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Photographic Color Printing

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CHAPTER I

THE PROBLEM AND DEFINITIONS OF TERMS USED

Color to the photographer is a means by which nature and all its breadth can be recorded. Recent advancements have put color printing, which now requires a minimum of equipment, within the grasp of the amateur photographer.

The greatest advancements have been in color-film and color-printing paper. These advancements are related to centuries of photographic use and development.

The principles of photography were stated by Aristotle (384-322 B.C.) when he described the camera obscura. In Aristotle's writings reference was made to the formation of pictures projected through a small aperature (3:36).

However, some historians assert that Roger Bacon, an English Franciscan friar (1214-1294), invented the camera obscura. Not until the genius of the Renaissance, Leonardo da Vince (1452-1519), was a clear description of the camera obscura given. Leonardo writes:

> If the facade of a building, or a place, or a landscape is illuminated by the sun and a small hole is drilled in the wall of a room in a building facing this, which is not directly lighted by the sun, then all objects illuminated by the sun will send

their images through this aperature and will appear, upside down, on the wall facing the hole (3:39).

Leonardo and other artists of his time used the camera obscura in connection with painting. Obviously this kind of camera was bulky, for it had to contain a man. When this camera was fitted with a lens, it was possible to make the camera portable, due to the shortening of the focal length. In the eighteenth century, cameras of this type were a regular part of every artist's equipment.

Applying the results of Johann Schulze's experiments of 1727, which proved that silver salts were radically changed by sunlight, Joseph Niepce was able to make the first photograph (3:15). Niepce was disturbed, however, because of the reversal that appeared. The background of the picture was black and the objects white. This is an accurate description of negative photography. The making of the negative took place in 1816, but it was not until 1827 that Niepce was able to make a direct positive in black-and-white (10:18).

The concept of color had its beginning with Sir Isaac Newton and his experiments with light refraction in 1666. In the experiment conducted by Newton, white light was passed obliquely into one side of a glass prism and emerged from the opposite side as a band of colors instead of white light (12:3).

Further study and use of color in photography continued until 1861, when James C. Maxwell demonstrated the additive color process using blue, yellow, and red as the primary colors. In 1862 Louis Ducos du Houron designed a camera for making three separate negatives at one exposure, using angled transparent mirrors which in design and theory were the forerunner of the modern one-shot camera (12:9).

The demand for color in pictures was pressed by the commercial advertiser, with the first color prints appearing in the September 30, 1899, issue of The Saturday Evening Post (12:32).

Until the Berlin chemist Dr. Bela Gaspar in 1933 patented the process of color images created by the dye-forming action on a single piece of film, color photography was bound to the method that required three separate negatives or exposures (12:140).

Continued research has made it possible for the amateur photographer not only to use color film but to produce high quality color prints. It was the purpose of this paper to investigate the most recent method of making color prints.

I. THE PROBLEM

Statement of the problem. It was the purpose of this study to (1) determine the process that is necessary for dye formation in a colored negative; (2) to investigate the process of making a color print; (3) to evaluate a color print in regard to density and color balance; and (4) to enable one to correct the color balance of a colored print.

Importance of the study. The importance of this study will be the review of the background of color printing and the investigation of recent advancements that simplify the color printing process.

II. DEFINITIONS OF TERMS USED

Camera obscura. This is a camera consisting of a dark chamber with a lens or opening through which an image is projected in natural colors onto an opposite surface.

Color. Color is described as the sensation resulting from stimulus of the retina of the eye by light waves of certain lengths.

Color addition. Color addition results when two or more colors are superimposed. In photography the primary colors are blue, green, and red.

Color couplers. Color couplers are produced by the chemical reactions of oxidized developer to form dye images.

Color subtraction. Color subtraction results when white light falls on an object and only a portion is reflected or transmitted.

Color wedging. Color wedging is the result of improper light control in a tri-color camera.

Tri-color printing. Tri-color printing technique involves three separate exposures: one to green, one to red, and one to blue light, to produce a color print.

In the preceding pages high lights of photographic history have been mentioned and the problem and its importance stated. Special terms of color photography were defined.

Chapter II will review the research and developments necessary for the production of dye images in color negatives.

Chapter III will describe the equipment necessary for color printing. This chapter will also give a step-by-step procedure to follow for the development of a color print.

CHAPTER II

COLOR

I. MEASUREMENT AND PROJECTION

The range of light waves to which the human eye is sensitive is quite limited as compared to the total light produced. This range is commonly referred to as the visible spectrum. Physicists have measured these rays and compared them to the meter stick. The visible light waves vary between 1/400 billionth of a meter to 1/700 billionth of a meter (5:59).

