Sept. 16, 1924. 1,508,916

P. D. BREWSTER

COLOR PHOTOGRAPHY

Filed June 6, 1914 3 Sheets-Sheet 1

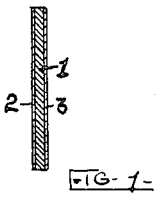

FIG-1-

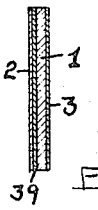

FIG-2-

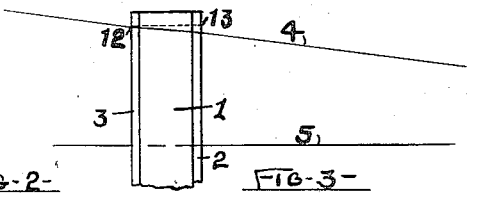

FIG-3-

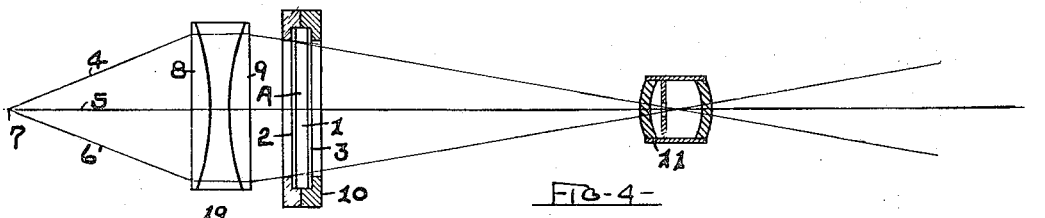

FIG-4-

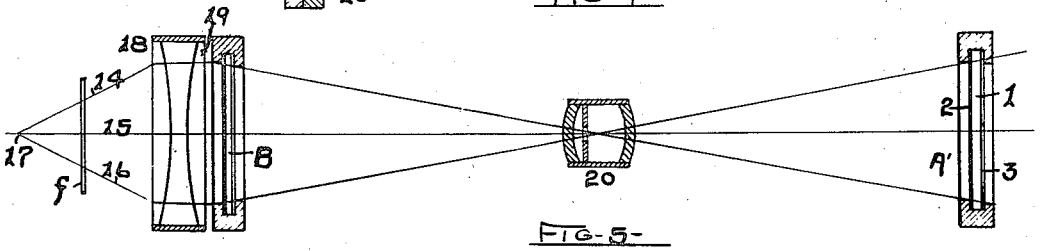

FIG-5-

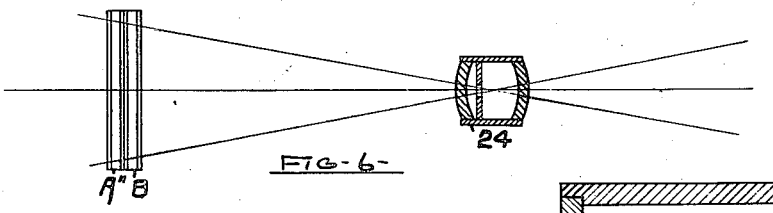

FIG-6-

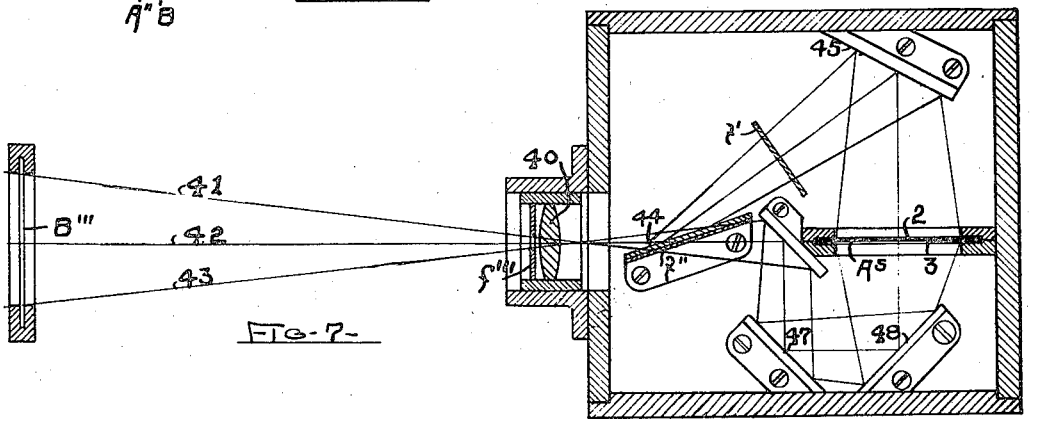

FIG-7-

Witnesses:

