we can produce as many copies as we like. The combined method involves another operation, that is the reversal of the negative image obtained by primary development. Also, if we make a mistake and spoil the result, we have lost both screen-plate and picture; while with the separate method our only loss is the panchromatic plate, and the screen-plate is still intact. As to which is the easier process, this is merely a matter of opinion. As regards excellence of results there is not, in the writer's opinion, anything to choose between them, assuming, naturally, that the best results are obtained in both cases. Possibly for the novice the separate method is a little the easier, that is, if he can make a transparency.

THE COMPENSATING FILTER

In the case of screen-plate emulsions, as with all other color-sensitized ones, the characteristic preponderance of the activity of the blue and violet rays still exists, so that it is necessary to insert between the object and its image a correcting or compensating filter, which reduces the rendering of the colors by the plate to that seen by the eye. In Fig. 18 are shown two curves representing the luminosity of the spectral colors as seen by the human eye and by the plate, the former being marked V and the latter P. As will be seen, the peak of the curve of the latter is about wave-length 4500 in the deep blue, whereas the visual luminosity peak lies

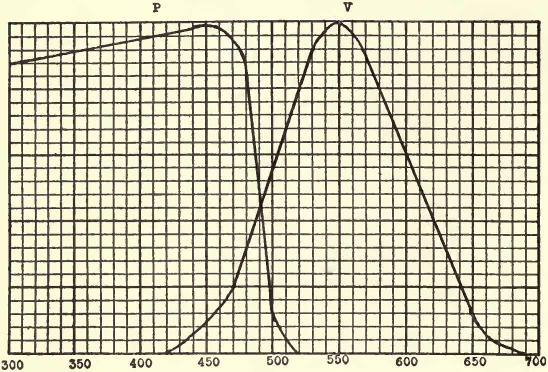


FIG. 18

about wave-length 5500 in the yellow-green. By an error in making the drawing, the wave-lengths are there given in hundreds instead of thousands. An extra zero should be added to each number to make them agree with the text.

The filter that will shift the plate's vision so as to coincide with that of the retina is of a faint reddish-yellow tinge and can be made with tartrazin, pheno-safranin and aesculin. The instructions for filter making given in Chapter III must be rigorously followed: instead of using the above named dyes, of which the pheno-safranin has the disadvantage of rapidly fading on exposure to light, we may use the more stable combination of fast red D and filter yellow. The density of the first named dyes, that is, the quantity per square meter of filter area, is tartrazin 0.2 g, plus pheno-safranin 0.017 g, plus aesculin 4.0 g. The densities for the more stable dyes are filter yellow 0.6 g, plus fast red D 0.07 g.

It is not immaterial where the filter is placed, as it has an effect on the focus of the lens. Placed in front of the lens, it shortens the distance of the plane focused on by one-third of the thickness of the filter, but as this reduction of the object-plane is extremely small in all out-door work compared with the distance of the object it can be ignored. It is only when one reproduces objects, such as a picture, or flowers, in something like natural size that it need be taken into account. By far the best position for the filter is behind the lens; here it is protected from light, from accidental displacement and from injury, and it automatically makes its own correction in focusing. In all cases focusing should be done with the filter in position. As to the method of calculating the area of the filter for any given lens, see Chapter III. It is extremely important that the filter should fit close to the lens, so that no white light can creep around the edges or be reflected from the front surface to any part of the plate; for this reflected light would cause local or general fog, and consequent falsification of the colors.

As in the use of the screen-plates the glass is always turned towards the lens and the sensitive surface away from it, it is clear that this must be allowed for in focusing. The matt side of the ground glass should, therefore, be reversed in position and face outwards, and its thickness should be that of the screen-plate, if critical sharpness is required. An ingenious idea that has been put forward is to clean the emulsion from a spoiled plate and place this, with the color elements outside, in place of the usual ground glass.

While directions have been given for making a filter, it must be understood that this is for the autochrome plate. While it can be used for the Paget plate, the makers of this issue special filters and it is well to purchase these. These filters are adjusted for average daylight, and they cannot be used successfully with any other light, so that special filters must be prepared for these. It may not seem worth while to make these filters, but possession of a set enables winter and evening work to be attempted. The following formulas are, therefore, given to complete the information.

For use with Nernst lamps:

Gelatine, 1 : 15 solution	40 ccm
Tartrazin, 1 : 2,500 solution	3 ccm

To this add:

Aesculin	0.4 g
Distilled water	37 ccm
Ammonia	3 drops

To every 100 square cm allow 8 ccm of the above solution. The aesculin solution must be made only just before use. This filter is combined with a blue filter of the following composition:

Patent blue, 1 : 1000 solution	2 ccm
Gelatine, 1 : 15 solution	46 ccm
Distilled water	38 ccm

Allow 7 ccm per 100 square cm.

For incandescent gas, the same filters are used, but the quantity of the blue gelatine is reduced from 7 to 5 ccm for the same area.

For a 25 ampere arc:

Gelatine, 1 : 15 solution	40 ccm
Tartrazin, 1 : 500 solution	4 ccm
Pheno-safranin, 1 : 7000 solution	1 ccm

Add to this:

Aesculin	0.4 g
Distilled water	35 ccm
Ammonia	3 drops

Allow 8 ccm for the same area. This filter is particularly useful for photo-micrography with screen-plates.

For flashlight work, the composition of the filter will depend on that of the flash mixture; Lumière's Perchlora mixture is two parts of magnesium powder and one part of potassium perchlorate, and for this the correct filter is:

Gelatine, 1 : 10 solution	40 ccm
Tartrazin, 1 : 500 solution	5 ccm
Pheno-safranin 1 : 7000 solution	3 ccm

To this add:

Aesculin	0.4 g
Distilled water	32 ccm
Ammonia	4 drops

Allow 8 ccm per 100 square cm.

F. Novak suggested a mixture of two parts of magnesium and one part of dry thorium nitrate, and the compensating filter for this is:

Gelatine, 1 : 15 solution	100 ccm
Filter yellow, 1 : 200 solution	15 ccm
Crystal ponceau, 1 : 800 solution	4 ccm
Water	4 ccm

Allow 7 ccm per 100 square cm.

EXPOSURE OF THE SCREEN-PLATES

In ordinary black and white photography it is well known that there is a great latitude in exposure. One may make an error of two or three times one way or the other and yet obtain a negative that will give a good result; but with screen-plates this is not possible. A really correct rendering of the colors is only possible with correct exposure, this being due to the extreme thinness of the film of emulsion.

Various tables have been published as guides for the novice, but these are not reproduced for the simple reason that the factors involved in estimating the correct exposure are so delicate that they cannot be determined from a table with a sufficient degree of accuracy. As a standard of exposure, the makers of the autochrome plate state that one second with a lens working at *f* :8 in summer and sunlight near the middle of the day is correct; but everyone knows that the intensity of sunlight may vary enormously. Then again, one may wish to take an interior, or it may be necessary even in sunshine to use a very small stop; theoretically one has merely to increase the exposure in direct ratio to the decrease in illumination, so that in the case of the diaphragms, assuming that one used *f* : 32 instead of *f* : 8, the increase should be as 1 : 16, whereas actually it would be more like 1 : 24 or 1 : 32. Exactly in the same way, when working in a comparatively feeble light, the increase in exposure does not follow the usual law that intensity of illumination and duration of exposure are inversely proportional. This failure is well known, but is not often of importance in black and white work, but with screen-plates, in consequence of the very low practical sensitiveness of the emulsion, it has to be considered. The expression "practical sensitiveness" is advisedly used, for that of the autochrome emulsion is about 36 H. & D., but the color elements cut this down to three and the filter to one and one half.

The most satisfactory method, in fact, the author goes so far as to say, the only satisfactory method of determining exposures with screen-plates is to use one of those meters which measure the intensity of the light by the darkening of a strip of sensitive paper. The two most useful meters of this type are those manufactured by Watkins and Wynne, in England. In these special paper is employed, actually a specially treated bromide and not a printing-out paper, and the instruments are provided with special scales that compensate for the failure of the above law. If tables are useless, so also are those meters that gauge the light by visual examination or reduction by absorbing material.

When the separate method is used, one is not tied down to the use of such slow emulsions, and may use the fastest panchromatic plates obtainable; in this case the usual speed must be adopted for use with the meters and the increase necessitated by the taking screen worked out. It has frequently been recommended to hypersensitize autochrome plates by bathing them in various dye solutions, such as pinachrome, etc.; but this is not a process that should be attempted by the novice. A special filter is required and the result is rarely correct.

It may be as well to call attention again to the fact that the screen-plate must be placed the wrong way round in the dark slide, that is, with the glass toward the lens. It is essential, therefore, that the emulsion be protected from damage by any spring which keeps the plate in register. The autochrome plate is issued with a piece of black card in contact with the film, the other side being white, and this should be put in the plate holder, back of the plate. For the separate method it is imperative that the taking screen and the sensitive emulsion be in as close contact as possible, and it will be found that the English, or book-form dark slide, is much superior to the average American plate holder, not only in ease of filling, but also in giving closer contact. Finally, the back of the glass must be clean; any dirt or finger marks will be visible in the picture as a darker patch. It is easy to clean the glass after loading in the dark room, by pulling out the sliding shutter and polishing with a clean cloth.

Development

The desensitizing of color plates has been dealt with elsewhere and the same process may be utilized for all screen-plate work. With the separate method, the safranin dyes may be used; but for the autochrome plate the makers advise the use of the ammonium salt of aurantia, in 1 : 2000 solution, for one minute, as this does not delay the appearance of the image nor prolong development as does safranin.

The original developer recommended for the autochrome plate and applicable to all other combined plates was pyro-ammonia, and it is still considered the best by many workers. The following solutions and method are advised:

A.	Sodium bisulphite solution	3 ccm
	Pyrogallol	26 g
	Potassium bromide	26 g
	Water to	1000 ccm
B.	Sodium sulphite, dry	100 g
	Ammonia, sp. gr. 0.880	100 ccm
	Water to	1000 ccm

As the particular ammonia solution advised above is not always available, in America at least, one-fourth more of the weaker solution, of specific gravity 0.9, should be used. For use, dilute one part of this B solution with three parts of water. The above solutions are mixed in the following proportions:

Solution *A*	1 part
Solution *B* diluted	1 part,
Water	8 parts

The duration of development is dependent on the time of appearance of the first sign of the image, exclusive of the sky in landscape work; and the temperature of the solution should be 16° C. (60° F.). The temperature is important, as any material increase will make the gelatine soft, and trouble may be caused. The duration of development for other temperatures may be calculated from the following table, which gives the factors by which the total time of development should be multiplied to obtain the same result:

10° C. (50° F.) multiply by	1.6
16° C. (61° F.) multiply by	1.0
20° C. (68° F.) multiply by	0.8
25° C. (77° F.) multiply by	0.6

The developer is modified according to the appearance of the image, more of the dilute B solution being added in proportion to the delay in its appearance. The following table shows the additional quantities of dilute B solution that should be added to every 100 ccm:

Time of appearance in seconds	*Add diluted B solution*	*Total time of development in minutes and seconds*	
22–24	None	2	0
25–27	2 ccm	2	12
28–30	8 ccm	2	30
31–35	15 ccm	2	30
36–41	20 ccm	2	30
42–48	25 ccm	2	30
49–55	30 ccm	2	45
56–64	35 ccm	3	0
65–75	40 ccm	4	0
over 75	45 ccm	5	0

Almost any developing agent may be used, the following, however, in the author's opinion, being one of the most satisfactory, as it gives brilliant results without fog:

Metol	4 g
Hydrochinon	12 g
Sodium sulphite, dry	50 g
Potassium bromide	6 g
Ammonia, sp. gr. 0.92	33 ccm
Water to	1000 ccm

Rodinal, amidol, adurol, metoquinon and chloranol have all been suggested, but as they present no particular advantages, adherence to one of the above is advised.

In the separate method, in which a panchromatic plate is used, one would naturally adopt the normal developer, such as metol-hydrochinon. With these plates, ammonia should be avoided as far as possible, and it is assumed that the worker knows how to develop such plates. There is only one caution that need be given, that development should not be prolonged until the results are hard and contrasty; they should tend to the side of softness, and for those who follow the directions given on the cards enclosed with the plates, the times for "portraits" should be adopted. Freedom from fog, as far as possible, is desirable, but if the desensitizing method be adopted this need not be feared.

REVERSAL OF THE IMAGE

The preliminary development of the combined plate, as has already been explained, gives a negative image in the complementary colors, and to convert this into a positive this primary image is dissolved. This is effected by treatment with acid potassium permanganate or acid bichromate solution, and the latter is on the whole preferable, as the stock solution keeps better and there is no chance of black spots being caused, which may happen with old permanganate solution. The latter should be prepared in two solutions, and the permanganate should be kept in the dark:

A.	Potassium permanganate	4 g
	Distilled water	1000 ccm
B.	Sulphuric acid, pure	20 ccm
	Distilled water to	1000 ccm

Mix in equal volumes immediately before use. The bichromate bath is:

Potassium or ammonium bichromate	5 g
Sulphuric acid, pure	10 ccm
Water to	1000 ccm

As soon as development is complete, the developer should be poured off and the dish filled up with water and gently rocked for a few seconds. The water is then poured off and the dish again filled with water; this can be repeated three or four times until the plate has been washed for from thirty to forty-five seconds, and then the reversing solution can be applied. Plenty should be used, and the action should be allowed to continue for two or three minutes; then one can turn on white light or go out into daylight. The reversing bath should be allowed to act not less than five minutes, and it is here that so many beginners go wrong, in not giving the solution time enough to dissolve the primary image. The author prefers to throw the first lot of solution away and pour on fresh and allow to act another three minutes. It is not wise to be economical, either in time or solution, at this point.

As soon as the primary negative image is dissolved, the picture in colors will be seen on looking through the plate, as well as the still unreduced silver bromide film. It has been suggested that the plate, after treatment with the reversing solution, should be washed and dried, but while this method saves a little time and trouble it should not be adopted, as the color rendering is never as good.

THE SECOND DEVELOPMENT

This has the purpose of reducing to the metallic state the emulsion which has not been affected by the primary exposure and development. This reduced silver prevents any light from penetrating through the color elements where it should not, and increases the brilliancy of the picture.

After the reversing solution has done its work, the plate should be washed for a minute or two, the easiest way being to fill the dish with water, rock gently, throw away the water and refill, and repeat this treatment. When dealing with the autochrome plate it must be remembered that the film is extremely tender and that a strong stream of water from a tap may damage it. The second developer may be the same as that used for the first time, or the following recommended by MM. Lumière:

Sodium sulphite, dry	15 g
Amidol	5 g
Water to	1000 ccm

The silver bromide must be exposed to white light, such as daylight, to bring it into a developable condition. The plate should be covered with the developer and exposed in the dish to daylight until the bromide is completely developed. If development has been put off until evening one has not, of course, daylight available, and any white light may be used, such as gas, electricity or a small piece of magnesium ribbon. Here there is no chance for overdevelopment, but there is decided chance of underdevelopment, so that one should not be in a hurry to stop this process, and the plate should be exposed to white light all the time. The disadvantage of underdevelopment is that, if the picture is subsequently fixed, any unreduced bromide will be dissolved and the stopping-out power of the silver lowered.

