Oct. 9, 1923. 1,469,811

J. G. CAPSTAFF

COLOR PHOTOGRAPHY

Filed July 12, 1922

FIG. 1.

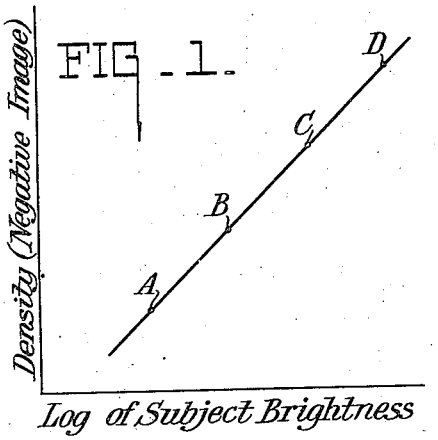


FIG. 2.

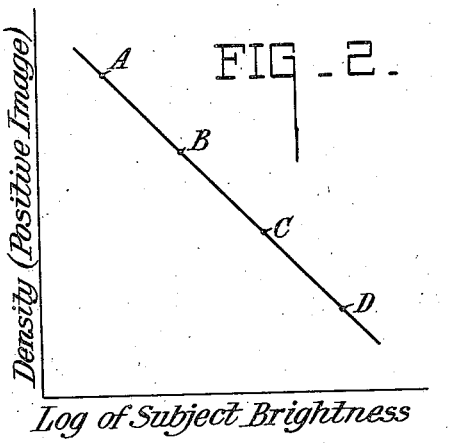


FIG. 3.

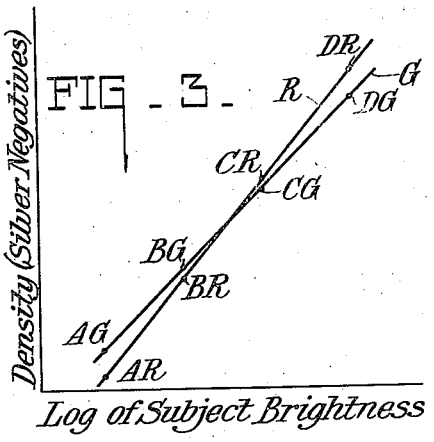


FIG. 4.

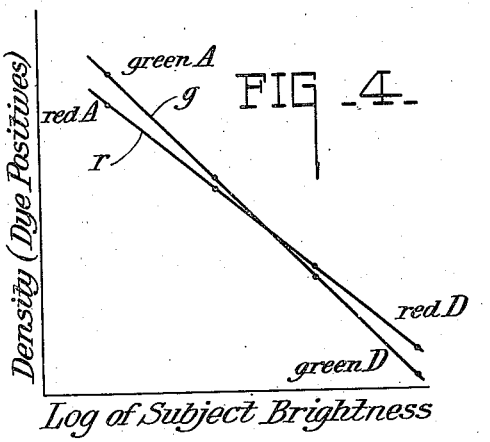


FIG. 5.

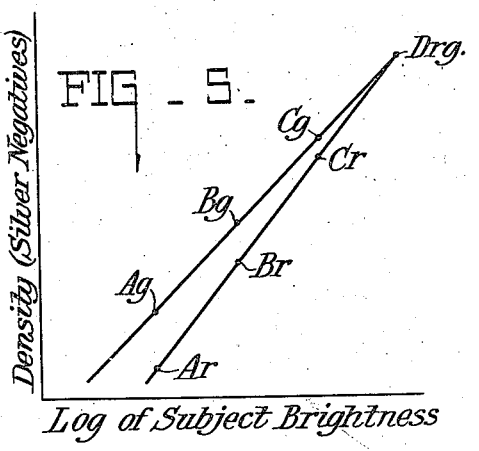
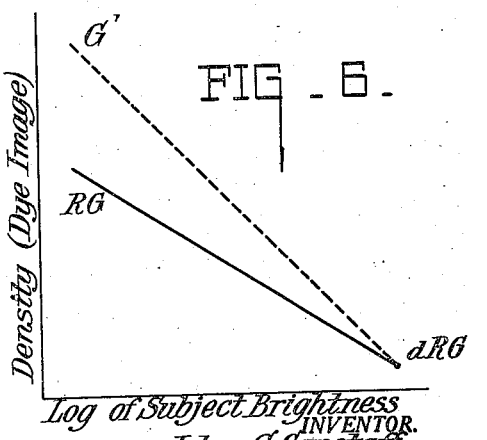


FIG. 6.



INVENTOR.
John G. Capstaff,
BY P. L. Stinchfield
W. M. Perrins
ATTORNEYS.

Patented Oct. 9, 1923. 1,469,811

UNITED STATES PATENT OFFICE.