William Robinson

A. L. Burhans

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Sept. 16, 1924. 1,508,916

P. D. BREWSTER

COLOR PHOTOGRAPHY

Filed June 6, 1914 3 Sheets-Sheet 2

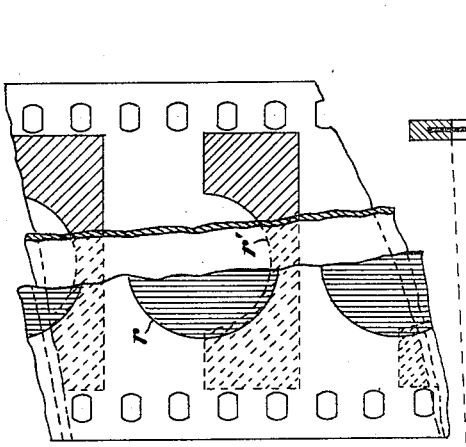

Fig. 7b.

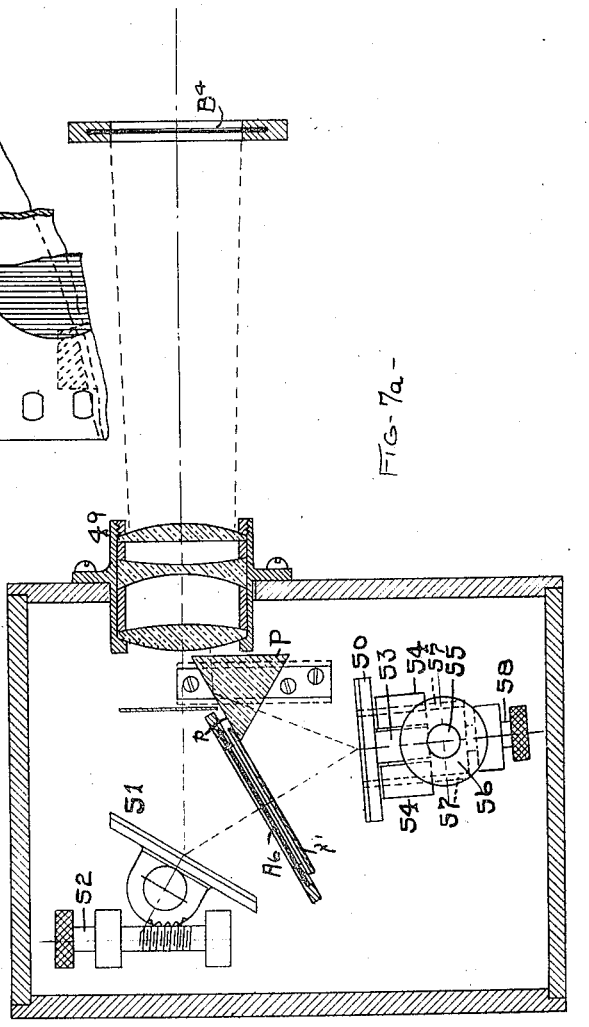

Fig. 7a.

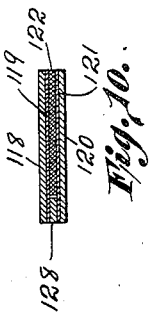

Fig. 10.

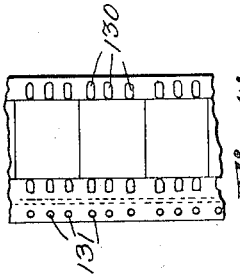

Fig. 11.