INTENSIFICATION

If the exposure is correct, and the reversal and second development properly carried out, there is no need to intensify, and the picture may be considered to be finished. But if the picture appears weak it may be intensified. The original method was physical intensification with silver, for which three solutions are required:

A.	Citric acid	3 g
	Salicylic acid	0.5 g
	Pyrogallol	3 g
	Distilled water	1000 ccm
B.	Silver nitrate	10 g
	Distilled water	100 ccm
C.	Potassium permanganate	1 g
	Distilled water	1000 ccm

While many workers have experienced trouble with this process, it is very easily carried out, provided a few simple points are carefully observed.

In the first place the plate must be free from the slightest trace of the second developer. To ensure this it is best to mix one part of the reversing bath with 100 parts of water, then flood the plate and rock not longer than five seconds, and immediately pour off and wash with four or five changes of water. The actual intensifier is:

A solution	900 ccm
B solution	100 ccm

Naturally, only enough will be used to cover the plate; the mixed solution should be poured over the plate and the dish rocked to and fro for not longer than thirty seconds. Then pour the solution away and examine the plate by transmitted light; if it looks brilliant enough, the plate may be subjected to the clearing treatment described later; but if not fresh intensifier should be mixed and again applied. One of the most frequent causes of trouble is economy in this solution; this invariably leads to a muddy looking picture, as the silver is deposited everywhere, on the fingers, the dish and those parts of the picture where it should not be; it is far better to be a little lavish and secure good results. Exactly how far to carry intensification is entirely a matter of opinion. The greater the intensification, the more brilliant the colors; but it is easy to overdo it and then the colors become glaring, and there is at the same time a loss of the more delicate nuances.

After intensification the plate should be washed with repeated changes of water for not less than one minute, then flooded with the neutral permanganate solution *C* for not more than one minute, and again washed for five minutes; it can then be dried. Unless the plate is properly washed after intensification, the acid in the film will cause the permanganate to dissolve the image to some extent. Another cause of trouble is the precipitation of minute crystals of silver in the *B* solution, or on the lip of the bottle, which are washed off on pouring out the solution. Care should be taken not to disturb any deposit, and it is better to suck up the required quantity with a pipette from near the top of the stock.

As an alternative the following method of intensification may be used:

Cupric sulphate	20 g
Potassium bromide	20 g
Hydrochloric acid	5 ccm
Water to	1000 ccm

The picture is bleached in the above, which takes but a minute, then rapidly rinsed with three or four changes of water and flooded with a five per cent solution of silver nitrate to which a few drops of nitric acid have been added. In fact, any intensifier, except those like uranium, which give a colored deposit, may be used.

FIXATION AND DRYING

If the picture has not been intensified, there is not the slightest need to fix it, but after intensification it must be fixed, and the following is a suitable formula:

Hypo	100 g
Sodium bisulphite solution	50 ccm
Water to	1000 ccm

About three minutes immersion is ample, and then it can be washed and dried. Rapid drying of an autochrome is important, as otherwise green patches may make their appearance at the edges of the picture, and occasionally elsewhere. A good plan is to take hold of the plate firmly by the edges and then, with the arm at full length, jerk the plate rapidly up and down so as to sling off as much water as possible. Then dry the glass and, if you have a fan, place the plate at some little distance from this so as not to have too strong a draught impinging on the film. If this is not available, the plate should be placed film outwards against the wall or supported with the lower edge resting on a few thicknesses of blotting paper. If the plate is dried in a strong current of air, the film has a tendency to curl at the edges, and if dried by heat there is a very good chance of the film melting. In no case must alcohol be used for drying, as this will invariably lead to one or more of the dyes being extracted from the colored screen-elements, with local patches of incorrect color as the result. It may be taken as an axiom that alcohol must be avoided with all combined screen-plates.

VARNISHING THE PLATE

Many operators omit this operation altogether, but it can be recommended, for not only does it give good protection to the tender film but it also increases the transparency of the picture. An excellent formula is:

Gum dammar	20 g
Manila copal, powdered	50 g
Carbon tetrachloride	1000 ccm

The mixture should be well shaken or stirred up occasionally during twenty-four hours. Then the bottle should be placed in a water bath and the temperature raised until the solution boils; this should be continued for five minutes and the solution filtered while still hot. This varnish dries rapidly and gives a colorless film. Alcoholic, ethereal or celluloid varnishes must not be used. It is not actually necessary to warm the plate before varnishing, but it is preferable to do so, as it drives the last trace of moisture from the gelatine.

Artificial Light Work

The extreme slowness of the combined screen-plates and the consequent long exposures in the light of an ordinary studio naturally led to experiments with flashlight mixtures, with excellent results as regards color rendering. The formulas for these and the necessary compensating filters have already been given. It is advisable to use a diffusing screen made of some such material as thin white linen in front of the flash lamp; this screen should be of goodly size, about four and one-half feet high and three feet wide, and placed about eighteen inches from the lamp. A suitable arrangement of the lamp and sitter is shown in Fig. 19; in which *C* is the camera, *R* a white reflector, *F* the background, *M* the sitter, *B* the white diffusing screen, and *L* the lamp, which preferably should be of the type in which the

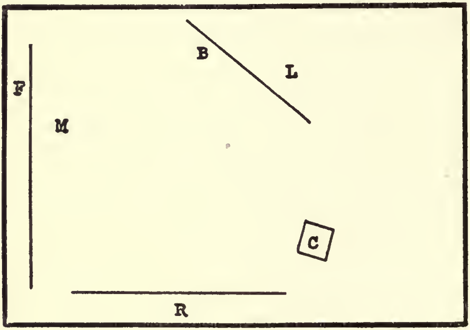


Fig. 19

powder is spread out in a long tray. The quantity of powder is dependent on the distance between the lamp and the sitter, the size of the plate used, and the aperture of the lens. For a 3¼ x 4¼ or 4 x 5 plate, with the sitter about six feet from the lamp and a lens working at *f* : 4.5, about eight grams should be used. The lamp should be rather higher than the head of the sitter.

For flower and still life work, magnesium ribbon may be used with good effect, and if it be burnt behind an opaque screen so as to shield the lens, it can be much nearer the object and less used. It may be of use to point out that three pieces of ribbon, each five inches long, do not give the same light as one piece fifteen inches long. This is probably due to the long glowing ash of the longer piece. For instance, setting the action of four inches of ribbon as one, that of an eight-inch piece was 2.5. To the photomicrographer the screen-plate process is invaluable, particularly in petrological work and crystallography with polarized light, and probably the separate method will commend itself, as from the original negative any number of slides or prints may be made. It is impossible to give any useful hints as to the exposure, as this will depend on the light, the numerical aperture of the condenser and the objective, and the degree of magnification. As to the filters to be used, possibly enough on this subject will be found in the following pages.

Failures

Unfortunately perfect immunity from failures cannot be insured, and these are the more serious because one is limited in remedial processes, as the color balance is so apt to be upset. Possibly the easiest method of dealing with the subject will be to divide it up into the different practical steps.

Exposure failures: General want of sharpness may be due to not focusing through the filter, or to the ground glass not being reversed, or to the plane of the latter not being coincident with that of the sensitive surface. This latter defect can be remedied in future work by measuring the thickness of the screen-plate and obtaining a ground glass of the correct thickness, or, as already suggested, using a cleaned-off plate for this; the average thickness of the autochrome plate is from 1.2 to 1.8 mm.

In the case of the separate process, general or local want of sharpness may be due to insufficient contact between the taking screen and the sensitive plate, which may probably generally be ascribed to want of flatness in the latter.

If the plate after the first development is more or less black over the whole surface and shows no color, it has been placed the wrong way round in the holder, that is, with the sensitive side, and not the glass, toward the lens. To avoid the occurrence of such an accident, it is as well after filling the plate holders to draw up the sliding shutters an inch or so, naturally working at a safe distance from the lamp; the reflection of the light will at once show whether the glass is in the correct position; also, it looks black, whereas the sensitive surface looks white.

The picture may be very dense, with marked want of detail both in the high-lights and shadows. This is caused by gross underexposure and insufficient primary development. There is practically no remedy, though the results can be somewhat improved by reduction, but this is a delicate matter, as the thickness of the gelatine is so little that the action of a reducer may be too violent. Probably the best reducer is made by adding five parts of the reversing solution to 100 parts of water. The reduction should be carried on in white light, and close to a water supply, so that the moment enough action has been obtained the plate can be rapidly rinsed and the action arrested. If the plate is rather too dense in the shadows only, reduction may be resorted to and intensification omitted. If the plate is too heavy everywhere and yet shows full detail, the primary development was a little too short or the temperature of the solution was allowed to drop.

Ill-defined patches of greater density than that of the picture as a whole point to dirt on the glass, which, by preventing access of light to the glass, causes less density in the primary image and consequently greater density in the second development. Local reduction may be resorted to, but it is a risky matter.

A brilliant picture, wanting in details in the high-lights, is generally due to too long primary development, or the reversing bath has been used too long. There is no remedy for this. If the whole picture is weak and almost colorless in the shadows as well as the high-lights, then overexposure and too long primary development are the cause. The only thing to do is to intensify repeatedly with the silver intensifier. If the picture looks correct after intensification, but almost disappears in the fixing, either traces of permanganate were left in the film, which reacts with the acid of the bath and acts as a reducer, or the second development was not carried far enough. The best remedy would seem to be physical development with the following:

Ammonium sulphocyanide	24 g
Silver nitrate	4 g
Sodium sulphite, dry	12 g
Hypo	5 g
Potassium bromide	0.5 g
Distilled water	100 ccm

For use, add 10 ccm to 80 ccm water and 10 ccm metol-hydrochinon, rodinal or other developer. This solution should be renewed as soon as it gets muddy. The action is rather slow, and if the image appears whitish, when finished, it should be bleached in a one per cent solution of mercuric chloride, washed, and developed with an ordinary developer, diluted.

Failures due to the filter show a more or less blue tinge. If the whole picture is blue or bluish-green, then the filter has been omitted altogether; stray white light in the camera also tends to give this effect. There is no remedy for this. If the filter was used, then one must assume that it has faded somewhat, due to careless undue exposure to strong white light, or if the filter is home-made, then incorrect quantities of the yellow dye have been used.

When using artificial lights, too reddish pictures are due either to the use of an improper filter or to underexposure. Because nearly all artificial lights have an excess of orange rays and are deficient in the blue, the tinge of filters for this work should always be more or less greenish to cut down the excess of orange and red.

Naturally, undue exposure of the plate to an unsafe darkroom light may cause fog. If this is general, it is caused by exposure of the film, whereas if the glass has been unduly presented to the light, the latter may penetrate the screen elements, and then the general fog is either greenish or bluish, according to the color of the safe-light.

One of the most annoying and frequent failures, especially with beginners, is the appearance during the second development of negative patches, when the plate is looked at. This is particularly noticeable in portraits, when patches of black silver make their appearance on the cheeks and hands of the sitter, or sometimes on white objects, such as a man's collar. This is always due to insufficient action of the reversing solution. Local reduction is the only remedy for this.

Small black specks generally arise in the manufacture of the plates, and are practically unavoidable; on the other hand, they do not often occur and are as a rule very small. Should they happen in the shadows they may usually be ignored, but in the highlights they should be touched with a match, sharpened to a point, or with a very fine camel-hair brush, moistened with the reversing solution or the following:

Potassium iodide	3 g
Iodine	1 g
Water	50 ccm

As soon as the spot disappears, immerse the plate in water, then in the fixing bath. These spots are actually metallic silver and the above solution converts them into silver iodide, which dissolves in the hypo.

Green spots are due to injury to the insulating varnish between the screen-element layer and the emulsion, which allows access of water to the former, so that the green dye dissolves. There is practically no remedy except local retouching with water-colors, so as to break up the area, but this is unsatisfactory at its best.

EXHIBITING SCREEN-PLATES

Naturally, the use of the screen-plate for lantern slide work presents great attractions and they sometimes form a welcome relief to the black and white variety. On the other hand, they cannot be shown at their best along with ordinary slides, for as a rule the latter are shown on far too large a scale for all screen-plates. The color elements absorb a great deal of light, with the result that, when projected on too large a scale with an ordinary arc or lime light, they look too dark and a great deal of their beauty is lost. It is, of course, a matter of personal opinion, but the author considers that a four-foot picture is the largest that should be shown with screen-plates. With regard to the absorption of the light, this is over ninety per cent with the autochrome and about seventy-five per cent with the Paget plate. There is another factor in the projection of screen-plates and that is the size of the color elements. If we take the diameter of a lantern plate as four inches and project this on a four-foot disc, we have a magnification of twelve diameters. Each color unit is magnified in like degree, so that, if they are too large, they will be distinctly visible. In the case of the autochrome the mean diameter of the elements is 0.015 mm; in the case of the Paget they are squares of about 0.63 mm for the blue, and 0.84 mm for the red and green. If we multiply these by twelve, we obtain 0.18 mm for the autochrome and 1.008 cm for the Paget, and it is obvious that at the normal distance of the first row of the audience, which we may put at ten feet, they will be quite invisible. Practically the nearest distance at which the color element becomes visible at is 1000 times its diameter, therefore one can easily calculate the correct distance for the nearest observers for any degree of enlargement.

Another important point in the projection or viewing of screen-plates is that the color elements are adjusted to give the best results for a mean daylight, and the color rendering is not correct for any other light; although we are in the habit of considering the projection arc and lime-light as white, they are distinctly yellow. To obtain the best possible results, the lantern must be provided with a color filter, or each slide bound up with a stained gelatine plate. The latter method is the one which should be adopted if the screen-plates are to be shown in alternation with black and white slides, while if color slides are to be shown alone, then only one filter need be prepared and this should be placed close to the condenser. This correction filter can be made with rose Bengal and patent blue, and as similar filters are required, as will be seen later on, for visual examination of the pictures, it will simplify matters to give the methods of making these now.