The sensation that has been termed blue has a wave length of 460-500 millimicrons. One millimicron is equal to one billionth of a meter. The wave lengths of 500-570 millimicrons has been termed green, while those of 610-700 millimicrons are called red. The other colors that are experienced are mixtures of these primary colors or waves in varying proportions (2:5).

In 1861, a British physicist, James C. Maxwell, set out to prove that any color could be produced by mixing the primary colors of blue, green, and red. This experiment was performed by projecting an identical slide through each of the primary colors. "The result was a color photograph, crude but prophetic of the future" (9:243).

This process has been called the additive method of projection in that the three primary colors were added to each other to make a color photograph. It should be noted that this method only holds true for colored light. The mixing of color pigments is an entirely different matter.

Subtractive. The subtractive method deals with the amount of light reflected or absorbed by an object. A seemingly colored object absorbs or subtracts some of the light rays and reflects the rest (9:191). When white light falls on a red object, the green and blue rays are absorbed or subtracted so that only the red rays are reflected.

The same theory applies for the rest of the colors. For example, when white light falls on a blue object, the green and red rays are absorbed or subtracted and only the blue rays are reflected.

Additive. The additive method of making color photographs was used for many years in the production of color prints. This method is still used in ink printing presses. The additive method of making color prints requires an identical negative in each of the primary colors. To obtain three identical negatives, it is necessary either to take three separate exposures or to use a tri-color camera to obtain records in each of the primary colors.

The introduction of the tri-color camera in 1878 greatly increased the development of color photography. With this camera it was possible to make a single exposure and to have records in all three colors. The placement of mirrors, made of glass or collodin stretched over a metal frame, was very important to prevent color wedging. This is done by placing mirrors at varying angles to the lens.

II. NEGATIVE FORMATION

It was not until 1935 that Eastman Kodak Company introduced a color sensitive film that recorded all three colors on the same piece of film (8:245). Such multilayer material is called a monopack.

The growth and use of this new type of film was closely allied to the growth of color subtractive and color processes dependent upon dye coupling formation. "It must be kept clearly in mind that chemical dye destruction and dye bleaching are not synonymous" (6:449).

In processing colored film, a metallic silver image is formed much the same as present-day black-and-white. Along with a metallic image, a color image must also be produced. The dyes for image formation in the first colored films were formed after the metallic image and also formed separate from each other. In present-day color film the dye-forming materials are included in the emulsion.

The thickness of this film is about one-thousandth of an inch. The lowest emulsion next to the support varies from two to five ten-thousandths of an inch in thickness, while the top two emulsions are approximately two ten-thousandths of an inch in thickness (8:451).

To allow adequate light transmission, the top emulsion is poor in silver salts, having been diluted to almost pure gelatin. However, silver halides must be present for adequate formation of the silver image. The emulsions may carry not only light sensitive silver halides but also sensitizing and light filtering dyes and substances for the formation of color images. The production of stable, non-migrating, sensitizing, and filtering dyes was one of the most important factors contributing to the commercial success of monopacks.

Dye formation. In the process of film development, whether it be black-and-white or color, the result is always the same: metallic silver and oxidized developer (1:249). In the color process the oxidized developer is quite active and is used to form the color dyes. The formation of these dyes occurs in each layer of the emulsion almost independently of the other. For example, when white light is subjected to the negative, each layer of the emulsion controls its own portion of that light. If the emulsion sensitized to red light forms a negative of red absorbing dye, then the red light transmitted by the film as a whole will be inversely proportional to that of the subject. The only difference between it and a positive will be this inverse relationship. The same theory holds for green and blue light (4:199).

If the dye-forming materials were perfect in their recording and transmission of light, as has been illustrated, there would be no difference in the production of positive-to-positive print from that of negative-to-positive. However, these dyes are not perfect. They tend to break down at the extremities of their range, so that in the negative-to-positive printing the process is printed back on itself and tends to compensate for these losses, while in the positive-to-positive this action tends to be accelerated.

The colors seen in a colored negative are approximately complementary in hue to the colors of the subject. This is true because a saturated color consists of a concentration of light of one (or two) of the three colors and relatively little of the other two (or one). In the negative, the large quantities of light are represented by large absorptions and the small quantities by low absorptions. Hence, the negative transmits the opposite color as far as white light is concerned. When the negative is printed, a reversal happens again, and the true color is obtained. Color negatives then are inverted in the brightness scale and are of roughly complementary colors (4:200).

The red absorbing dye in colored film has impurities of absorption in both the green and blue range. The red dye should transmit both without absorption, but it does absorb appreciable amounts of each.

Absorbing dye. In colored film which has a dye-forming coupler in the emulsion, the coupler is normally colorless and forms dye only with oxidized developer. It has been found possible, however, to give these compounds a color; that is, to make them absorb colored light in such a way that this color disappears when the final dye is formed. The coupler is, accordingly, made to have the same absorption for blue and for green light as does the maximum impurity of the red absorbing dye after it is formed. Since the coupler is uniformly distributed through the emulsion before exposure, this emulsion starts off by having a uniform orange color throughout.