Witnesses:

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Sept. 16, 1924. 1,508,916

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COLOR PHOTOGRAPHY

Filed June 6, 1914 3 Sheets-Sheet 3

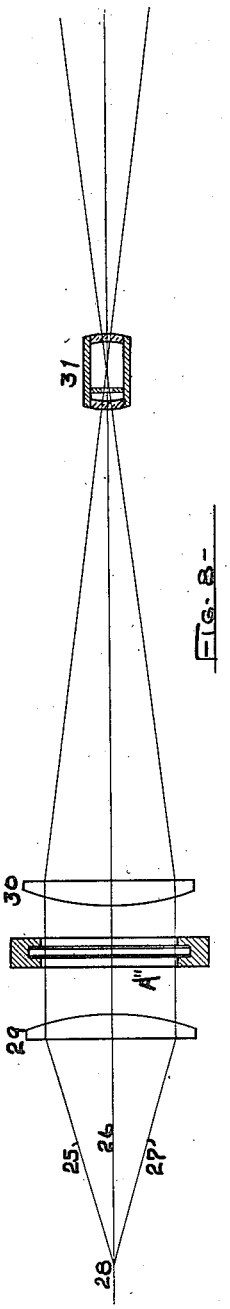

FIG. 8.

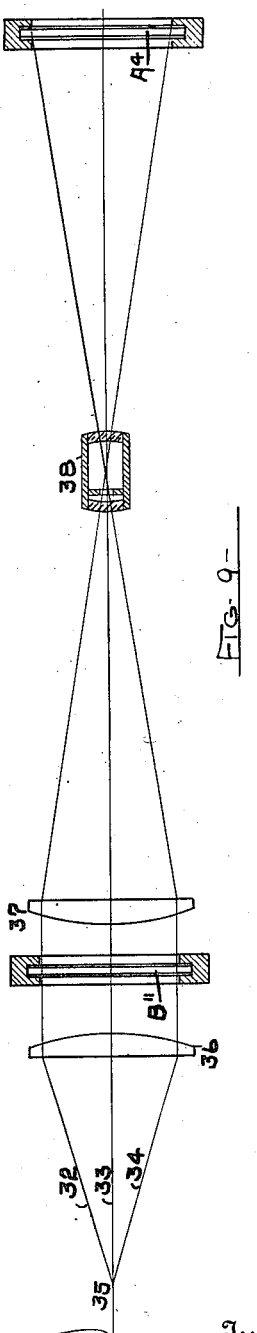

FIG. 9.

Witnesses:
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By his Attorneys
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Patented Sept. 16, 1924. 1,508,916

UNITED STATES PATENT OFFICE.

PERCY D. BREWSTER, OF EAST ORANGE, NEW JERSEY, ASSIGNOR, BY MESNE ASSIGNMENTS, TO BREWSTER PATENTS CORPORATION, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

COLOR PHOTOGRAPHY.

Application filed June 6, 1914. Serial No. 843,351.

To all whom it may concern:

Be it known that I, PERCY D. BREWSTER, a citizen of the United States, residing at East Orange, in the county of Essex and State of New Jersey, have invented certain new and useful Improvements in Color Photography, of which the following is a full, clear, and exact description.

This invention pertains to so-called "color photography," that is, the production of photographs in which objects are exhibited in substantially their natural colors, and relates more particularly to the positive photograph and the production of the same.

While the negative used may be of any suitable type, I prefer one of the kind described in my prior Patents Nos. 1,145,968, issued July 13th, 1915, 1,191,941, issued July 25th, 1916, and 1,208,739, issued December 19th, 1916. In these patents I have described fully a number of specific ways of producing color negatives of the kind referred to, but for the present purpose one example will be sufficient, and may be briefly explained as follows. (It is to be clearly understood, however, that the precise method of making the negative is immaterial to the present invention, and also that I use the term "film" to include as equivalents glass plates and other sheets or plates suitable for the purpose).

The raw film stock for the negative is, in the particular example mentioned above, coated on both sides,—on the front with a transparent emulsion sensitive only to blue and green, and on the back with an emulsion sensitive only to red and orange. Exposing this film (through a yellow filter to screen out the violet and ultraviolet rays and some of the blue) on a subject that we will suppose consists of a red circle on a background of which the upper half is light blue-green and the lower half is white, the blue and green rays act on the front emulsion while the red and orange rays pass through and act on the rear emulsion. Developing the film in the usual way we find that on the front emulsion the circle is transparent, with no deposit, while the two halves of the background are black, rendered by deposits of the same or substantially the same density. On the back the circle is black, the blue-green half of the background is transparent, and the white half is black. We now color these deposits, (by well understood chemical processes), the front being colored green and the back red, so that on the front the background is green with the circle remaining colorless; while on the back the circle is deep red, the lower half of the background is red and the upper half is colorless. By transmitted light the negative then shows the circle dark red, the upper half of the background dark green, and the lower half black due to the light being unable to pass through both red and green. Our "color" negative is now completed, and can be used for printing any number of positives by the method described below, as can also other color transparencies, for example, those made by the "Autochrome" and analogous processes.