In the first place, three stock solutions should be prepared:

A. Gelatine	7 % solution
B. Patent blue	1 : 1000 solution
C. Rose Bengal	1 : 1000 solution

For use with an arc the following quantities of the above solutions are required for one square meter of filter surface:

Solution *A*	300 ccm
Solution *B*	30 ccm
Solution *C*	30 ccm
Water	225 ccm

For oil, gas, or the old carbon filament electric lights, use:

Solution *A*	300 ccm
Solution *B*	37.5 ccm
Solution *C*	23 ccm
Water	225 ccm

For incandescent gas and Mazda lamps use:

Solution *A*	300 ccm
Solution *B*	23 ccm
Solution *C*	37.5 ccm
Water	225 ccm

In order to save the trouble of coating with gelatine solution, some fixed-out dry plates may be immersed in the dye solution mixed in the above ratios, using water instead of the gelatine solution, for about five minutes, then rinsed and the screen-plates examined through them against the particular lights with which they are to be used. One can soon tell whether the plates require deeper staining or reducing in color; the actual tint required is quite a weak one. The idea of using these tinted filters is to cut down the excess of red and green, the patent blue cutting down the former and the rose Bengal the latter. Other dyes with similar absorptions may be used; but in all cases the filters must be dry before the pictures are examined, as with many dyes the tints change considerably in drying.

To increase the brilliancy of the pictures it has been suggested that aluminum screens be used, and they certainly are an improvement for narrow rooms and halls; but in theatres of greater width the audience at the sides has a less satisfactory view than when an ordinary screen is used. For home exhibitions, ordinary Bristol cardboard forms an excellent screen, or, if the room is long enough to permit of the lantern being placed behind the screen, a sheet of ground glass or white sheeting or pure white, not blue-white, tracing cloth stretched over a frame may be used.

For viewing in the hand a viewing-frame has become very general. This is nothing more than a mirror placed horizontally, with a wooden or metal frame, at an angle of 45 degrees, with an aperture for the picture. Side wings of cloth, card or black material prevent side light from reaching the mirror, which is placed flat on the table, the picture being viewed in the mirror. Naturally the picture is placed upside down and inside out, that is, with its picture side away from the mirror. In all cases the pictures should be protected by a cover glass and bound up like an ordinary slide. For showing at exhibitions, it is better to arrange them in frames, so that no white light can creep round the edges, and use the long line-o-lite electric lamps, placing these at the top and bottom of the rows of pictures, with asbestos or metal backing painted white, arranged so that no light, except that passing through the pictures, can reach the eyes. This arrangement enables them to be shown at night and also makes one entirely independent of daylight, which is sometimes difficult to reflect so as to give even illumination. To prevent access of daylight to the front of the pictures, battens may be run out over the top of the frames and black cloth nailed to them, the extent to which the battens should project being determined by the position of the windows of the gallery. Side wings at the end of each row, and within it if it is very long, are also needed.

PRINTING FROM SCREEN-PLATES

Having obtained a color picture by means of a screen-plate, one naturally wants to print from it, and we can divide this subject into two distinct parts; first, the production of another screen-plate, and secondly, the production of paper prints.

As regards the first, we may dismiss the separate method in very few words, as it merely entails the making of other black and white transparencies and binding them up with the viewing screens. But in the combined processes, the reproduction on another plate involves some little difficulties.

At the outset it must be recognized that an absolutely faithful reproduction is out of the question. The second picture must always be contaminated with black, that is, the colors are of lowered luminosity. On the other hand the results are not displeasing, and if the original is not at hand to be compared with, no one is any the wiser. The most satisfactory method of reproducing an autochrome by contact is that devised by the Lumières, and if carefully followed the failures are few; the necessary apparatus can be easily knocked up, even of cardboard. A rectangular light-tight box *A*, *B*, *C*, *D*, (Fig. 20), 40 cm (16 in.) in length is required, which should be painted dead black inside, to prevent reflections. At one end is cut an aperture, in which is placed a special compensating filter *E*, the composition of which has been given in connection with flash-light work. This must be arranged so that no white light can creep around the edges. At the other end is placed a plate-holder, a printing frame or some similar arrangement, which also must be light-tight. In this is placed the picture to be reproduced, with its glass toward the inside of the box, and behind the picture is placed the autochrome plate, with its glass in contact with the film of the picture; behind is placed the usual black card. *G* is a block of wood, or other support, preferably weighted at the bottom, so that it will not tip over, and into the top is screwed an ordinary brass electric binding screw. *S* is a spiral of iron wire; *G* must be so placed that the spiral of wire is opposite the center of the filter, and about 5 cm from it. The spiral should be formed by coiling iron wire round a cylindrical rod of 3 or 4 mm diameter, as closely as possible, and then slightly pulling it out until the coils of the spiral are separated by about 1 cm. This is merely the holder for the magnesium ribbon that is used as the illuminant. Copper or brass wire must not be used for the spiral.

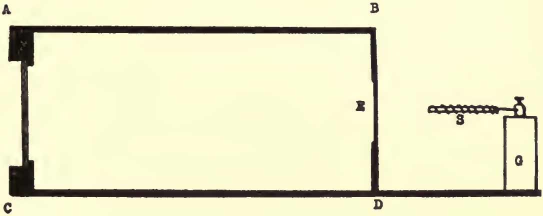


FIG. 20

The required length of magnesium ribbon is cut off, and this will naturally depend on the density of the picture; with ribbon of 2.6 mm width, which is about the average, from 10 to 20 cm will be needed. It should be folded end to end and then placed edgewise in the spiral. An opaque card or something that will act as a shutter must be placed over the filter aperture; a good sized book that will stand up on its edge is handy. The ends of the ribbon can then be ignited by means of a candle or spirit lamp, the shutter removed from in front of the filter, and the exposure made. The plate is then treated exactly as though it had been exposed in the camera.

No definite data can be given as to the length of ribbon required, but one can tell from the results as to whether under or overexposure has been given, and this will be a guide in future work. It is important to have the ribbon standing on its edge in the spiral, as if lying flat it may go out.

Obviously one can use the camera and either enlarge or reduce the size of the picture; but as the color elements are also enlarged at the same time, there is obviously a limit beyond which one should not go. Precisely the same arrangement as just described may be used for the illumination. The lens of the camera takes the place of the printing frame and the connection between the illuminating box and the lens should be made light-tight, which can be easily done with a cloth.

It is possible to reproduce an autochrome by means of a Paget screen-plate, and thus obtain a negative from which any number of transparencies can subsequently be made; one may proceed exactly as described above, only substituting the Paget taking screen and panchromatic plate for the autochrome.

It will be found most convenient to carry out these operations in the dark room, and further it may be said that in no case should daylight be used as the illuminant, as its composition varies so much that false color rendering is almost certain. Other illuminants than magnesium may be used, but in every case the special filter must be used. Magnesium is cheap and handy and its composition always constant, so that it is by far the most convenient.

As regards the reproduction of screen-plates in colors direct on paper, the only method of doing this is by the bleach-out process, which is described later, and it can not be recommended. The paper has to be prepared and the results are not worth the trouble involved, especially as they are not permanent and rapidly fade in light.

To prepare permanent prints from screen-plate pictures, one must have recourse to one of the tri-color subtractive methods already described; to utilize these it is obvious that we must have the three constituent negatives, but these are not difficult to make. The first requisite is a set of sharp-cutting filters, the purpose of which is to isolate each individual color, that is all the red, all the green, and all the blue. These filters must be of such a nature that they transmit only the light of one color. They can be made without much trouble and as they are not used except as light screens, they need not be made with such careful attention to parallelism of surfaces, or cementing, as is necessary in the case of lens filters. It will in fact be more convenient to make them the full size of the pictures.

The red filter can be made from two glasses, one coated with methyl violet and the other with rose Bengal and tartrazin, or crystal violet and tartrazin. The rose Bengal filter is made from:

Tartrazin	10 g
Rose Bengal	5 g
Gelatine, 8 per cent solution	700 ccm

The methyl violet is:

Methyl violet	0.7 g
Gelatine solution	700 ccm

The crystal violet is:

Crystal violet	0.4 g
Tartrazin	5.0 g
Gelatine solution	700 ccm

The above quantities are sufficient for 1 square meter. It is not advisable to mix the violet with the rose Bengal. A few drops of glacial acetic acid may be used with both the violets to facilitate solution. Unless the dyes are used in the form of a solution previously made, care must be exercised that they are actually in solution. There should be no difficulty in this, as they are readily soluble in the hot gelatine, only, if added all at once, small lumps of the dyes may become coated on the outside with chilled gelatine and may therefore not dissolve well. It is preferable to make the gelatine solution double strength, use half of the water to dissolve the dyes, and then mix. The dyed gelatine should be filtered through linen that has been well washed and wrung out of hot water.

The green filter must be made with two glasses; one should be coated with:

Tartrazin	2 g
Naphthol green	1 g
Gelatine, 8 per cent solution	700 ccm

and the other is coated with:

Acid green JE	0.5 g
Gelatine solution	700 ccm

In place of the acid green, 3.0 g of brilliant green may be used.

The blue filter is prepared with:

Yellowish eosin	4.0 g
Gelatine, 8 per cent solution	700 ccm

3.0 g bluish eosin may be used instead of the yellowish. The second glass is coated with:

Methylene blue 4B	1 g
Gelatine solution	700 ccm

For those who do not want the trouble of making the filters, the Wratten & Wainwright gelatine film filters of the requisite size may be bound up between glasses. The numbers of their filters are, for the red No. 29 or F, for the green No. 61 or N, and for the blue No. 50 or L.

A moment's consideration will show us that as we want to reproduce the red, we must use a red-sensitive plate, and it will be found more satisfactory to use panchromatic plates for all three negatives, as by doing so the gradation in the three negatives will be more alike than when we use different kinds. There is some latitude here, as we are able to modify the final result, and one might choose a panchromatic for the red, an isochromatic for the green and an ordinary plate for the blue filter exposures; but it cannot be advised. Whether a fast or slow panchromatic plate be used is of no particular moment; the slow kind will give as good results as the fast and is less likely to fog. At the same time it must be borne in mind that we are making negatives, not transparencies, and this must be kept in view in developing. Brilliant-looking plates with clear glass shadows are not the desideratum; but soft negatives, rather thin in the high-lights, with fully exposed shadows, should be aimed at. It is immaterial what developer is used, and the beginner should use that to which he is accustomed. Naturally the desensitizing process may be adopted, and the plates should be backed.

In the reproduction of a screen-plate it is clear that we might place it with the film in contact with the sensitive plate. Then we should have the color elements reproduced quite sharp, and every negative would be broken up into minute dots corresponding in size. For some positive processes this might not be a disadvantage, but in the case of the separate system in which the positive is bound up with a viewing screen, we cannot obtain contact with the sensitive surface. The result will be more or less want of sharpness, but this will not be of serious moment, and it breaks up the screen pattern, so that almost closed or continuous tone negatives are obtained. Actually it is advisable to follow the same plan with an autochrome, that is, to interpose between the sensitive surface and the picture film a colorless transparent medium of greater or lesser thickness.

There are some very simple mathematical formulas by which we can tell not only what ought to be the thickness of the intervening medium, but also the distance of the light source, and the resulting want of sharpness in the resulting negatives. But one of the main ideas in this little book has been to avoid, as far as consistent with clarity, mathematics and deep theory, so that it will be assumed that it is required to make the negatives from autochrome and Paget pictures. A camera may be used and it should be racked out to 50 cm. If this is not possible, then the simple device given on p. 169 should be used, and it will be assumed that it is required to enlarge the screen elements so that they just close up. Then the size of the light-source is found by the following simple rule:

$$\text{Size of light} = \frac{\text{Element-size} \times \text{Enlargement} - 1 \times \text{Camera Extension}}{\text{Separation-thickness}}$$

The degree of enlargement to cause the image to coalesce is taken as 4, the camera extension is set at 500 mm, the separation thickness is that of the autochrome, which is approximately 2 mm, and the size of the element is taken as 0.025 mm, so that we have:

$$\text{Light size} = 0.025\,\frac{(4 - 1) \times 500}{2} = 18 \text{ mm}$$

Now the aperture in the box, where the complementary filter was placed, and which can now be replaced by the sharp-cutting filters, is actually the source of light, therefore, we merely have to cut a card with a circular aperture of 18 mm in diameter and place over it a ground glass to obtain the required effect.

In the case of the Paget plate, we may take the size of the color element as 0.115 mm, and the thickness of the viewing screen as 0.5 mm. Then we have:

$$\text{Light-size} = 0.115\,\frac{(4 - 1) \times 500}{1.5} = 115 \text{ mm}$$

If this size is too large to be convenient, and it might be if the camera were used, then the thickness of the glass, or the distance between the two films, is found from the simple equation:

$$\text{Separation-thickness} = \frac{\text{Camera Length}}{\text{Size of Light}} \times (\text{Size of En-}$$

largement − 1) × Size of Element. So, if we set the size of the light at 50 mm, then:

$$\text{Separation} = \frac{500}{50} \times (4 - 1) \times 0.115 = 3.45 \text{ mm}$$

When using the camera, the lens should be removed and the ground glass put in its place, with an opaque card of the correct aperture. If the aperture is larger than the lens flange, then the lens board may be removed, which is usually possible.

Magnesium ribbon will be found the most convenient light-source. It may occur to the reader that this is really a very small source of light: but actually the ground glass becomes the light, and it is easy with magnesium to evenly illuminate such a relatively small area. Daylight may be used, and the camera should then be pointed direct to a white cloud or a white sky, not a blue sky.

It is unnecessary to enter into any further particulars than have already been given as to the printing processes. The same rules apply, and the so-called complementary colors must be used for printing.

Stereoscopic Work with Screen-plates

The combination of stereoscopy and color would seem almost ideal, and should present no particular difficulties to the expert worker in stereoscopy. But there are one or two points that it may be as well to explain. Naturally, if the separate system is adopted and two separate plates are used, no advice is needed, as it is a simple matter then to obtain the right-hand picture for the right eye and the left-hand picture for the left eye. But when we use a long plate on the combined system (and this is the only way to get correct results as regards evenness), the matter is not so simple. It would seem that one might merely turn the plate longways with the glass toward the eyes, and the result should be correct. As a matter of fact, one does get relief; but it is not stereoscopy, but pseudo-stereoscopy, that is to say, the more distant objects stand out in front of the near ones. It is a curious fact that many people cannot see this until it is pointed out. There is also another point that not all people can see, and that is that the color elements appear on different planes, so that instead of having red and green dots side by side, the red appear farther away. This is particularly apparent when the lenses of the stereoscope magnify, and is primarily due to the want of achromatism of the eye. It can be lessened by using lenses of longer focus.

It will be assumed that the worker knows the ordinary rules of mounting stereoscopic pictures, that the separation of objects should be approximately 82 mm, and the total length of the pictures should be 180 mm. Then it will be found as a rule that part of each picture must be cut off. The cutting of an autochrome plate is not an easy matter until you know how: for if the glass is cut in the usual way and then snapped it is ten chances to one that the screen-film will tear irregularly and the plate be completely spoiled.