JOHN G. CAPSTAFF, OF ROCHESTER, NEW YORK, ASSIGNOR TO EASTMAN KODAK COMPANY, OF ROCHESTER, NEW YORK, A CORPORATION OF NEW YORK.

COLOR PHOTOGRAPHY.

Application filed July 12, 1922. Serial No. 574,363.

To all whom it may concern:

Be it known that I, JOHN G. CAPSTAFF, a subject of the King of Great Britain, residing at Rochester, in the county of Monroe and State of New York, have invented certain new and useful Improvements in Color Photography, of which the following is a full, clear, and exact specification.

This invention relates to improvements in the art of color photography, and particularly to certain steps in the making of color component images which are to be viewed in superposition.

Such a process is described in my Patent 1,196,080, granted Aug. 29th, 1916, which process in brief consists of the making of color component negatives through complementary filters, submitting the resultant silver images to a bleaching-tanning bath, dyeing the resultant bleached images, the dye being adsorbed differentially and inversely to the silver image, and superposing the images.

I have discovered that when an image obtained by bleaching in the manner described in the patent is submitted to the action of a dye of the type there mentioned that the resulant dye image is formed, developed or built up in a manner analogous to the formation or development of a photographic image as developed from a latent image, and I have applied this discovery to the technique of making color pictures that are well balanced through a wide scale of tones.

As is well known, the density of a developed image is not directly proportional to the time of development but is rather a logarithmic function of that time. Moreover, as is also well known, the contrast in the developed image, denoted in photographic literature by "gamma", increases with development, there being for any particular set of photographic conditions, a value "gamma infinity", at which the image is fully developed; and if development is pushed further, it results in a substantially uniform increase of density and usually in the introduction of general fog as a result of the development of particles over the entire sensitized area, and particularly in the less exposed areas.

Analogously, when a bleached image of the nature mentioned is submitted to the action of an appropriate dye, dye is adsorbed to the image the rate and extent of adsorption being analogous to the action of development described. The dye does not tint the photographic emulsion nor the image therein uniformly nor proportionally to the time, but builds up a dye image in which the contrast, which may be called the "dye-gamma", increases to a maximum which may be called "dye-gamma-infinity" when the dye image is fully formed.

If dyeing is carried beyond the "dye-gamma-infinity" stage the dye image is built up in density without materially affecting "gamma", though it builds up particularly in the high lights.

If dyeing is stopped before that stage there results an image of less density and of lower "dye-gamma" than the fully dyed image.

It will thus be seen that the action is quite analogous to that of development. I have applied the discovery of this property to the formation and control of the images of a multi-color process. Other conditions being the same, the gamma of a silver image will vary with the color of the light by which the camera exposure was made. In particular, color component images made through a red filter will have a higher gamma than those made through a green filter. By properly controlling the dyeing of the bleached images made by my patented process, it is possible to control the color ratio of the final dye images so that they will have the same "dye-gamma".

I will now proceed to make this somewhat clearer by reference to the accompanying figures comprising a series of diagrams illustrating characteristic curves of the images at various steps in the process.

Fig. 1 represents an ideal negative;

Fig. 2 an ideal positive;

Fig. 3 two color-filter negatives;

Fig. 4 two dye positives corresponding to the silver images of Fig. 3;

Fig. 5 two color-filter negatives balanced for the high-lights; and

Fig. 6 the dye images made by differentially dyeing bleached images corresponding to the silver images of Fig. 5.

These diagrams, it is to be understood, are made as simply as possible. In practice the curves are not straight lines, as here shown, but are more or less curved, their form depending on the particular emulsion, developer, exposure, temperature, dye baths, and

other factors used in the particular circumstances.

It will be assumed that the subject to be photographed includes neutral objects, each reflecting equal amounts of red and green light, but that the objects have different brightnesses. The photographic silver negative image including such objects, whether taken by green light, red light or red and green light, should represent them by a series of densities proportional to the logarithm of their brightness. In Fig. 1 the characteristic curve of such a negative image is shown, the density of the several points A, B, C, and D being plotted against the logarithm of their brightness, A being very dark, and D very light. The corresponding positive image would yield a line having a reverse slope, as shown in Fig. 2, where density of image is plotted against the logarithm of the original subject brightness. If a color image including such subjects comprises two colored complementary images made from exposures taken through red and green filters it is obvious the slopes of their characteristic lines should be the same.