In accordance with the present invention, the positive is a transparency (preferably bearing an image on each side) to be viewed directly by transmitted light or to be projected on a screen. At the present time the invention is believed to find its most widely useful embodiment in the form of cinematographic film, consisting of a series of pictures representing successive phases of an object in motion. As such films are well known, it is deemed unnecessary to illustrate the same herein.

In printing from a color negative upon a positive film which is coated on both sides, the procedure preferably followed is such that on one side of the film will be produced a photographic image by the action of light of one color or group of colors, and on the other a photographic image by the action of light of a different color or group of colors; after which the two images are colored differently, as for example, one green and the other red, the two colors being so chosen that when the two images are viewed simultaneously, directly by transmitted light, or projected upon a screen as in cinematography, they will combine to produce a single image in substantially the natural

colors of the object. Several modes of procedure by which these results can be attained will now be described.

Referring to the accompanying drawings, Fig. 1 shows in cross section a film of the type which I prefer for the production of the color positives.

Fig. 2 is a similar section showing combined with the film a ray-screen or filter which is useful or necessary under some conditions.

Fig. 3 is an edgewise view, on a large scale, of a positive film, illustrating a feature which may exist therein and which, under some circumstances, is a disadvantage.

Fig. 4 is a diagrammatic view of an ordinary optical system for projecting lantern slides and moving pictures.

Fig. 5 is a diagrammatic view illustrating simple and convenient means for printing positives by projection of the negative image or images.

Fig. 6 is a similar view illustrating a convenient method of printing by contact.

Fig. 7 is a diagrammatic sectional plan-view of a camera (described in detail in my aforesaid Patent No. 1,208,739) which can be used for printing positives by projecting two negative images upon opposite sides of the positive film.

Fig. 7[a] is a diagrammatic sectional plan-view of another camera of the general type described in my application Ser. No. 815,153, capable of use for printing positives by projection.

Fig. 7[b] is a plan view illustrating a positive film having images on its two sides, one larger than the other so that when the film is projected (by rays converging through the film to the projecting lens) the two images will combine and produce a single or unitary image on the screen. Part of the upper coating or emulsion (carrying the upper image) and part of the celluloid stock or support are broken away to show clearly the image on the underside. Red is indicated by vertical and green by diagonal shading.

Fig. 8 shows diagrammatically a projection system which can be used for projecting positives possessing the feature illustrated in Fig. 3.

Fig. 9 is a diagrammatic view showing means for printing (from a suitable negative) positives having the feature illustrated in Fig. 3.

Figs. 10 and 11 are respectively a sectional and plan view of one form of film disclosed in my Patent 1,228,877.

Referring particularly to Fig. 1, which shows in section a small piece of sensitive film such as may be used for the purposes of the present invention, 1 designates a transparent support, preferably flexible and composed, for example, of celluloid. On one side this support is coated with an emulsion or other medium 2, which is sensitive chiefly to a group of colors extending down, say, to and including yellow-green of the visible spectrum; in other words, a group of colors above yellow. The other side of the support bears a coating 3 which is sensitive chiefly to red and orange, and possibly to yellow, but which may be panchromatically sensitive.

In accordance with my present invention, color positives may be printed from the negatives in various ways. Where the colored image is to be viewed directly the positive can, if the negative is suitable, be printed by contact, as any ordinary lantern slide or cinematographic film is printed. In projection work, the optical system commonly used is illustrated diagrammatically in Fig. 4, in which light rays 4, 5, 6, emanating from a source (not shown) at the point 7, are refracted by the condensers 8, 9, pass through the positive A in a suitable support 10, and are brought to focus upon a screen (not shown) by the projecting lens 11. It will be observed that, with the exception of the axial ray 5, the rays converge from the condensers to the projecting lens. Hence rays 4 and 6, for example, pass through the emulsion 3 at points nearer the center of the film than are the points at which the same rays pass through the emulsion 2. The result is that if the two images are identically the same in size on the film, that is, "congruent" save as separated by the transparent support 1, the ray 4, for example, will project different points of the image. This feature is illustrated on a larger scale in Fig. 3, in which 12 and 13, at the ends of the dotted line, indicate corresponding points in the congruent images. In short, the image on the screen will not be "unitary" but will be double, outside of the center of the picture, one image overlapping the other and thus impairing the definition. In order to avoid this defect I provide for printing the positive in such manner that the two images shall be congruent at the center, but shall differ in size progressively from center to margin, the rate of difference being regulated, other things being equal, by the distance between the film and the projecting lens, so that corresponding points in the two images (the smaller image being next to the projecting lens) will be in the paths of their respective rays. In that case the image on the screen will be unitary and the definition thereof will not be materially impaired, if at all. In other words, the image projected from the emulsion 2, and that projected from the emulsion 3, will be in substantially congruent register on the screen. When the two images on the film are of such character in respect to size as to give a unitary image, or congruent images, on the screen when projected in the ordinary way (or by special