The proper way to set to work is to place the picture, film up, on a flat support, and then with a straight edge and a sharp penknife cut right through the gelatine and screen-film down to the glass, about one-sixteenth of an inch on either side of the middle dividing line. Then turn the plate over and with the aid of the straight edge cut the glass. But, as it is not easy to see the dividing line, the best way to go to work is to draw a straight line on a sheet of card or paper, set the straight edge to this and with the diamond draw another line, bearing rather heavily. The cutting point of the diamond will mark the card and give a gauge by which to cut, for if the dividing line be made to coincide with the pencil mark, which must be longer than the width of the plate, the diamond line will be the position of the straight edge. It is advisable to rule the diamond line in pencil also so that it may be seen projecting beyond the edges of the plate. If the cut then be properly made so as to fall between the cuts through the film, the glass may be snapped without the film tearing except at the cuts. The distance of the diamond must be found for each tool, as they differ slightly, but the normal working distance is about 2 mm.

The pictures having been cut and transferred, the film sides should face the observer, and the plates may be stuck down to a glass with a little dab of seccotine or other stickfast at each corner, then masked and a cover glass bound up. Possibly it should be pointed out also that the longer the focus of the camera lenses the better, and that 18 to 25 cm is better than the usual 9 to 15 cm, as the illumination at the margins of the pictures is better, and too large a diaphragm should not be used.

CHAPTER XIII

THE BLEACH-OUT PROCESS

AS a laboratory experiment this is an extremely interesting process, but from the practical point of view it is not worth wasting an hour over, in the present state of our knowledge. It was originally suggested by Ducos du Hauron and Chas. Cros from purely theoretical reasoning and lay dormant from that time, 1867, until 1895, when it was put into practical use. The principle of the process is based on what is known as the Grotthus-Draper law, which is, that only light which is absorbed can exert chemical action; this may be extended and amplified by stating that, as only complementary colors are absorbed, it is only these that can act on a colored substance.

Briefly put, three fugitive aniline dyes, red, yellow, and blue, are mixed together in suitable proportions, so as to give a neutral grey tint. If such a film be exposed to white light they will all fade and we shall see the white support; but if exposed to colored light, then the limitation already pointed out as to the complementary colors comes into play. Under a red glass, the blue and yellow dyes fade, as together they make green; under green glass, the red fades, as this is complementary to green; under the blue, the yellow and red fade out, leaving only the blue. The action of any intermediate color is explicable in the same way, black being, of course, formed by none of the dyes fading. It is clear, then, that we must start with a colored original, and for purely experimental work, nothing is better than pieces of stained gelatine bound up with glasses.

A great deal of experimental work has been done on this process, and bleach-out paper was for a few years a commercial article. Unfortunately, while great advances have been made in the rapidity of the bleaching, it has not yet been possible to find any real fixing agent, that is, any substance that will prevent the dyes, forming the image, from still further bleaching. So the results, when exposed to white light, gradually fade out.

Exact formulas cannot be given, as so much depends on the dyes; but sufficient may be told to lead the experimenter on the right road. Unfortunately, the preparation of the paper direct is not satisfactory, as the dyes have a tendency to wander or migrate into the paper itself, so that most of the best results have been obtained by coating on opal glass, whence the film is stripped. If it is not desired to use this, then gelatinized paper may be used; this can be prepared, as has already been suggested, by fixing out bromide or other paper, and hardening. The plan already proposed of stretching the paper may also be adopted.

To prepare the dyed gelatine, the following solutions should be made up: methylene blue BB, 2 per cent solution in water; auramin concentrated, 2 per cent solution in alcohol; bluish erythrosin, 0.5 per cent solution in water. Soft emulsion gelatine and hydrogen peroxide will also be required. There are two methods of preparing the paper; either the paper is immersed in an ethereal solution of hydrogen peroxide, or an aqueous solution of the peroxide is used to make the gelatine solution. Dealing with the former method first, prepare a solution of:

Soft gelatine	100 g
Distilled water	1000 ccm

Allow the gelatine to soak for about 15 minutes, then melt by the aid of a water bath, and divide into three portions. To one, add 40 ccm of methylene blue solution; to the second lot add 20 ccm of the auramin solution, and to the third 15 ccm erythrosin solution. Then add the yellow solution to the blue, and finally, with constant stirring, gradually add the red solution. Towards the end this red solution must be added very gradually, and after each addition, a drop of the mixture should be placed on white paper. As soon as a faint reddish tinge is apparent, the addition of the red must be stopped; the main color must be grey.

Now keep the dyed gelatine at a temperature of about 40 ° C. (104 ° F.) for from four to five hours; then filter, and it is ready for coating. If the paper has been stretched on glass it can be treated exactly like a plate which is to be collodionized, that is, supported on the back with a rubber bulb, the dyed gelatine poured on and the plate inclined until the surface is covered, and then put on a level slab to set. If it is to be coated by floating, then the gelatine must be poured out into a dish, any air bubbles broken or led to the sides, the paper bent into the form of a J and the bottom of the loop carefully lowered on to the surface at one end of the dish, with the short end of the loop pointing towards the middle of the dish, and the other end slowly lowered and the paper allowed to slide along the surface of the gelatine. With a little practice this can be done without forming any air bubbles. As soon as the paper begins to curl at the edges, it should be slowly drawn off the surface and immediately turned over on to a flat plate to set. The temperature naturally plays a great part in determining the quantity of gelatine that adheres to the paper; the lower it is, the thicker the film. From 35 ° to 38 ° C. (95 ° to 100 ° F.) is a good range. If the first coating does not give an even coat, the paper may be floated again when it is dry. The paper should be dried in the dark.

To sensitize this paper with the ethereal solution, the latter must be made by shaking 15 ccm of 30 per cent peroxide solution with 200 ccm ether for about ten minutes and allowing to settle in a burette or funnel; the water is then drawn off. This forms a one per cent solution of peroxide in ether. It must be noted that the peroxide solution is not the household one, which only contains three per cent of peroxide; the proper one is ten times the strength, and is sold as "perhydrol."

If it is considered preferable to use the ordinary peroxide solution, then this must be used instead of water to make the gelatine solution, and the temperature must be kept as low as possible in melting it. It is, in fact, advisable to soak the gelatine for thirty minutes before melting. The dye solutions may be added in the same way as above, but probably the erythrosin will have to be increased to 30 to 40 ccm. This can be determined as before.

Instead of using the peroxide as sensitizer, either anethol or thiosinamin may be substituted. Anethol is the camphor obtained from aniseed oil, and has its characteristic smell. Thiosinamin is a colorless crystalline substance obtained from oil of mustard, and has but a faint garlic odor. A saturated solution should be made of the former in water and the paper bathed therein, or 10 drops of an alcoholic solution may be added to the gelatine. In the case of thiosinamin, one per cent may be added to the gelatine just before coating.

In lieu of gelatine, collodion may be employed, about three per cent of pyroxylin in alcohol-ether (equal parts of each). The best method of working is to prepare the collodion as follows:

Pyroxylin	30 g
Ether	500 ccm
Alcohol	250 ccm

Pour the alcohol on the cotton and when thoroughly soaked add the ether, and shake until dissolved. The dyes should then be dissolved in 250 ccm alcohol and added to the collodion, and finally ten drops of anethol. If the latter is obtained in crystals, then 0.5 g should be added to the alcoholic dye solution, or the same quantity of thiosinamin. Even more satisfactory results are obtained with the following dyes, the quantities being for 1000 ccm of collodion:

Primrose	1.5 g
Victoria blue	0.4 g
Curcumin crystals	1.66 g
Auramin	0.34 g

Curcumin is the coloring matter obtained from turmeric; if there is any difficulty in obtaining it, some powdered turmeric may be digested with alcohol for three or four days and then filtered; about ten per cent should be used. In this case the yellow solution must be added cautiously to the other dyes, testing occasionally on white paper, so that a neutral grey is obtained.

If the opal glass is to be used and the picture subsequently transferred, the glass should be coated with a 0.5 per cent solution of rubber in benzol; ordinary bicycle-tire cement may be used, thinned down to about one per cent. The gelatine is coated on the glass in the usual way, and alter exposure, washing, etc., the edges are cut round and the paper squeegeed down and stripped when dry.

To improve the stability of the dyes if anethol is used, the prints should be treated to successive baths of benzol, which dissolves this. If thiosinamin is used they must be treated with a weak nitrous acid bath, which can be made by adding about 10 drops of sulphuric acid to a five per cent solution of sodium nitrite, and then washed. Finally the prints should be treated with a ten per cent solution of tannin followed by a saturated solution of tartar emetic (antimony potassium tartrate), then rinsed and immersed in a saturated solution of lead acetate, washed and dried.

It is possible to prepare transparencies by this process, but as it requires three or four coatings or transfers, the game is not worth the candle, considering that so much better results can be obtained by other methods.

CHAPTER XIV

THE LIPPMANN PROCESS OR INTERFERENCE HELIOCHROMY

THIS is probably the most beautiful of all color processes from a theoretical standpoint and yet is also that which has been the least practised, mainly because one has to prepare the plates, exposures are very long, and there is no known means of reproducing the results. It has remained, therefore, purely a laboratory process.

The first suggestion as to the possibility of this process was made by W. Zenker in 1868; it was later suggested by Lord Rayleigh in 1887, and O. Wiener in 1890, but it was not until 1891 that G. Lippmann, of Paris, actually succeeded in obtaining a color photograph in this way.

In order that the subject may be fully grasped we must enter, even though but superficially, into an explanation of the rudimentary principles of light. A brief explanation has already been given of the dispersion of light and the occurrence of the Fraunhofer lines, and the following table gives the principal of these in the visible spectrum with their wave-lengths and the number of vibrations per second:

Fraunhofer Line	*Wave-length*	*Vibrations per Second in Billions*
A	7593.97	395
B	6867.38	437

Fraunhofer Line	*Wave-length*	*Vibrations per Second in Billions*
C	6562.96	457
D_1	5896.08	509
D_2	5890.13	509
E	5270.43	569
b_1	5183.73	579
F	4861.43	617
G	4301.43	696
h	4101.84	731
H	3968.61	760
K	3933.86	763

The wave-lengths are given in Ångstrom units (10-millionths of a millimeter.)

Beyond *A* lies the infra red, the invisible region of which we are sensible in the form of heat; while beyond *K* is the ultra-violet, by which the chief chemical actions are caused.

Light always proceeds in straight lines and is usually supposed to be a wave-like motion in a hypothetical medium which is called the ether. We may assume that the particles of the ether are so closely compacted that a disturbance or vibration of one must give rise to corresponding vibrations in neighboring particles. This being granted, there must be a certain time required for the transfer of the agitation from one particle to another. If we picture the ether particles as a series of beads closely strung together on a wire, we may crudely represent them by *I* in Fig. 21. If now a pull is given to the first particle at *A* the vibration will travel along the wire and the beads will vibrate to and fro on both sides of the plane *AB* and we may, assuming that the direction of the light is from left to right, represent what happens by *II* in Fig. 21, in which *A′B′* is the plane of equilibrium or rest, and *a* is the crest, *b* the trough of the wave; the distance of the particles *a*, *b*, *c*, from *A′B′* is called the amplitude of the wave.

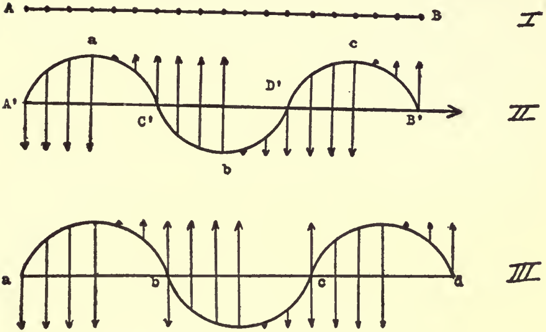


Fig. 21

A wave-length is the distance between any two points similarly situated as regards the equilibrium plane, so that *A′D′*, *C′B′*, or *ac* are each a complete wave-length, and obviously the midway points are half wave-lengths, thus *A′C′* is the half wave-length of *A′D′*.

When a ray of light meets a reflecting surface it is thrown off according to a well-known law, that the angle of reflection is equal to the angle of incidence; and if a ray is incident normally to a surface, that is, at right angles to it, it is reflected back at the same angle and on the same path. We can thus represent the state of affairs by *III* in Fig. 21, and the incoming and outgoing waves would travel the same paths; but at the points *abcd*, which are obviously each half a wave-length apart, the pull on the ether particles would be in contrary directions, as shown by the arrows; therefore, as the forces are equal it is obvious that there is no movement and there can be no light, consequently no chemical action. The points *abcd* are called the "nodes" and the spaces in between the "loops," in which the ether particles may be considered to vibrate to and fro pendulum fashion. Such a system forms a series of "stationary" or "standing" waves, and it is clear that if such a system traverses a sensitive film, there would be, under proper conditions, chemical action only in the loops, and on development the metallic silver would be deposited at these places only. So, a series of laminae would be formed exactly half a wave-length apart, their distance of separation being dependent on the color of the incident light, as will be seen from the above table.

White light incident on such a laminary series of mirrors is reflected according to its wave-length; each zone reflecting only light of that color which has a wave-length corresponding to twice the distance of separation of the layers.

The fundamental basis of this process is that the sensitive film shall be transparent and in contact, during exposure, with a reflecting surface which returns the light on its incident path. For the reflecting surface, which must be in optical contact with the film, Lippmann chose mercury, which, as everyone knows, is liquid at ordinary temperatures and highly reflecting.

There are two methods by which we can prepare the sensitive film, either by the old Taupenot albumen process, which was first used by Lippmann, or by the gelatine emulsion method. This latter is faster but a little more trouble to make. For the albumen take:

Albumen	1000 ccm
Potassium bromide, 10 % solution	43 ccm
Ammonia	43 ccm

Beat to a froth and allow to stand for twenty-four hours to liquefy, and then filter through glass wool or decant from the flocculent sediment. Glass plates should be thoroughly scoured with hot soda and water, well washed and dried, and polished with alcohol until they show a perfectly even film when breathed on. Ordinary glass is not as a rule thick enough, and it is more satisfactory to use white plate glass, about one sixteenth inch thick. As the film is extremely transparent and it is not easy to tell which side has been coated, it is as well to mark the wrong side with a diamond or the edge of a three-cornered file. It will also be found that as a rule one side of the glass is smoother than the other, and this smooth side should be coated; it is easy to detect the smoother side by holding the glass level with the eyes and glancing along it.

The albumen is the white of eggs, and if the operator is not accustomed to separating the whites from the yolks, it is as well to break each egg separately into a cup and then strain off the white into the bulk. The whipped and filtered albumen will keep for two or three months in a well-corked bottle.

The glass should be flowed over with this solution, drained for about thirty seconds and then placed on a leveled slab to dry in a place free from dust. The plates should then be heated for two minutes to 60° C. (140° F.) and allowed to cool. This heating may be effected by placing the plates on two or three thicknesses of blotting paper on top of an iron plate, or what is more convenient, an empty cracker tin of fair size. The plates may be placed in a rack and with an ordinary Bunsen burner the temperature will soon be raised inside the tin, if the lid be put on. A thermometer can be inserted through a hole close to the plates. About four minutes of this treatment will suffice. This is less likely to crack the glass. A stock of plates can be prepared and packed face to face, wrapped in pairs in tissue paper, and will keep indefinitely in a dry place.