As red absorbing dye is formed, this orange dye disappears in exactly the same amount. However, the blue and green absorptions of the red absorbing dye match exactly that of the orange dye that has disappeared. Hence, as far as green and blue light are concerned, nothing has happened. When such material is printed, it is necessary to use light containing more green and more blue than would be used ordinarily to make a correct color print (4:210).

Color film. There are sound arguments in favor of precision in exposing color films. However, color-negative films offer greater exposure latitude than do color reversal films. A one-half stop variation from the ideal exposure of a reversal film may produce an unsatisfactory transparency. Such an error in color-negative film exposure will hardly be noticed if the negative is correctly printed. For a scene of average brightness range, color-negative film exposed over a two and one-half stop range will be satisfactory for making good quality prints. This does not allow a photographer to be careless about exposure, but it means that minor errors can be readily corrected during the printing stage (11:8). Another advantage of using color-negative films is that they can be used many times to make any quantity of reproductions without any loss of quality.

The selection of a camera to do color picture taking is not limited to any particular film size. The color-negative films vary in size from the twenty-four by thirty-six millimeters to as large as eight by ten inches (6:134).

CHAPTER III

PRINTING

I. EQUIPMENT

Enlarger. Almost any enlarger can be used for color-negative film printing. However, an enlarger that has a fluorescent lamp is not generally used. This type of light does not have sufficient amounts of red, and thus results in heavy filtering and long exposure times. Also, greenish condenser lenses should be avoided if possible because of the off-balance color that they will transmit. The enlarger should be of such construction that it will not be easily shaken during exposure, and the head must be secure so that prints will remain in sharp focus.

The enlarger head should also be checked for any light leaks. If the head does have some stray light beams it must be hooded or masked during exposure so that white light does not strike the enlarging paper. If a new bulb is being used, it should burn for approximately one hour, as most lamp color characteristics change during this period.

Lens. A color-corrected lens will give prints showing better definition and greater freedom from color fringing than lenses intended for black-and-white printing only.

Voltage. Fluctuations in line voltage are more common than is generally realized. If these changes occur during exposure, the balance of color will be directly affected. The result is most noticeable in the blue component and the least in the red.

The effect of slow or sudden changes in line voltage can be controlled by the installation of a "voltage regulator." Even though the line voltage may vary between ninety-five and one-hundred thirty volts, the regulator will control the output to an essentailly same rate.

Timer. A timer that will accurately repeat exposure times is also very important. The timer becomes a must, especially in the tri-color method of printing. This timer must either have hands that can be set in relative darkness or have a luminous dial. Once exposure times have been determined, an unlimited number of prints is possible if the timer functions properly.

Filters. In tri-color printing, it is necessary to have a filter holder that can be attached to the enlarger head so that the filters may be moved without disturbing the enlarger. This can be accomplished by the placement of a bracket on the lens; thus the filter will be between the paper and the lens. This bracket is also used to hold the diffuser while the test exposure is made.

An infra-red filter must also be used in the enlarger. This filter may either be placed between the lamp and the negative or between the negative and the lens. The placement of the infra-red filter between the lamp and the negative is preferred.

Trays. In the method being investigated it is only necessary to use three trays for processing the prints. It is also necessary to have two other wash baths of running water. One bath is used to wash the print between the developer and fix and between the fix and the bleach. The second bath is used only for washing prints that have been in the bleach. Extreme caution must be taken so that there is no contamination between the processing solutions. Special care should be taken to see that no bleach is carried back to the developer. It is suggested that printongs be used. The use of printongs is essential because the chemicals used for color processing are sometimes irritating to the skin.

Temperature. The temperature that is recommended for the developer is 70°F, and this temperature should be closely maintained. The use of running water with a temperature regulator will simplify this problem. Another method is to place a thermometer in the stream of water and manually control the temperature. The rest of the process has a tolerance of several degrees. For the fixer and bleach the temperature may vary between 68° and 75°F. The wash baths may vary from 65° to 75°F.

Chemicals. The chemicals must be mixed with water of 80°F. The vessels that are used for mixing and storage must be clean. Before the solutions can be used they must be cooled to the temperatures previously noted.

II. EXPOSURE AND DEVELOPMENT

Negative selection. Because of the number of variables that must be brought under control in the initial setup of color-printing conditions, it is highly unlikely that a perfect print will be produced on the first attempt. The first print, therefore, to be acceptable, must be satisfactory in both density and color balance (11:22).