means for use with positives whose images are congruent throughout) they may be said to be registered or in registry, these terms being used as generic expressions in the appended claims to include both types of film.

Negatives having non-congruent images, from which non-congruent positives can be printed, as by contact with the use of parallel rays of light, can be made by the method described in my prior Patent No. 1,191,941, referred to above. This method can be illustrated by Fig. 3, by imagining that 1 is the negative film and that the rays 4, 5 proceed from the camera lens. It will then be readily seen that the image produced on the emulsion 2 will be smaller than that on emulsion 3, and that, ray 5 being assumed to be the axial ray, the two images will be congruent at the path of that ray. Such negatives can also be made by means of the camera shown in Fig. 7, as clearly explained in my Patent No. 1,208,739, hereinbefore mentioned.

Fig. 5 illustrates diagrammatically a simple and effective method for printing positives to produce images in projection registry, of the type in which the images are centrally congruent but are progressively different in size from center to margin. In this figure, the printing rays 14, 15, 16, emanating from a point 17, are refracted by the condensers 18, 19, through the color negative B, whose image must of course be "non-congruent" (except at the center) to the same degree as is desired in the positive. Having passed through the negative the rays are brought to focus by the lens 20 upon the "raw" positive A'. It is clear that the angularity of the rays striking the positive should be the same as that of the rays with which the completed positive is to be subsequently projected, and hence the focal length of the lens 20 is governed very largely by the focal length of the lens (for example 11) which is to be used in the projection apparatus. Usually the positive will be of the same size as the negative, in which case the equivalent focal length of the lens 20 will be one-half the distance between the position of the completed positive and the projecting lens (11) in actual use. Then in printing the positive the same size as the negative the lens 20 will be at the same distance from the negative and from the raw positive as the projecting lens is (in actual use) from the completed positive. This feature is illustrated roughly in Figs. 4 and 5, where it is seen that the angularity of the rays is the same in each case.

Of course the converse of the foregoing is true: If the focal length of the printing lens 20 is chosen arbitrarily, the projecting lens (11) must be of such focal length that in actual operation it can be used at a distance from the positive equal to twice the focal length of the printing lens. I prefer, however, to adapt the printing method to the projecting system since in that case the resulting positives can be used in present projecting machines with little or no alteration thereof.

Where the conditions of subsequent use permit the positive images to be slightly larger than the negative images the positive may be printed in contact with the negative (having non-congruent images) in the manner illustrated in Fig. 6, in which B' and A' are the negative and positive respectively. Here, as in the former case, the printing rays, represented by 21, 22, 23 from the lens 24, have the same angularity as have the rays with which the completed positive is to be projected on the screen, or vice versa.

I prefer to make the positives with non-congruent images of the type described, as such positives can be used in existing projection lanterns with little or no alteration thereof; but it is possible to project, with great enlargement and satisfactory definition, positives which have their images congruent throughout. Convenient means for this purpose is illustrated in Fig. 8, where A''' indicates such a positive. The projecting rays 25, 26, 27, emanating from 28, are brought to parallelism by a collimating lens 29. Having passed through the positive A''' the parallel rays are caused to converge by the lens 30 to the projecting lens 31 which brings them to a focus on the screen, not shown.

If the negative has congruent images the congruent-image positive can be printed therefrom by simple contact, but to secure the desired sharpness of definition in the positive images the printing rays would be as nearly parallel as possible.