To sensitize them, the plates should be immersed in:

Silver nitrate	100 g
Glacial acetic acid	100 ccm
Distilled water to	1000 ccm

This may be used in a dish, preferably of glass. If porcelain be used, a new tray should be taken into service to avoid any possible contamination from previously absorbed solutions. About three minutes immersion is sufficient. They should then be drained for about one minute and immersed in distilled water for five minutes, the water poured off and fresh applied, and this repeated six times. They may then be color-sensitized, and although their sensitiveness is very low only a green light should be used. The sensitizer may be:

Glycin red, 1 : 500 alcoholic solution	8 ccm
Cyanin, 1 : 500 alcoholic solution	2 ccm
Ammonia, 2 % solution	15 ccm
Distilled water to	1000 ccm

Bathe for two minutes, rinse in distilled water once, and dry at 60 ° C. (140 ° F.).

Valenta in 1892 was the first to publish a gelatine emulsion formula, and various modifications have been given; the following, one of the simplest and best, was later also given by Valenta:

A.	Gelatine	10 g
	Silver nitrate	6 g
	Distilled water	300 ccm
B.	Gelatine	20 g
	Potassium bromide	2.4 g
	Sodium chloride, pure	1.5 g
	Distilled water	300 ccm

Soak the gelatine in water for half an hour, then melt by the aid of a water bath heated to 40 ° C. (104 ° F.). When complete solution is obtained, add the salts and cool the solutions to 35 ° C. (95 ° F.). Then pour *A* into *B* rather slowly, stirring all the time, and immediately pour into 1000 ccm of alcohol with constant stirring. The emulsion separates out into flocks; these should be collected on a piece of clean linen (an old handkerchief is excellent), the ends brought together so as to form a bag, tied, and hung over a stick across a beaker filled with water. This should be changed every five minutes for half an hour. The author has found a slight modification of this more convenient: a good sized glass funnel to hold about 2 liters is obtained and a short piece of rubber tubing furnished with a pinchcock attached to its stem. A piece of cloth large enough to completely cover the top of the funnel and lap well over the sides is used. The emulsion is collected in this from the alcohol bath and it is then gathered into a bag and swung round at arm's length for a minute or two, which gets rid of most of the alcohol. The cloth is then stretched over the funnel and the center pushed down, the funnel filled with water and the emulsion stirred up with a glass rod for two minutes and then allowed to soak for five. Then the pinchcock is opened, the water run out, and the funnel filled up again so as to completely cover the shreds. About six changes of water will thus wash it perfectly. Finally the ends of the cloth are again gathered together and the bag swung round three or four times. The emulsion should now be put into a marked beaker, and melted in a water bath, the temperature of the emulsion not being allowed to rise over 35 ° C. (95 ° F.), and the volume made up to 600 ccm.

An alternative method is to make the emulsion as described above, coat the plates immediately after filtering through the wool, place the plates on a level slab to set and then wash in running water for fifteen minutes, and dry.

These emulsions are, like all others, wanting in color sensitiveness. The original plan of sensitizing them was to bathe the coated plates in dye solutions and it is still the best plan, but it may be more convenient, particularly if the emulsion is not washed until after coating, to add the dye to the emulsion. Both methods will be described, but we must deal with the coating first. It was originally supposed that a very thin film of emulsion was necessary, and the plates were coated and then whirled to sling off all but a very thin film. It has now been discovered that such thin coats, while they are rather faster, are not essential. The easiest plan in coating is to place the plates in a stack against the wall or other convenient place, pick up the first with a pneumatic bulb, pour over the emulsion to freely cover the surface, drain for fifteen seconds, and then place on a level slab to set. Practically, the thinner the coat the faster the plate, and if the above method gives too slow a plate, then the glass may be warmed, which will cause more emulsion to drain off.

All the original formulas for color-sensitizing called for the old cyanin, but much better results can be obtained with the newer isocyanins, and pinachrom is very satisfactory. For the bath method use:

Pinachrom, 1 : 1000 alcoholic solution	5 ccm
Distilled water to	1000 ccm
Borax, saturated solution	10 ccm

Bathe four minutes, rinse, and dry rapidly. As full details have already been given as to bathing and drying plates there is no need to add more. Green light must be used as soon as the dye is added, but before that a bright orange light may be used. If it is thought that sufficient red sensitiveness is not obtained with the above dye, though this will only be noticed in spectrophotography, then a mixture of sensitol green and sensitol violet may be used, in the ratio of two parts of the former to one of the latter; and not more than 6 ccm should be added to the bath. If the dye is to be added to the emulsion, then 3 ccm of the dye solutions should be added to 1000 ccm of emulsion.

Before leaving the emulsion making it may be useful to point out that H. E. Ives has stated that the best results are obtained in spectrum work, for which the process is eminently suited, by using the following solutions:

A.	Gelatine	20 g
	Distilled water	500 ccm

B.	Gelatine	40 g
	Potassium bromide	5 g
	Distilled water	1000 ccm
C.	Silver nitrate	6 g
	Distilled water	100 ccm

Dissolve the gelatine, cool, add the salts, then add *A* to *C* and pour into *B*. Working temperature 35 ° C. (95 ° F.). Coat the plates by flowing the emulsion on to cold glass, drain off and set, and wash the plates for fifteen minutes. The emulsion should be color-sensitized by adding 1 ccm of the dye solution to 100 ccm, or for bathing the strength should be 1 : 100,000.

As previously stated, the film is exposed in contact with mercury, and obviously the glass must face toward the lens. The chief difficulty here is the plate-holder; it must be capable of holding the mercury without leakage, and the mercury must be run in and out when the plate is in position. Specially constructed holders are obtainable commercially and it will be better to purchase one; but the following brief description may be useful. The front of the holder carries a strip of rubber about 4 mm wide and 2 mm thick, against which the glass is pressed. The back is a solid piece of wood, metal lined, with a rubber strip all round, and this is a firm but resilient red rubber. The back fits tightly in place and is held by two steel cross bars that fit on pins with fly nuts which screw it firmly into place. In one corner of the back is screwed a small steel pipe to which is fastened a rubber tube, connected with the mercury reservoir; at the diagonally opposite top corner is a screw, with a hole driven right through its length and a small cap fitted; the purpose of this is to allow egress of the air as the mercury flows in. The lower pipe is fitted with a tap; to fill the slide with mercury, the tap is opened, the screw cap unloosened and the container slowly and gradually raised until it is higher than the top of the holder; the tap is then turned off and the container can be laid on the back of the camera. After exposure, the tap is opened, the container slowly lowered, and the mercury runs back. This holder and the mercury make the whole very heavy and allowance must be made for this.

It is very important that the mercury be kept clean, and if pure in the first place it can be used repeatedly without trouble. The best way to clean it is to procure a large chamois leather; well wash this in warm water and soap, and dry; then soak in gasoline for an hour or two, kneading it occasionally with the hands, and dry. This may make the leather harsh and stiff, but it can be easily suppled by pulling and working between the hands. It should be placed in a clean dish and the mercury poured into the middle and run backwards and forwards for a short time, and then the ends of the leather gathered together and twisted round so as to force the mercury through.

One caution is necessary; immediately after exposure the mercury must be run out; if left in contact with the film, the latent image on this is completely destroyed.

It is impossible to give a very definite idea of exposure, but the plates are from 1000 to 2000 times slower than a fast plate. For a landscape in bright sunlight, with a lens working at $f:4.5$, the exposure will be from one to two minutes. It will be seen that portraiture by this process is almost impossible, though Professor Lippmann did succeed in taking some very good portraits. For still life the plates are excellent. For spectrographic work, with a slit width of 0.3 mm, a condenser and sunlight, the exposure will be about one minute.

For development pyro-ammonia has been the favorite, and the following is a typical formula:

A.	Pyrogallol	1 g
	Distilled water	100 ccm
B.	Potassium bromide	20 g
	Ammonia, sp. gr. 0.96	67 ccm
	Distilled water	100 ccm

For use, mix 10 parts *A*, 20 parts *B*, and 140 parts water. Duration of action about three minutes, and the plate should be at once well washed.

There has been considerable discussion as to whether these pictures should be fixed or not; for the most correct rendering of color they should not be, and this is particularly applicable to spectrum work. If they are fixed the distance of separation of the silver laminae is slightly reduced and consequently there is a slight change of color. For ordinary work, the best fixer is a five per cent solution of potassium cyanide, which should not be allowed to act longer than ten to fifteen seconds; then the plates should be rapidly washed under a tap for about ten minutes and dried.

An alternative process and one which has much to recommend it, is development with the following hydrochinon developer:

Hydrochinon	3 g
Sodium sulphite, dry	7.5 g
Potassium carbonate	2 g
Potassium bromide	1 g
Water to	100 ccm

After washing for ten minutes, the plate should be immersed in a one per cent solution of mercuric chloride and dried. This gives the most brilliant colors.

The colors are only seen when the pictures are examined at a certain angle, and then are very pale, due to the reflection of white light from the surface of the film. To destroy this a glass prism of low angle, 10 to 12 degrees, is cemented to the surface with Canada balsam. These prisms can be obtained from any optical house at a reasonable price, as accuracy of surface and angle are not important. The Canada balsam used must be diluted with benzol or xylol, not chloroform, as the latter in time bleaches the image. Before sealing with the prism, a very pretty experiment can be performed. Examine the picture at the best angle, and it is better to support it in one position and shift your position until this is attained. Then, with a glass tube, blow on the film and the colors will be seen to change as the gelatine between the laminae swells. All colors become more red, while as the moisture dries out they

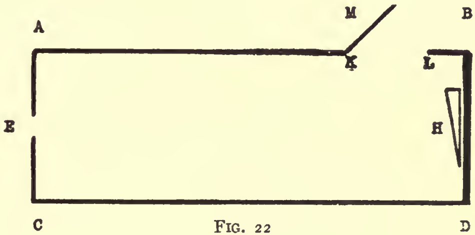


FIG. 22

change back to blue. It is thus possible to slightly alter the colors of a heliochrome, either by warming or damping, and as soon as the correct colors are seen it should be cemented up. The prism should be clipped on to the picture and then it should be placed in a warm place to dry. When dry, the excess balsam should be scraped off, the edges bound up with black paper, and the back of the glass bearing the picture painted with black varnish.

These pictures are best seen when side light is prevented from reaching their surfaces, and a viewing box can easily be made as shown in Fig. 22. In this *ABCD* is the box, in one end of which is supported the heliochrome, while at the other end is a peep hole *E* through which the picture can be seen. *M* is a small piece of mirror, adjustable on a hinge, which throws the light through the aperture *KL* cut in the top of the box. For exhibition on a screen with a lantern, the principle of the aphengescope or opaque object lantern projector must be used,

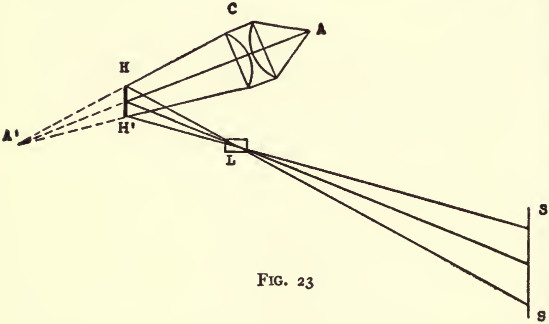


FIG. 23

as shown in Fig. 23, in which A represents the arc, C the condensers, and A' the image of the arc. The heliochrome is placed in the plane HH', so that the beam of light just covers the picture, and L is the projection lens, which should be placed as far from HH' as this is from the point A', so that the image of the arc falls in the objective; the picture will then be shown on the screen SS'.

CHAPTER XV

THE SEEBECK PROCESS OR PHOTOGRAPHY WITH SILVER SUBCHLORIDE

THIS is another interesting laboratory process of no practical value as, so far, no means of fixing the images has been discovered. It is named after J. T. Seebeck, who, prior to 1810, sent to the poet Goethe a treatise on the action of light on silver chloride, in which he disclosed the fact that under the influence of the spectral rays it assumed the colors incident upon it. Sir John Herschel in 1840, Robert Hunt, J. W. Draper and others followed on the same lines. Later, E. Becquerel of Paris paid particular attention to the subject and so far modified the methods of the prior workers as to use copper plates silvered on their surface. The plate was protected on the back with varnish to protect the copper base, and was hung by wires in a one to eight solution of hydrochloric acid and connected with a two-cell bichromate battery, the opposite pole being a platinum plate. The acid was electrolytically decomposed, the chlorine attacking the silver and forming silver chloride. The action was so regulated that a definite amount of chloride was formed, and the plate was then dried and heated until the originally white silver chloride turned to a delicate rose color. On exposure to the spectrum, or colored light, it assumed the colors more or less correctly. Becquerel was followed by Niepce de St. Victor, who also used silvered plates, and A. L. Poitevin, who did not publish the first account of his work with paper as the support until 1865, though it was begun in the early 50's. The chloride was produced by alternate baths of salt, and silver nitrate and salt, as for the success of the process an excess of silver nitrate must not be present. To accelerate the action, the paper was treated with an alkaline bichromate and cupric sulphate, which were used with the idea of absorbing the chlorine set free by the action of light. Practically this process is the basis of all subsequent processes.

Wharton Simpson, in 1866, published a method in which collodio-chloride of silver emulsion was coated on glass, exposed to light until it turned slate color, then under the colored original. To those desirous of making their own paper on the above lines, the following directions may be useful. Dissolve 20 g of silver nitrate in 12 ccm distilled water by the aid of heat, and add to 250 ccm of 96% alcohol; then add 10 g of pyroxylin, and then 250 ccm of ether. Also add 10 g of pyroxylin to 250 ccm of alcohol, dissolve in this 8 g of crystallized strontium chloride, and add 250 ccm of ether. Pour the second solution into the first in small quantities, shaking after each addition. Allow to stand twenty-four hours, and it is fit to use. After coating the paper or glass it should be dried in front of a fire.

Any chloride may be used instead of the above in equivalent weights, for instance, 4.3 g of potassium, 5.8 g of sodium, 6.3 g of ammonium, 6.1 g of calcium or 7.0 g of magnesium chloride; all being the anhydrous salts.

It is not, however, such an easy matter for the novice to coat collodion on paper, and any commercial printing-out paper may be used, if treated according to the following method, which was patented by Kopp in 1891, although it is practically Poitevin's 1866 process. Immerse the paper in a 5 per cent solution of salt for fifteen minutes. The purpose of this is to convert into silver chloride the excess of silver nitrate and organic salt, usually citrate or tartrate, that are always present in these papers. Then hang up to dry, and in this condition it will keep for a long time in the dark. Then in a clean dish immerse in the following:

Zinc chloride	1 g
Sulphuric acid	12 drops
Distilled water	1000 ccm

Expose to diffused daylight until the paper turns bluish-green, taking care that the surface of the paper is always beneath the solution, and that the bluish-green color is not overstepped. After this the paper should be well washed, dried off between blotting papers, and dried in the dark. In this condition it will keep for a long time. The following solution is then prepared:

Potassium bichromate	150 g
Cupric sulphate	150 g
Distilled water to	1000 ccm

Heat until this boils, and then add:

Mercuric nitrate	150 g
Nitric acid	5 ccm
Distilled water	q. s.