In practice, however, it has been found that images taken by red light will have a greater slope than those taken by green light, other photographic factors being the same. In Fig. 3, are shown the curves R and G for two negative images, resulting from equal exposures by red and green light respectively, and including a series of neutral objects of different brightness, the density of the several points as produced by red light being indicated by AR, BR, CR and DR, and the density of the images as produced by green light being indicated by AG, BG, CG and DG. If these images were bleached and tanned in accordance with my above mentioned patent and then dyed equally, the points could be plotted as shown in Fig. 4, the green filter image being dyed red and the red filter image dyed green. The shadows would have a greenish tinge since AG is greater than AR and the high lights a reddish tinge since DR is greater than DG and since, as stated in my patent, the dye is adsorbed differentially and inversely to the density of the original silver image. The green dye image of A is deeper than the red dye image; and the red dye image of D deeper than the green image.

In my discovery of the fact that dye images change their slopes as they are built up, I have a means whereby the differences in their slope may be controlled and balanced. If the dye image having the normally higher slope is built up to a less extent, the slope of the two images will be the same, and if they have the same depth or density as well, the colors will be balanced throughout. If the dye image having the characteristic line g in Fig. 4 is built up to a less extent, its slope will be the same as that of r and it will be parallel thereto but lower; that is, the picture as a whole will have a reddish tinge. The slopes would be the same but dye densities uniformly different. This defect may be corrected by making the negatives to be bleached such that for the point D in the highest lights the density will be the same. The two curves will appear as in Fig. 5. The curves in the negatives will intersect at the point Drg, and the points Ag, Bg and Cg of the green filter images will have greater density than the corresponding points of the red filter image. When these images are bleached and dyed, the curves will intersect at dRG, Fig. 6, in the high lights, and if the dye images were fully developed, the green dye image, made by dyeing green the bleached red filter silver image, would have a steeper characteristic line G′ than would the other image. The dyeing of this image is therefore stopped at the point where its images have been built up to the same extent as the red dyed bleached green filter image and both fall on the line RG and are balanced throughout.

As noted above the actual practice is not as simple as the theoretical considerations indicate, partly because of the variations in the shapes of the curves, which are not straight lines and cannot be made to balance absolutely throughout their length. However the principles outlined above determine a method of controlling the curves. In motion picture practice the exposures are made and from these master positives are printed. From these master positives there are printed the duplicate or final negatives which are to be made into the final color pictures; these are made in registery on opposite surfaces of a double coated film. This is described in my prior patent.

The dryness of the film affects the density but not the slope of the dye image. As it is customary to dye one side of the film, then dry it; then dye the other side and dry the film again, it is important that the dryness of the film at the times of dyeing be controlled.

The several colored image layers may be assembled to form a transparency or they may be formed in coatings already in position on opposite surfaces of a film, this being my preferred method. A very great advantage of this method is that it throws much of the corrective control into the final step so that errors that may not have been discovered can be corrected by variations in the dye bath. It is possible to carry along the printing steps of the process by standard methods and exercise the control by the final dyeing step at a time when the complete color image is being formed.

When this corrective control is applied in a prior step it is too late, at the time of dyeing, to introduce any considerable correction.

Errors in exposure ratio can, to a certain extent, be compensated for by the methods herein described, particularly when combined with variations in the intermediate printing steps, which in such cases would be so timed and proportioned as to bring the characteristics of the final silver images as nearly as possible to the preferred relation.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In the art of color photography wherein color component silver images are made and severally transformed into complementary dye images, the improvements that comprise the formation of the silver images with different characteristics of density and contrast, and carrying the transformation to different stages of completeness to compensate for the differences in characteristics.

2. The method of producing color pictures comprising the making of complementary color images having different contrast scales and dyeing them differentially, the dye images being built up to different extents to compensate for the different contrast scales of the original images.

3. The method of producing color pictures comprising the making of complementary color images having different contrast scales and different densities, and dyeing the images differentially, the dye image corresponding to the image having the less contrast and less density being built up to a greater extent than the other.

4. The method of producing color pictures comprising the production upon opposite sides of a transparent support of different color-component photographic images having different contrast scales, and then dyeing the two images different colors, the extent of the dyeing of the images being controlled in accordance with the contrast scale of the respective images.

5. In the art of color photography in which two complementary color component silver photographic images are formed in registry upon opposite surfaces of a film, and then treated to render the images differentially adsorptive of dye, and then dyeing them in complementary colors, the improvements comprising, first, the formation of the two series of silver images with different contrast and density characteristics, and, second, the controlled differential dyeing of these images, after bleaching, so as to compensate for their difference in characteristics.

6. In the art of color photography wherein two complementary color component silver photographic images are formed in registry upon opposite surfaces of a film as a result of exposure and development, and then are treated to produce images that are differentially adsorptive of dye, and then dyeing such images in complementary colors, the improvements that comprise, first, the control of the ratio of the two exposures so that one image will be denser than the other, and, second, the differential dyeing of these images after treatment in accordance with the difference in their original densities.

Signed at Rochester, New York, this 8th day of July, 1922.

JOHN G. CAPSTAFF.