To produce non-congruent positive images from a congruent negative a method analogous to that illustrated in Fig. 8 may be resorted to. Thus, in Fig. 9, B'' is the negative having images congruent throughout, which negative is arranged between two lenses as in the positive A''' in Fig. 8. The rays 32, 33, 34 from the point 35 are rendered parallel by the collimating lens 36, and having passed through the negative are converged by the lens 37 to the lens 38 which brings them to focus on the raw positive A^4. Inasmuch as the rays striking the film A^4 from the lens 38 are divergent, it will be seen that the area which they cover on the front emulsion (the one next to the lens) will be smaller than the area covered by them on the rear emulsion, thereby making the image on the front smaller than the one on the back; but where the axial ray (33) passes through the film the two images will be congruent.

In printing by methods which require

that the rays which are to affect the rear emulsion of the positive must pass through the front emulsion, as in Figs. 5, 6 and 9, for example, the front emulsion must be sufficiently transparent to permit the passage of such rays through it. In such case it is advantageous to make the "green-sensitive" emulsion the transparent one, chiefly because an emulsion can readily be made highly sensitive to green and other colors above yellow and at the same time practically non-sensitive to red and orange; thus permitting the latter rays to pass through without being affected by them. In any case, the transparent emulsion should have as high degree of transparency as possible, both to pass the greatest amount of light, and to minimize spreading or diffusion of the transmitted rays with consequent impairment of definition in the image produced by them.

If the rear emulsion is sensitive to rays which should affect only the front emulsion, such rays should be prevented from reaching the rear emulsion, at least in any material amount. For this purpose the front coating may be stained a suitable color, to screen out the undesired rays, yellow being suitable if the green-sensitive emulsion is in front. Or the support 1 may be stained, or the film may have, as in Fig. 2 a transparent colored coating or layer between the support 1 and the front emulsion.

If it is desired to print with the red-sensitive emulsion in front this emulsion must not, of course, be materially affected by the rays which should affect the rear coating. This, however, presents no great difficulty, as it is well known that with certain derivatives of cyanine an emulsion can be made very sensitive to red and yet be practically blind to certain rays in the green. By using a printing light which has rays of only two colors, for example red and green, it is thus possible to secure satisfactory color renderings with a red-sensitive emulsion in front. Of course if such a red-sensitive emulsion is used on the back and the printing light has only two colors (say red and green) the green rays need not be screened out.

Although, for the best results, the emulsions on the negative stock or "raw" film should be, when considered together, sensitive to substantially all the colors of the object to be photographed in order to produce the best condition of orthochromatism in the combined negative images before staining or coloring the same, the emulsions on the positive stock need not be; particularly if printed from a two-color negative of the kind described by means of light of only two colors, corresponding to the two colors of the negative. Thus the positive can be sensitized primarily for the two colors, say red or orange or orange-red on one side and green on the other, or any other two colors that may be suitable for the purpose.

In printing positives I prefer, in any case, to use rays of only two colors, usually red and green. This may be done in various ways, as for example by employing a light which emits rays of all colors and then screening out all but those desired. Thus in Fig. 5 it may be assumed that rays of all colors are emitted by the source at 17; then to print on the red-sensitive emulsion (3, for instance) a red filter is placed somewhere between the source and the film A', say at *f*, and the exposure made, thereby producing a latent image on the red sensitive emulsion. The red filter is then replaced by one of a suitable green color, to permit green but no red rays to pass, thus producing a latent image on the green sensitive emulsion.

If the two emulsions are of unequal "speed" the difference can be easily compensated for by suitable variation in the intensity of the light, or the duration of the exposure, or both. For example, suppose that the red-sensitive emulsion is markedly slower than the other. Then in following the procedure described in the preceding paragraph, the exposure through the red filter can be lengthened, or the intensity of the light increased, while the filter is in use, or both the intensity and the time may be increased. Similar compensatory methods can be used if one or the other of the negative images is too "weak" or too "strong", as by reason of under or over exposure, or under or over development, or is too deeply colored.