The nitrate should be placed in a porcelain evaporating dish, the acid added, and then distilled water in small quantities, heat being applied and more water added in small quantities until solution is effected. This should then be added to the boiling copper solution with constant stirring. A reddish precipitate will be formed, and the solution should then be allowed to cool and filtered, and either water added or the solution evaporated till it measures 1000 ccm. This will keep well in the dark in a stoppered bottle. The blue-green paper should be immersed in this solution for thirty seconds, or until it becomes colorless, well drained and then immersed in a 3 per cent solution of zinc chloride and rocked till it turns blue again, then well washed in running water, blotted off, and allowed to hang up for about ten minutes and exposed while still damp. Yellow and green soon make their appearance, and when sufficiently intense, the paper should be removed and the yellow and green parts painted with a varnish. An ordinary negative varnish may be used, and two or three coats should be given, the paper being heated after each coat so as to thoroughly dry it. The other colors can be seen but faintly, being covered with a yellow fog, and to remove this the print should be immersed in a 2 per cent solution of sulphuric acid and rocked until the colors are visible, then rapidly washed, blotted off and dried.

In this condition all the colors, as well as black and white, should be well represented, but they are not permanent, nor is it possible to make them completely so; but they can be made more so by immersion for five minutes in the mercury-bichromate bath, in which all color disappears, then in the sulphuric acid bath, which again develops the color. The print should be thoroughly blotted off and painted with gum arabic acidulated with 5 per cent sulphuric acid. This can be made by dissolving 20 g of gum in 100 ccm of water, adding 5 ccm of strong sulphuric acid, with constant stirring, and then filtering. This acts as a provisional fixer or desensitizer and also brightens up the colors by giving them more gloss.

Instead of the zinc chloride solution, advised above, a one per cent solution of sodium nitrite (not nitrate) may be used. Undoubtedly the above process is the most satisfactory if correctness of coloring is considered, but some fairly interesting results can be secured, with far less trouble, by treating commercial printing-out paper with the salt or zinc chloride solutions to insolubilize the excess of silver, then merely exposing to light until it turns violet or slaty blue, and exposing under the colored original. This does not however, give whites or blacks, and better results are obtained by exposing under the nitrite first.

The results obtained by Kopp's method may be examined by weak daylight, and they will keep in the dark unchanged for years; some have been kept for twenty years.

CHAPTER XVI

THE DIFFRACTION PROCESS

THIS process was invented by Professor R. W. Wood, of Johns Hopkins University, and is a beautiful application of the phenomena of diffraction by gratings. It is, however, merely a laboratory process, as the results are only capable of being seen by one person at a time or of being projected on a very limited scale, nor, so far as the author is aware, are the necessary diffraction gratings commercially available. On the other hand, it is a comparatively easy process and capable of indefinite reproduction.

The theory involved is simple, and no explanation will be required for those familiar with the phenomena of gratings. A grating is a sheet of metal or glass ruled with extremely fine lines, ranging from 2000 to 20,000 per inch. When white light falls on a glass grating it is split up into a series of spectra, as shown in Fig. 24.

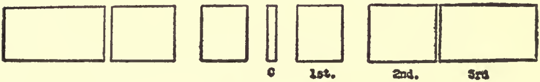


FIG. 24

The light passing straight through the grating is seen as a white central band *C;* on each side are seen the spectra with the violet end nearest the central image. The spectra are called the first, second, third, etc., to the *n*th order spectra, according to their position as regards the central beam; and these spectra become longer and fainter the higher their order. Theoretically there is no limit to the number of spectra that can thus be formed, but the first order spectrum is the only one used in this process, because it is the brightest. The distance from the central beam depends entirely upon the number of lines per unit or inch, and the finer the ruling, that is, the greater the number of lines per inch, the further removed are the spectra from the central image. It is obvious, then, that we can so choose the rulings that any three colors may be on the same plane, as roughly shown in Fig. 25, in which the light and the gratings are supposed to be behind the page, and we are looking on the spectra formed on the paper. With three gratings, that which gives the image *A* has the coarsest ruling, that which gives *B* being finer, and *C* being finer still. If these rulings are correctly chosen, the red of *A*, the green of *B*, and the blue of *C* will all appear on the same vertical line *OO*.

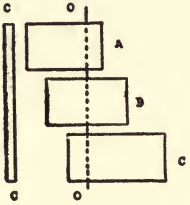


FIG. 25

It has already been pointed out that from the three lights red, green and blue we can produce all colors, so obviously in this case we are in a position to reproduce all colors by the use of three gratings, either by projecting the spectra on one plane or by superposing the gratings; and this is the fundamental basis of the diffraction process. The three gratings are printed on one bichromated gelatine film.

The rulings chosen by Professor Wood had 2000, 2400 and 2750 lines per inch for the red, green and blue respectively, but one is not tied to these particular numbers, finer gratings being used in the same ratio.

Three constituent negatives are required, taken in the usual way through the red, green and blue selective filters. From these negatives three positives in silver must be made as usual; from these positives the final result is obtained. The support for the final picture must be plate glass, as ordinary glass is not flat enough. The sensitive mixture is:

Gelatine	40 g
Potassium bichromate, saturated solution	50 ccm
Distilled water	1000 ccm

Soak the gelatine in the water for fifteen minutes, then dissolve by heat and add the bichromate solution, and filter while hot. The glass must be thoroughly cleaned and polished. Enough of the solution is poured on to cover the surface, the excess drained off for about ten seconds, and then the plate placed on a leveled slab to set and dry in the dark. The coating should be thin and the plates will dry in about two hours.

There are two methods of printing, by contact or by projection. Of the two possibly the latter is the easier, although, unless an arc lamp is available, the exposure is unduly prolonged; with an arc it is approximately from one to two minutes. The main difficulty is the registration of the images, though this may be gotten over by making ink dots on the glass side of the positives and bringing these into register. It is as well to support the two positives in a clip, such as is used for holding lantern slides for binding, and, with the aid of a focusing magnifier, bring the two images into registration; then, with a pen, put a dot of ink on the glass of the positive nearest the eye corresponding with some clearly marked object at one side of the picture, and also make another dot at the top or bottom of the positive. Then reverse the positives, putting that which was nearest the eye farther away; again make the images coincide and put on ink dots to register with the first ones; repeat this for the third positive.

A lens must be used to project the image of the positive on the sensitive plate. This lens may be supported in a V-shaped block of wood or clamped in an ordinary retort clamp, as this latter enables one to adjust it laterally and horizontally. Assuming that the positives are to be reproduced the same size, then, as is well known, there must be just double the equivalent focus between the lens and the positive and the same distance between the lens and the plate. No elaborate means are required for holding the sensitive plate, but it must be held rigidly in the same position for the three exposures. The positives are placed near the arc; it should be possible to place all three in approximately identical positions, and this can be effected if they are placed in a printing frame and jammed down into one corner. A sheet of yellow glass, or a fixed-out plate deeply stained with tartrazin, must also be provided.

To obtain even illumination of the positives, a condenser is essential, and it is obvious that a projection lantern will considerably facilitate matters. One of the gratings is placed in contact with the sensitive film, the yellow glass interposed between the light and the condenser, and the image of the positive sharply focused on the film; then without disturbing its position at all, the grating should be removed and ink dots made on the film corresponding to the dots on the positive. These give one a visible means of registering the three images.

The grating with the lowest number of rulings is placed in contact with the film, the yellow glass removed and the exposure made through the positive taken through the red filter. The yellow safe-light must now be placed in front of the light, the positive taken through the green filter substituted for the red one, the next finer grating placed in contact with the film in place of the coarser one, the second exposure made, and the operation repeated for the third picture. A preferable procedure, however, is to make the third picture on a separate plate, using the finest grating, and turn the positive around so that the image is reversed, as this can then be used as a cover glass for the other two pictures. The exposed plates are washed in water at 35 ° C. (95 ° F.) and then stood up to dry. It should be noted that the ruling of the gratings should be vertical.

The results are without any color at all; but when properly viewed the colors are at once seen. The viewing arrangements are very simple, being nothing more than a double convex lens, against which is placed the grating-picture, and a metal disc with a small peephole in the center which is placed at the focus of the lens. The light should be practically a line and this can easily be arranged by using the edge of a bats-wing gas burner, or an electric light may be used with an opaque screen with a slit about one eighth inch wide cut in it. If the light, lens and peephole are all in line, one only sees the central white image but if the lens and peephole be placed at a slight angle, the colors instantly start into view. What this angular arrangement does, of course, is to throw the first order spectra into the eye. Knowing the colors of the original, one soon knows the particular angle that will give the correct coloring; but, as an experiment, the effect of different angles should be tried, for it is possible in this way to show green cherries or roses with red leaves, or blue roses with purple leaves.

In contact printing, the same care must be taken about registration, and it can easily be worked out in the same way by ink dots or card guides. The exposure is best made by direct sunlight, and the sensitive plate and the grating, with the positive slide outside, should be placed at the bottom of a narrow lidless box, painted black inside, and pointed to the sun. The exposure at midday will be about thirty seconds.

Having once obtained a successful result, any number can be printed from it by contact on bichromated gelatine. Failure of registration is shown by overlapping of the edges of objects in the result, and errors in exposure may be seen by the colors being incorrect. For instance, overexposure with the red grating will cause yellows to be too orange, and errors in the blue printing will make the greens too blue. Modifications of this process have been suggested, but as they complicate without material improvement, we can ignore them. T. Thorp used a single grating and changed its angle for each exposure. While this gives as good results, it necessitates the use of three illuminants with three separate pictures inclined with regard to the rulings, and the viewing apparatus is more complicated. H. E. Ives proposed to use a black and white line-screen as well as the positive, and change the angle of the grating after each exposure, but this necessitates rather careful mechanism for changing the angle and shifting the line-screen after each exposure.

As pointed out, as far as possible a line of light should be used for viewing, for if too broad a source is used one has numerous spectra superimposed and consequent lack of color, as white is thus formed. If the line of light is at right angles to the ruling of the gratings, only a narrow stripe of color is seen, as the spectra are formed on each side of the central beam parallel to it and to the direction of the rulings.

Chapter XVII

THE PRISMATIC DISPERSION PROCESS

THIS process was first suggested by Chas. Cros in 1869. He proposed to split up the light by means of a prism, which was to be turned so as to direct the three colored rays to slightly different positions on the sensitive surface. Cros' idea was purely theoretical and he made no attempt to carry the process into practice. The idea was subsequently taken up by J. Drac and L. Moelants, but has never passed the experimental stage. Subsequently F. M. Lanchester, in 1894, patented a modified process in which, instead of using a single slit to obtain a single spectrum, which obviously considerably limited the available light, a series of slits, that is, a black and white line screen, was used, so that a series of minute spectra would be formed on the sensitive surface. Assuming that the light incident on these slits was reflected from a colored object, it is clear that only the colors of the object would appear in the individual spectra. Various modifications of this process were proposed by Raymond, Cheron, Lippmann and others. The disadvantages of all these methods was that the image of the object and that of the slits must be simultaneously projected on the sensitive surface; consequently the apparatus was extremely bulky, and the available light very little. They also suffered from the obvious disadvantage, incident to all prismatic spectra, that the distribution of the colors is very unequal, the reds being cramped together and the blues unduly spread out. Thus one may roughly state that the blue rays would occupy about three times the space of the red, instead of being proportionately distributed, as in normal or diffraction grating spectra.

In 1904, J. Rheinberg devised an apparatus in which this unequal distribution of the colors was overcome by the use of a specially computed direct-vision prism, with which the color spaces were practically the same as in a normal spectrum. This, like all these processes, is better fitted for the laboratory than for practical work, as the original taking apparatus has to be used for viewing the results. There is no commercially available instrument and it would be somewhat costly to make. Full details will be found in *The Photographic Journal*, 1912: 162, and *The British Journal of Photography*, 1912, *Color Photography Supplement*, 19, 28, 33, 38.

Another process, which might be called the refraction process, was first suggested by Liesegang in 1896, and a year later independently by J. A. C. Branfill. In this process the action of the cross-lined screen is taken advantage of, namely that each aperture in a cross-lined screen acts as a pinhole camera and produces an image of the diaphragm. Thus, when using a square diaphragm, the dots on the sensitive surface are square, and with triangular stops three cornered figures are formed. If the diaphragm, instead of being a single aperture, is divided into a series of apertures, there are as many dots on the sensitive plate as there are apertures. This being established, it is clear that if the stop aperture be split up into three areas, each covered by a color filter, one would have three images formed in the three colors, consequently the image of a colored object transmitted by a lens would be represented on the sensitive surface by minute areas corresponding to the colors of the subject. One may look upon this method as a screen-plate process in which the screen-elements are optically formed during exposure and not on a separate, preformed plate.

There is considerable loss of light in this process, due to the fact that the apertures in the cross-lined screen transmit but a fraction of the incident light. The apparatus necessary is only the cross-lined screen, which presents no particular difficulty, as it can be obtained commercially. The only requirements to be satisfied are that the opaque lines shall preferably be the same width as the transparent interspaces, and that the lines cross at right angles. The fineness of the ruling is elastic, as one may obviously decide to work with a fairly coarse or a fine ruling, according to the purpose of the final picture. Probably for general work from 70 to 100 lines per inch would suffice, as this would give color elements one-third the size, that is, from 210 to 300 per inch. Theoretically, there is no limit to the fineness, but the finer the ruling the more difficult it becomes to register the picture.

The construction of the diaphragm is not an easy matter, for one is naturally limited as regards the size of the filters by the working aperture. Consequently one must decide always to use a given aperture or else to prepare as many filter diaphragms as may be necessary to satisfy the requirements of sharpness of the image, taking into consideration here the marginal definition on the plate. Obviously the most practical plan would be to use as large a diaphragm as possible, and, drawing a circle on paper of the exact size, to describe a square outside the circle and divide this into equal areas, which shall be those of the filters, trusting to a supplementary filter to obtain equal exposures. Or one might vary the areas of the filters corresponding to the filter factors, but then one must have unequal color areas in the resultant picture; in all probability this would be the most satisfactory plan, as this will theoretically be necessary to form a neutral grey. These are points which would have to be worked out, as no one has done more, so far as the author is aware, than to work this process on paper.