In order to make a test print it is necessary to select a negative that is typical of those to be printed. If possible, the subject should include some neutral areas, or near neutral areas. For example, sunsets or flowers are not good subjects, because they can be printed over a wide range of color balance and still be pleasing. However, the face in a portrait or a sunlit concrete surface makes a good reference negative.

Calculator. Use of the exposure calculator will assist in determining the proper time each filter should be exposed. It is not necessary to use any colored filter with the calculator; only a diffuser. Before the test exposure is made the negative should be cropped and sharply focused. The lens opening should be set to the largest opening. When a small test strip of enlarging paper is inserted into the calculator, an exposure of thirty seconds can be made.

Development of the test strip will take five minutes, with agitation twice each minute. The timer can be used here also to standardize development time. Next, the test strip should be washed in running water for one minute before placing it in the fixing solution. After the print has been in the fix for one minute, it is permissible to turn on the room lights. The remaining portion of the process may be done under normal room lights. The test exposure may now be evaluated without bleaching. The exposure time will be indicated in the column at the left for each of the filters indicated at the bottom of the test strip. The time selected should be from the lightest completely formed color patch.

Exposure. Using these results it is now possible to make a colored print. First remove the diffuser and replace with additive filters. Do not change the enlarger settings. Turn off all white lights, place enlarger paper in the easel, and use exposure times determined by the test strip exposure print. It is of utmost importance to expose in this order--blue, green, and red. When moving additive filters, care must be taken not to disturb the enlarger.

Development. Processing of the print requires five minutes in the developer and one minute in the wash before placing in the fixer. The fixing process requires three minutes, but white lights can be turned on after one minute. After fixing, the print must be washed for five minutes before placing in bleach. The bleaching process requires ten minutes, with fifteen minutes of washing before drying the print.

Drying. Prints may be air dried or placed emulsion side down on lintless blotters. If glossy prints are desired, first air dry and then re-wet and squeegee onto a ferrotype tin. If heat is used when drying, it should be limited to 170°F.

III. EVALUATION

Study the color balance and density level of the test print.

Look at areas that should be reproduced as whites or grays, and decide whether they have been affected by some variation from neutral color balance. Look at the reproduction of high lights and decide whether over-exposure has caused them to be muddy or under-exposure has caused them to lose detail.

Some changes in exposure conditions will probably seem desirable. If the test print is far from the proper density or color balance, the changes required can probably be estimated only roughly (11:29). A second test print may seem desirable before final exposure conditions are determined.

Since tri-color printing is a negative-positive process, exposures through the additive filters must be changed by a relative increase in the direction that the test print is off balance. For example, if the test print is too blue, correction can be made by increasing the blue-filter exposure relative to the green and red-filter exposures. Somewhat more exposure will then be given the blue-sensitive emulsion layer of the next print, causing relatively more yellow dye to be formed (11:31).

The choice as to whether color balance is going to be corrected by increasing one (or two) of the three exposures or, alternately, by decreasing the other two (or one), will depend upon the test print's density. Experience with the tri-color method is the best guide for estimating exposure adjustments.

CHAPTER IV

SUMMARY AND CONCLUSIONS

I. SUMMARY

The taking of colored pictures to most photographers is just as simple as taking black-and-white pictures. The film is different, but it loads the same and sometimes requires little change in the basic exposure. The results in color photography are usually quite good, although many photographers do not have a background in colorimetry. However, if consistently superior results are to be maintained each time, an understanding of the fundamentals of color is particularly important.

Scientists have demonstrated that the visual appearance of any color can be matched by appropriate mixtures of blue, green, and red light (light, not paint). Blue, green, and red light emerge, therefore, as the primary colors. However, another fundamental appears when we overlap beams of these primary colors. Where red and green mix, yellow is formed. Where red and blue mix magenta is formed; and blue and green form cyan. The colors yellow, magenta, and cyan then become the complementary colors. In color photography complementary colors are used to control the amount of light that is reflected or transmitted by the primary colors.

Exposure of color film, which has several layers of light sensitive material, forms a laten silver image in each layer. As the film is developed, by-products react with chemical couplers to form the three colored dyes. In negative color film these dyes are formed in reverse as to light and dark areas, as well as in roughly complementary colors. When these negatives are printed the reversal takes place again, and the original scene is reproduced.

In tri-color printing some adjustments in exposure may be necessary to balance the colors. This may be done by increasing or decreasing the exposure of one (or two) of the primary colors. This decision is left to the photographer.

II. CONCLUSIONS

Great strides have taken place to simplify the color printing process. The amateur photographer may now do color processing using conventional black-and-white equipment and a few additional items that are inexpensive. The time required for print development is less than that for black-and-white prints.

It is no longer necessary for the amateur photographer to have a commercial establishment process the color film.

This process may be used by the amateur photographer in the home darkroom or it may be included in an advanced photography course.

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