A camera of the type described in my Patent No. 1,208,739, above referred to, can be advantageously used for printing positives as well as for making either type negatives. Such a camera is illustrated in Fig. 7, which shows a lens 40 receiving rays 41, 42, 43, transmitted through a negative B''' having images of the non-congruent type. After passing through the lens the rays impinge upon a transparent reflector 44, which reflects part of the rays and transmits part. The reflected rays proceed to the reflector 45 and finally reach the raw positive film A^5, while the transmitted portion of the rays are reflected to the other side of the double coated film by the reflectors 47, 48. In this method it is not necessary, or even desirable, to have either emulsion transparent; and in fact, if either is sensitive to the rays which should affect only the other, the latter should preferably be opaque, at least to the rays referred to, or positive film stock of the type illustrated in Fig. 2 can be used. In the method illustrated in Fig. 7, the printing can easily be effected by two-color rays. Thus if the emulsion 2 is sensitive to green and emulsion 3 to red, for example, a green

filter f' can be used somewhere between the light-splitting reflector 44 and the emulsion 2 and a red filter between the reflector 44 and the emulsion 3. A convenient position for the latter filter is at f'', on the back of the reflector. If necessary or desirable, particularly when the light projected through the negative B''' is white, a filter f''' may be used to cut off the violet and ultraviolet rays and possibly some of the blue. A similar filter (not shown) may be used for the same purpose in any of the other printing methods.

Another form of camera of the general type described in my prior Patent No. 1,208,739 is illustrated in Fig. 7ª. In this form, a reflecting prism P is arranged behind the lens 49 and covers about half of the latter. Half of the rays from the negative B^4 through the lens 49 are reflected by the surface p to a reflector 50 and by the latter are reflected to the positive film A^6, which is arranged at an angle to the axis of the lens for the purpose of economizing space so that a lens of shorter equivalent focal length can be used. The other half of the rays are reflected by a reflector 51 to the other side of the positive film A^6. The prism P has preferably such angles, and is so positioned, that the rays which pass through it will enter and emerge at substantially right angles to the front and rear surfaces respectively, and if the reflection at the surface p is not total the said surface may be silvered in the usual way. Though differing in specific structure from that shown in Fig. 7, the camera shown in Fig. 7ª can be used in exactly the same way as the former. The mirrors 50 and 51 can be adjusted by any convenient means. For example the mirror 51 can be turned on the pivot 51ª by a tangent screw such as shown at 52. The mirror 50 is shown as provided with a boss 53 pivoted between two lugs 54 so as to be pivotally adjustable by means of a tangent-screw shown in plan at 55. The lugs 54 are mounted on a member 56 (shown in dotted lines) which is slidable in guides 57 (also shown in dotted lines), toward and from the film A^6, by means of a screw 58.

If the film or support for the two images is not transparent the images can be projected by reflection, as for example by means of apparatus such as the camera shown in Fig. 7 or Fig. 7ª. In such method of projection the two images are illuminated in any convenient manner, not shown, and the rays reflected by the images are projected by the lens upon the screen. I prefer, however, the method in which the projecting rays pass through the images and the support thereof.

In printing cinematographic positives the negatives and positive films are in the form of long strips, which are of course moved in unison in the printing plane. Mechanisms of various kinds for thus moving positive and negative films are well known, and inasmuch as such mechanism or mechanisms form no part of the present invention it is unnecessary to illustrate the same herein.

When the exposed positive stock is developed (in any convenient way) the positive images are produced, one on each side of the film, the nature of which images can best be explained by reverting to the color negative described above and noting what it does to the printing light. This negative, it will be remembered, shows by transmitted light a red circle on a background of which the upper half is green and the lower half is substantially opaque, or black; because on one side the lower half is red and on the other side is green. Now, when the printing light strikes the negative, red rays (and red rays only) will pass through the circle, being stopped elsewhere by the background, which is green on one side, at the bottom and at the top. Hence when the positive is developed, the red-sensitive emulsion will have a deposit in circular form, but the background will be transparent. On the other hand, the green printing-rays are stopped by the red circle and by the lower half of the background on the red side of the negative film; but they pass through the upper half of the background, which is green on one side and colorless on the other. Hence on the green-sensitive side the positive will have an image of the upper half of the background while the lower half, and the circle, will be transparent. Viewed by transparent light, or projected upon a screen, the two images combine to form a single or unitary image, which image may or may not be a strictly correct rendering, in monochrome, of the colors of the object according to their visual luminosities.

From the foregoing it will be seen that the two images are complementary, in the sense that neither correctly represents the entire object and that each completes the other, so to speak.