The only possible plan for making the filter diaphragms would seem to be to use a microscopic cover glass, of the required size to fit the lens tube, and cement the filters down in strip form, which is not such an easy matter, as the edges must fit without white interspaces or overlapping. Or one might expose on bichromated gelatine and stain up with dyes that take differentially on hard and unhardened gelatine; when one would have the difficulty of adjusting the color depth to the rigid requirements of the theoretical filters. One also meets here with the difficulty of inserting the diaphragms in the lens tube, as it is quite possible that a little trouble might ensue in the case of anastigmats of large aperture because of the thickness of the glass, small though this is.

It would be necessary to use a compensating filter, as in all screen-plate processes, to reduce the vision of the plate to that of the eye, and this could only be done by trial and error, using a white surface as the object and making successive filters and exposures until it was rendered as white.

There are mathematical rules for finding the separation between the cross-lined screen and the sensitive surface, which is dependent on the stop aperture, and the extension of the camera; but the simplest plan is to use a magnifier and examine the image, and so adjust the distance that the colored rectangles or other figures are seen to be sharply defined with distinct edges: this involves a somewhat delicate screw adjustment for the screen, which must necessarily be at the same distance from the sensitive surface at all points. It should be mentioned, in connection with the focusing, that it is impossible to obtain critical sharpness with ground glass, and assuming that the camera is to be used for other work as well, then the only thing to do is to mark a small cross with a hard lead pencil on the center of the ground glass, and cement a microscopic cover glass over this with Canada balsam. This gives a perfectly clear spot on which when focusing with the naked eye nothing but the cross can be seen; but, if a magnifier be used, the image and the cross are easily focused. The magnifier used should be of the type in which the distance from the glass can be adjusted and then fixed once for all, and it should have a sleeve by which the distance from the glass is made permanent for all time. If the lead pencil cross be once sharply focused and the glass fixed for this, it must not be again altered.

Other modifications of this process have been suggested on paper, in which the cross-lined screen is eliminated by making the emulsion support act as a series of minute lenses, which should be formed in a substance like celluloid, which is plastic under heat and pressure, these minute lenses forming the images of the diaphragms on the posterior surface of the support, which should be covered by the emulsion. It would also be possible to use these minute lenticular forms, which can be linear, cylindrical or hexagonal, on a separate plate were it possible to obtain contact with the emulsion surface.

CHAPTER XVIII

TWO-COLOR PROCESSES, BI-PACKS AND TRI-PACKS

THE possibility of using two instead of three colors was pointed out by Ducos du Hauron in 1895, and he suggested that red and blue were quite sufficient to produce a color result, provided that too bright a light was not used for examination, or the light was yellowish, or the support was tinted yellow. This idea was further utilized by J. Gurtner, who, in 1902, proposed to use orange and green as the printing colors, thus ignoring the deep reds. Some five years later G. A. Smith adopted the red and green dyad for the mixing of colored lights for cinematographic projection. That the results obtainable by a two-color process can never be theoretically correct is unquestionable; but such pictures, when examined by artificial light, are so satisfactory as to delude even experts. The only colors that are really defective are the violets and deep blues, assuming red and green as the printing colors.

Gurtner's method was to place two sensitive plates in contact. The film of the front one, which was a slow chloro-bromide emulsion, was stained orange and turned with its film towards the second plate, thus acting as a filter for the latter. Ducos du Hauron suggested a tri-pack; that is three sensitive plates or films made up into a block with filters in between, so as to limit the action of the spectral rays. Obviously, in both cases, but one lens was required and any ordinary camera could be used with slight alteration of the plate-holders. Some such process would be invaluable if practical, but there is a fly in the ointment.

It is impossible to obtain critical sharpness by any such method. In the first place, critical sharpness exists in one plane, and one plane only; but, with a comparatively small diaphragm in the lens, there is an appreciable distance along the optical axis, through which the sensitive plate may be moved without apparent loss of sharpness. But this is not sufficient to allow of three plates or films being used and critical sharpness obtained. The most serious obstacle to sharpness lies in the films themselves. If such a plate-block be outlined, the subject will be more readily grasped. The front element should preferably be a glass plate with its glass towards the lens, for if films are used it is difficult to obtain the necessary flatness of the surface. Behind this front element is placed the second sensitive surface, and a filter may or may not be interposed; this second element may be a film and here the sensitive surface may face or be turned from the lens. The third element is again preferably a plate, as this helps to keep the surfaces flat; a filter may or may not be interposed between the second and third films. The light has to pass through two sensitive films containing silver salts and these are normally by no means transparent. It is true that the front element of the pack may be one of the transparent Lippmann plates, as was suggested by Du Hauron, as this is acted upon by the blue rays, and can, therefore, be the slowest and consequently transparent. But when we come to the second sensitive surface, which is usually devoted to the record of the green rays, we can no longer allow it to be transparent, for it would be too slow. Therefore, it has to be an emulsion of the normal type, faster than the front but slower than the rear plate. Hence the plate is more or less translucent and the particles of silver salt diffuse the light and make it impossible to obtain in any case, no matter how thin this coating may be, critical sharpness on the rear element. In the case of the two-color process we can use a transparent front plate and a fast panchromatic plate in the rear, and obtain better results. There is also another factor that has been ignored in the consideration of these processes, and that is that the rear element, being the one on which the red is recorded, that is, the minus-blue plate, is printed in blue. Now this blue impression is the one that gives us what the artists call the "drawing" of the picture. The yellow print may be hopelessly out of focus, the red less so, and the results will not be objectionable. But the moment loss of sharpness is shown in the blue it is instantly detected.

Were it possible to overcome this defect, the tri-pack or bi-pack system would be one of the simplest to use for color photography, because the only alteration needed in the camera would be the alteration of the plateholder so that it would take two or three plates.

For two-color work, however, the bi-pack offers considerable advantages. We can use a slow, more or less transparent chloro-bromide or chloride plate, and place behind this an orange filter and a panchromatic plate. If we decide to use commercial filters, such as Wratten & Wainwright, then we can safely say that the distance between the front and the rear elements will be only 0.1 mm, or approximately one two hundred and fiftieth of an inch, for this is the mean thickness of their gelatine filters.

The best results are obtained in two-color work by using for the two negatives the regions shown in Fig. 26; *R* represents those rays which should act on the panchromatic plate and *G* those for the front plate; but unfortunately the sensitiveness of the normal chloro-bromide plate is shown in *P* by the continuous curve; while that of a chloride emulsion is shown as the dotted curve. There are no commercial plates of either kind which are color-sensitized, so we should have to sensitize them. The most satisfactory dye for this purpose would be the new German dye pinaflavol, but whether this is yet obtainable commercially is not known. This dye sensitizes far more satisfactorily than all others for just the particular region that we want to record on our front element. But it is also necessary to stain this front plate to cut out the action of the violets and deep blues, while this new dye is a basic dye and we do not know whether it would stand admixture with a staining dye, which must be an acid dye. The sensitizing and screening dyes may be combined in one bath and probably the following would be a suitable combination:

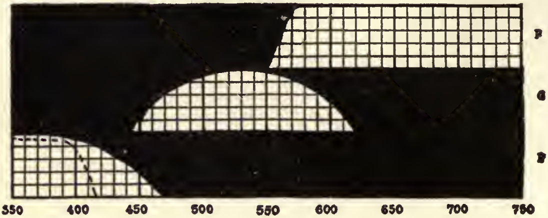


Fig. 26

Erythrosin	0.1 g
Tartrazin	1.0 g
Distilled water	1000 ccm

Bathe three minutes and dry without washing, although the plate should be just rinsed. Instead of tartrazin, naphthol yellow may be used in about the same strength. The exact quantity of the yellow dye will depend on the results desired. The more used, the more the blues and violets are cut out, and the worse they will be rendered in the final picture.

The filter to isolate the red region can be made with yellowish eosin 2 g and tartrazin 4 g per square meter, but Wratten & Wainwright's No. 22 or E2 is suitable. This, of course, must be the same size as the plate used, and the rear plate must be a panchromatic plate, preferably backed. Instead of staining up the front plate, a filter can be placed on the lens; this can be made with 1 g of filter yellow per square meter, or either a Wratten K1 or K1½ can be used; the former gives better rendering of the blues.

There is no need to give instructions as to the development of these plates; but a caution may be necessary as to the front one. It may show rather more contrast than is desirable as compared with the rear one, and further it will probably not stand such a strong developer, and should be developed separately in this case.

If one decides to use the tri-pack system, then the front plate should be a chloro-bromide or transparency, but as it has to record the blues it should not be stained, and a yellow filter on the lens, such as a K1, will be efficient. The second element has to be the recorder of the greens and should, therefore. be orthochromatic, and as has already been pointed out the smaller the thickness of this the better. Therefore a film should be used, and the ordinary roll film may be adopted. As a filter we must use one that cuts out the blue and violet but transmits the rest of the spectrum undamped; it is obvious that we cannot use here the normal green, as this cuts out the red, so we must use a yellow such as K2, which has about the right cut. Behind this middle element we must use a filter that isolates the red, and the normal tri-color red filter may be used (see p. 29). Wratten & Wainwright No. 25 or A is correct.

The tri-pack will, therefore, be composed of the following, counting from the front plate which faces to the rear: a chloro-bromide plate with glass towards the lens; a K1½ filter; a roll film or orthochromatic film with the film towards the lens; a standard tri-color red filter; a panchromatic plate with the sensitive surface towards the lens.

So far it has been pretty easy sailing, on paper, and the requirements are definitely fixed and fairly easily satisfied; but we now come to the crux of the whole matter, and that is how to adjust the sensitiveness of the plates and the filter actions so that the plates will all require the same exposure. The only thing to be done is to decide this by trial and error, by photographing a scale of greys with various combinations of plates until the scale is rendered alike on all three members. Alteration of the filters is practically excluded, because this would alter the absorptions and upset the color rendering. The most that one can do with the filters is to cut down the light with black and this is not an easy matter.

The tri-pack system outlined above is designated as the dialyte system. as Ducos du Hauron called his suggested arrangement a "polyfolium dialyticum." But J. W. Bennetto, in 1897, suggested a semi-dialyte system, in which one plate receives one image direct, and two plates at right angles to the former receive the other two images. This simplifies matters considerably, and there is no reason why this system should not be more generally adopted. A suitable camera is not on the market, but it would not be a difficult matter to make one. The principle is shown in Fig. 27, in which *a* represents the camera

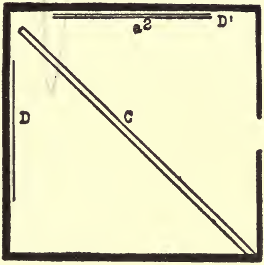


FIG. 27

front, *C* is a reflector at an angle of 45° which throws some of the light to a^2 where is placed a bi-pack of two sensitive plates with their surfaces in contact with a filter D^1 in between, while *D* is the filter for the single plate. Obviously this can be turned upside down and the two plates placed at the bottom of the camera. There is here a choice as to the division of the plates, but personally the writer would place the red filter plate at *D* and the transparent chloro-bromide plate at a^2, using a tri-color green filter between this and a panchromatic or orthochromatic plate. In this case, the reflector back must be coated with a minus green color, such as fuchsin or eosin, and the remarks on the construction of the camera on p. 52 should also be noted as to the thickness of the filters, etc.

In this system, the choice of plates and the determination of those most likely to give equal exposures is considerably facilitated, as one can definitely fix on a panchromatic for the red and green records, thus leaving only the chloro-bromide for the blue as the variable factor, and one variable is much easier to solve than two. One has, therefore, far less work in adjusting the relative speeds, because the speeds of the panchromatics may be so chosen as to be of great assistance in adjustment. One can here use a filter on the lens and thus avoid staining up a plate, and the standard tri-color filters may be used.

There may be some little trouble in registering the plates, because of the distortion from the reflector, but the notes on p. 55 will be of assistance. The registration can be readily tested, as by drawing a square with diagonal lines of a goodly size and photographing down it will be easy to see if the three negatives will register. If not, it is easy to determine which one is faulty and make the corrections accordingly. It may even be necessary to distort the reflector slightly by packing the edges with metal or hard rubber strips, but when once satisfactorily adjusted there should be no need to tamper with it again.

It is obvious that in all these processes, as one of the plates is placed with its glass to the lens, the image is reversed laterally; but this is actually an advantage as, if the pictures are used for lantern slides, this can be made on a separate glass and used as the cover glass.

If the positives are to be made by the iodide or mordanting process, it can be easily reversed, if necessary, in the stripping process.

If the dialyte or semi-dialyte systems be adopted, the printing colors are merely those of the normal three-color process, and these have already been dealt with. But with a two-color system we have to adopt a compromise: practically we must use a more orange red and a more greenish blue than the standard three colors, but any of the actual printing methods may be used.

For the diachrome process or those in which basic dyes are used, rhodamin 6GF or 12GF may be used, but as there may be difficulty in obtaining these, one can use fuchsin and auramin for the red and malachite green and auramin for the blue-green. If the relief or other methods which require acid dyes are used, then a mixture of naphthol green, acid green and naphthol yellow may be used for the green and a mixture of the acid reds with naphthol yellow for the red picture. Exact ratios of the dyes cannot be given, but a few trials will soon determine the best composition to use; in all cases the results should be examined by artificial light, for, as already stated, two-color pictures are only satisfactory when thus viewed. In print making, the colors should not be too deep, as the light has to pass through the film and be reflected from the white support. This obviates one trouble that is frequently met in transparency making, which is that the deep shadows are sometimes either violet or red and not black. This is chiefly due to the faulty transmissions of the dyes; if the shadows are violet, the red element probably wants a little more yellow in it, while if they are red, increase of the naphthol green will cut this out.

The Kodachrome process was introduced by the Eastman Kodak Co. in 1915, and is a two-color process based on the selective action of dyes for hardened and unhardened gelatine. Like all the other two-color processes it fails in the correct rendering of the blues, violets, magentas and purples; but for flesh tints, reds, oranges, greens, greys and blacks it is excellent, and some exquisite results can be obtained if the above limitations are borne in mind.

Briefly, the method of procedure is to expose two panchromatic plates behind suitable color filters and, after development, to so treat the plates that the gelatine is hardened *in situ* with the metallic silver and, after fixing and drying, stain up with the special dyes and superimpose. The best effects are obtainable with artificial light as the illuminant.

The working details follow; the two panchromatic plates can be exposed simultaneously, which obviously requires a special camera, or in succession. A special lighting system was devised by the Eastman Kodak Co. for portraiture, though naturally daylight can be used. The plates should be developed with metol-hydrochinon and the negatives should be rather of a soft character, which is obtainable as usual by shortened duration of development; over-exposure should be avoided as far as possible.

There are two courses now open to the worker: either to fix the negatives in the usual way and make duplicate negatives therefrom, or the less tedious plan of converting the original negatives into the dyed positives. For this latter system the negatives should be washed after development for about ten minutes and then bleached in the following:

A.	Potassium ferricyanide	37.5 g
	Potassium bromide	56.25 g
	Potassium bichromate	37.5 g
	Glacial acetic acid	10 ccm
	Water	1000 ccm

B. Potassium alum, 5 per cent solution.

For use, mix in equal volumes. Care must be taken to cover the plate with one sweep of the bath and use not less than 250 ccm for 500 square centimeters. The bleaching will take approximately four minutes, and the action should be allowed to continue for a short time after all the black silver has disappeared, it being converted into a brown image. The plate should then be washed for ten minutes in running water and fixed in a bath that does not contain alum, such as:

A.	Hypo	250 g
	Water	1000 ccm
B.	Sodium bisulphite	400 g
	Water	1000 ccm

For use, mix 1 part of *B* with 20 parts of *A*. This may be used repeatedly but not for more than 3400 square centimeters per liter (2000 square inches per gallon).

At this stage the plates look perfectly transparent with no sign of an image, and should be washed for twenty minutes and then immersed in a 0.5 per cent solution of ammonia and the dish well rocked for three minutes, and again washed for another five minutes. Surface moisture should be removed with a soft squeegee or by dabbing the plate with a pad of fluffless cloth, and the back must be dried. Drying must be uniform and the best plan is to dry before an electric fan. If the plates dry in patches, these will show in the finished picture. The drier the film the cleaner the high-lights, and the plates may be dried in an oven or left for at least three hours after drying in the usual way. This latter plan requires longer development, and the longer they are left after drying and before staining up the greater the contrasts in the resultant picture, so that if uniformity is required constant conditions must be observed.

Special dyes are issued, and a 1.2 per cent solution of the red dye and a three per cent solution of the green dye should be prepared. It is advisable to dissolve the dyes in a little hot water and filter the solutions through linen after dilution to bulk; distilled water should be used. The complementary colors are used, of course; that is, the negative taken through the red filter is dyed green, and that of the green filter dyed red. The dye solutions may be used repeatedly but should be kept up to strength by addition of fresh dye from time to time. As soon as the plates are immersed in the dye solutions the surfaces should be gently rubbed with a tuft of absorbent cotton to remove any air-bells. The average time of dyeing is about three minutes, but the progress may be watched by rinsing the plates with water, although it is not advisable to resort to this too often. Naturally they must be examined by the light by which they are subsequently to be viewed. If the composite picture shows a predominance of one color, the complementary plate should be more deeply stained. As soon as the plates are considered sufficiently stained, rinse them in a 1 per cent solution of glacial acetic acid, and wipe the surface of the film as already advised. It is important that the plates should dye quickly; the green plate dyes more slowly than the red, but even so should not take more than ten minutes; if it does the temperature of the dye baths should be slightly raised. Slow dyeing is also caused by insufficient bromide in the developer and overexposure.

To superimpose the plates, the green image should be placed on top of the red image and shifted about until perfect registration is obtained. Then the sides of the plates should be clipped together by large metal clips and short paper clips applied and these allowed to dry. If a mask is to be used it should be now applied on top of the green plate under the cover glass and the three plates bound up with long binding strips. Retouching may be effected with the dye solutions thickened with gum arabic solution.

If the duplicate negative method is adopted, and it is advantageous for several copies, then the original negatives are fixed, washed and dried in the usual way and from these transparencies made, and duplicate negatives; the best plates for both purposes being those of the character of the Seed 23. Both plates should be exposed at the same time at the same distance from the light, and developed together, aiming at fully exposed, soft, delicate negatives with all the detail of the original negatives; the further treatment is precisely as has been detailed above for the original negatives.

CHAPTER XIX

CINEMATOGRAPHY IN COLORS

THE combination of the illusion of movement given by the motion picture with colors has been for many years the hope of numerous inventors. But a brief sketch of their work can be given, as it would require a treatise larger than this book to exhaust the subject.

The fundamental basis of the motion picture is the phenomenon of persistence of vision. A bright light produces on the retina a certain impression, which lasts as long as the light is burning and a little longer, that is to say, the sensation of light is not instantaneously wiped out. If a succession of pictures be rapidly projected, about sixteen per second, the impression of the first picture persists on the retina until the second one is also there and is superimposed, and the same with succeeding pictures; therefore we have the impression of a complete picture, the sum of the individual phases of a movement, etc.

Precisely the same thing occurs with colors, The rapid alternation of red and green gives us the impression of yellow, of the constituents of which we are no longer conscious; so if a succession of red, green and blue pictures are rapidly and alternately presented to the retina, the composite result will be a moving picture in colors. The first suggestion as to such a process was made by H. Isensee, a German, in 1897, although Cros in 1867 had suggested the synthesis of a single picture by this method.

Isensee proposed to take the pictures through the tricolor filters and project them in the same way. Several inventions were patented in which the same idea was involved; but the great disadvantage of this process, and in fact of all processes in which different phases of a movement are represented in different pictures, is that one cannot obtain a perfect composite result. This is clearly seen if one imagines the use of the three-color filters with successive exposures of a very simple object; assume that a man is holding his arm at right angles to his shoulder and drops it to his side, and that during the movement of the arm we take three pictures. It is obvious that we have a red picture of the arm in one position, a green picture of the arm in another position and a blue picture in another. It is impossible to register these, and they will not superimpose sufficiently well on the retina to be sharp; we shall see the arm first with a red fringe at the top, then with a green fringe at the top and a blue fringe at the bottom and so on, so that a sharp single picture by this method is impossible.

Another and very serious defect is technically known as color bombardment. This is the physical effect produced by the rapid alternation of the colors. With some people this produces intense discomfort and severe frontal headache. It is probably due to the imperfect achromatism of the eye, for while the main effect on the screen is a homogeneous color, yellow, for instance, in the alternation of red and green, yet there is a peculiar pulsation or throbbing which is not flicker and yet is closely allied to it.

These troubles led to attempts to take and project the three constituent pictures at once, so that each picture was complete in itself as regards color. While this obviated the color bombardment trouble, it introduced other troubles in the necessity for special optical devices, which not only are costly but in the use of which one is much hampered by the fact that the average cinematographic lens ranges from two to three inches in focal length, and, therefore, one is cramped for room. If more than one lens be used, that is, either two or three vertically or horizontally disposed, the element of parallax is introduced, which is also sometimes called stereoscopic parallax. Exactly the same phenomenon appears in our own vision; each eye sees a slightly different view of an object and all objects beyond the particular plane focused on appear double and wanting in sharpness. This can easily be seen by holding a pencil or some such object at about ten inches from the eyes and focusing them on it, the background being a window with cross bars about a yard away. When the pencil is sharply focused the window bars will be found to be double, and if the bars are focused the pencil will appear as two. We are not conscious of this ordinarily, as the eye automatically focuses itself and ranges over the whole field of vision, so that we obtain the sum of the individual impressions. In the case of the cinematographic camera, there is no variation of focus, so that parallax or the doubling of near or distant objects is distinctly seen.

Another trouble which is purely a mechanical one is that the normal rate of taking pictures, and exhibiting them, is sixteen per second. If the single objective be used, the film has to travel three times as fast as for black and white. If three juxtaposed lenses be used vertically, one has to make the film travel three picture spaces at each exposure, and if they are horizontally juxtaposed, then triple width film must be used.

These difficulties led G. A. Smith in 1907 to revert to a two-color process, in which alternating pictures were taken and projected through a rotating shutter with red and green sectors. This process was known as Kinemacolor and some excellent results were shown. But this process was handicapped by color bombardment. It was simpler than those processes in which simultaneous projection of the constituent color pictures is used, as the only extra fitting for the projector was the rotating shutter, and possibly a few gear wheels to speed up the travel of the film. It may be accepted as an axiom that any process that requires a special projector or special fittings is hopelessly out of the commercial running.

The Smith system was based on the fact that in tricolor projection, the blue-violet constituent adds but little color as such. It brightens up the other colors and forms white. It does provide the pure blues and violets. But white is but a relative term and we accept as white in two-color projection that which is actually a yellow. The process was actually an additive one, and the black and white positives were projected through red and green filters, which were not of quite the same shade as the taking filters.

At the present time the efforts of most inventors seem to be directed to the production of subtractive pictures, in which each picture is itself a complete color record, and although but two colors are used the results in many cases are extremely pleasing. That the colors are absolutely true cannot be upheld, but the lack is so small that the average observer can rarely detect it. Moreover the question of color, whether in an oil painting or a photograph in colors, is so much a matter of individual feeling that probably no two critics would be in strict accord as to the correctness of a particular color rendering.

The processes that are used are to some extent secrets; but they would all be found to fall into the relief or mordanting methods already described. The use of double-coated film, that is, film with emulsion on both sides, is fairly general. While this facilitates the process in that one has two distinct images that can be appropriately colored, it introduces other troubles in the shape of rigorous necessity of registration, and it is obvious that care has to be exercised that each image is confined to one side of the emulsion.

The production of motion pictures in colors offers an enticing field for the experimenter, but it is beyond the reach of the average worker, as the outlay for the apparatus is heavy. Should anyone be desirous of entering this field, the soundest advice that can be given is to study the two or three hundred patents that have been issued on the subject, as no practical details have yet found their way into print. It should be borne in mind that a subtractive process with the colors on each picture on a single film that can be run through any projector is the desideratum.

Whether a three-color subtractive film is within reasonable reach of perfection is not known; but there are two or three two-color subtractive processes which threaten to become commercial within a reasonable time. Even if the cost of the production of the film can be kept down within reasonable limits, because after all this is an important question, it is a debatable point whether the public is sufficiently educated to pay more for seeing pictures in colors, and whether it would be more attractive to the multitude to see Charlie Chaplin fooling in colors than in black and white.

CONVERSION OF WEIGHTS AND MEASURES

The following tables are sufficient to enable anyone to readily convert the metric into the customary units, and are based on those published by the U. S. Bureau of Standards.

LENGTHS

Inches	*Centimeters*	*Inches*	*Centimeters*
0.3937	=1	1	= 2.5400
0.7874	=2	2	= 5.0800
1.1811	=3	3	= 7.6200
1.5748	=4	4	=10.1600
1.9685	=5	5	=12.7000
2.3622	=6	6	=15.2400
2.7559	=7	7	=17.7800
3.1496	=8	8	=20.3200
3.5433	=9	9	=22.8600

AREAS

Square Inches	*Square Centimeters*	*Square Inches*	*Square Centimeters*
0.1550	=1	1	= 6.452
0.3100	=2	2	=12.903
0.4650	=3	3	=19.355
0.6200	=4	4	=25.807
0.7750	=5	5	=32.258
0.9300	=6	6	=38.710
1.0850	=7	7	=45.161
1.2400	=8	8	=51.613
1.3950	=9	9	=58.065

MASSES

Grains	*Grams*	*Grains*	*Grams*
1	=0.0648	15.4324	=1
2	=0.1296	30.8647	=2
3	=0.1944	46.2971	=3
4	=0.2592	61.7294	=4
5	=0.3240	77.1618	=5
6	=0.3888	92.5941	=6
7	=0.4536	108.0265	=7
8	=0.5184	123.4589	=8
9	=0.5832	138.8912	=9

LIQUIDS

Cubic Centimeters	*Minims*	*Cubic Centimeters*	*Fluid Ounces*
1	= 16.230	29.574	=1
2	= 32.460	59.147	=2
3	= 48.690	88.721	=3
4	= 64.920	118.295	=4
5	= 81.150	147.869	=5
6	= 97.380	177.442	=6
7	=113.610	207.016	=7
8	=129.840	236.590	=8
9	=146.070	266.163	=9

The U. S. gallon = 3785.43 ccm; one liter = 33 fld. oz., 391 minims.

The above tables apply to the English weights and measures, with the exception of the liquid measures; the English gallon measures 160 fld. oz. = 4545.96 ccm.

The following therefore must be used for conversion of the same.

Cubic Centimeters	*Minims*	*Cubic Centimeters*	*Fluid Ounces*
1	= 16.894	28.4123	= 1
2	= 33.788	56.8245	= 2
3	= 50.682	85.2368	= 3
4	= 67.576	113.6490	= 4
5	= 84.470	142.0613	= 5
6	= 101.364	170.4735	= 6
7	= 118.258	198.8858	= 7
8	= 135.152	227.2980	= 8
9	= 153.046	255.7103	= 9

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POSSIBLE SOURCES OF VARIOUS DYES

(Where no names are given the dye is sufficiently common to be obtained from almost any maker.)

Acid green JE. Sherwin Williams Co., 11 Stillings St., Boston.
Acid yellow. National Aniline & Chemical Co., 21 Burling Slip, New York.
Acid rhodamin. H. A. Metz & Co., Inc., 122 Hudson Street, New York.
Aesculin. Merck & Co., 45 Park Place, New York.
Alizarin-cyanol. Cassella.
Auramin. Eastman Kodak Co., Rochester, N. Y. A pure variety is sold under the name of Pyoktanin aureum by Merck & Co.
Aurantia.
Aurophenin. National Aniline & Chemical Co.; E. I. du Pont de Nemours & Co., Inc., Wilmington, Del.

Bluish acid green. Sherwin Williams Co., Bachmeier & Co.
Bluish fast green. Sherwin Williams Co., Bachmeier & Co.

Carmin. Any drug store.
Carmine blue. Merck & Co.
Chrysoidin Y. Bachmeier & Co., 261 Franklin St., Boston, Mass.
Chrysophenin. National Aniline & Chemical Co.
Crystal violet. H. A. Metz & Co.
Curcumin. Eastman Kodak Co.
Cyanin. H. A. Metz & Co.

Diamin blue. National Aniline & Chemical Co., Schoelkopff Branch, Buffalo, N. Y. Sold as Niagara blue 4B.

Eosin, yellowish.
Erythrosin.

Fuchsin. Bachmeier & Co.

Glycin red. Kinzelberger, Prag, Czechoslovakia.

Indulin blue. Bachmeier & Co.

Janus red B. H. A. Metz & Co.

Lanafuchsin. Cassella.

Malachite green. Eastman Kodak Co.
Methylene blue. Eastman Kodak Co.

Methyl violet.
Mikado yellow. H. A. Metz & Co.

Naphthol green. Bachmeier & Co.
Naphthol yellow.

Orthochrom T. Eastman Kodak Co.

Patent blue. H. A. Metz & Co.
Pinachrom. H. A. Metz & Co.
Phenosafranin. Bachmeier & Co.
Pinaflavol. H. A. Metz & Co.
Ponceau.
Primrose. Also sold as naphthol yellow by most makers.
Prussian blue. Merck & Co.
Pyronin G. National Aniline & Chemical Co.

Quinolin yellow. H. A. Metz & Co.

Safranin Y. Bachmeier & Co.
Sensitol green & violet. Ilford, Ltd., Ilford, London, England.

Tartrazin.
Thionin blue. H. A. Metz & Co.
Toluidin blue. H. A. Metz & Co.

Vesuvin. Sold as Bismarck brown.
Victoria blue B.

Xylene red B. H. A. Metz & Co.

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