The positive having been produced in monochrome, the deposits forming the two images are colored in substantial correspondence with the colors or groups of colors which they are to transmit. For example, the deposit on the "green side" is changed from black to blue-green and that on the "red side" to red. Then upon viewing the film by transmitted white light or by projection with white light, the circle will be seen in red, the upper half of the background blue-green, and the lower half, being colorless in the film, will transmit all the light and hence will be seen in white. Other colors than those mentioned may be

used, depending upon the effects desired, but in general I prefer green or blue-green, and red or orange-red.

If the positive film just described is of the type having non-congruent images, that is, one larger than the other so that when projected by converging rays the two images will combine on the screen to produce a single or unitary image, the film will appear as in Fig. 7b. It will be observed in Fig. 7b that the red circle r' (on the upper side) is larger than the corresponding image r' on the other side of the film. It will of course be understood that the difference in size of the images is much exaggerated. In motion picture film for use with a projection lens having a focal length of a few inches the difference in size of the two images can hardly be detected with the naked eye, even at the extreme corners of the film.

If the two pictures or images are taken through the same lens, they are taken from the same point of view and hence are devoid of the parallax effects which are produced when two lenses are employed; and if they are taken simultaneously, a moving object appears in exactly the same position in both pictures or images. It will, moreover, be observed that the pictures are in successive pairs, so to speak, each picture of one series being paired with one of the other series; and it will also be seen that throughout the series of pairs there is the same degree of accuracy of registration. In other words, the pictures forming one pair are registered to the same degree of accuracy as are the pictures of the preceding or the succeeding pair. This condition follows both from the nature of the negative film from which the positive was printed and from the fact that the two series of pictures on the positive are in fixed relation, each to each, and hence cannot shift relatively to each other in the projector.

The coloring of the positive film may be effected in any suitable way. The method which I prefer at the present time is to treat both sides with an aqueous solution of iodin and potassium iodid to convert the deposited silver into silver iodid, then treat the two sides with basic dyes of the desired colors. The silver iodid is then dissolved out with potassium cyanid or with an alum bath containing tannin or tartar emetic, the action of these substances preventing the dye washing out. The film is then washed, leaving the images colored but transparent.

The exposed gelatin on one or both sides of the film can be stained a light yellow. This would tend to improve the color rendering, particularly in respect to green, for if the yellow staining is resorted to the image on the "green" side can be colored a lighter blue-green or a more blueish blue-green and still give good greens when the other side is colored orange-red. The highlights would then have a yellowish tinge, but scarcely to a noticeable extent especially when the film is projected in a darkened room.

Other methods may be used to produce the positive, as for example the method described in my Patent No. 1,228,877 issued June 5, 1917. In this method two films are placed face to face or back to back (and, if desired, fastened together along one edge) and are perforated simultaneously. They are then exposed in a camera of the type described in my Patent No. 1,208,739, hereinbefore mentioned, the films being passed in unison through the same film gate, to produce on one film a series of negative images by light of one color or group of colors and in the other a complementary series by light of another color or group of colors. After exposure the two films are developed and fixed in the ordinary way, and the positive film, coated on both sides with light-sensitive emulsions, is placed between the two and printed by light passing through the negatives from both sides. If the negative films were back to back in the camera they are preferably turned over for printing, so that the images will be in contact with the emulsions on the positive film. Registry in printing is secured by means of pins fitting in the perforations which were simultaneously made in the negative films. Consequently the images on the opposite sides of the positive film are registered with accuracy.

A type of negative film is illustrated in Figs. 10 and 11 comprising four separable parts, the negative films 118 and 120 with the sensitized surfaces 119 and 121 on the inside, a spacer 128 and separator 122. The film is perforated for the standard holes 130, 130 on both sides, but is cut with an additional margin in which the holes 131, 131 are punched, preferably simultaneously, through both films and the spacer 129. After exposure the films are separated, developed and fixed and stained (if desired) and are then reassembled with the spacer between them exactly as they were before exposure with the pins in place and the positive film placed between and printed by light from both sides.

What I claim is:—

1. A cinematographic positive for the projection of unitary images in substantially the natural colors of the object or objects represented, comprising a strip of film bearing two complementary series of differently colored monochrome images, one series on each side, the images on one side being paired with the corresponding images on the other, the images of each pair being congruent at one point but progressively

different in size from such point to the margins.

2. A cinematographic positive for the projection of pictures representing successive phases of an object in motion, consisting of a transparent film bearing on its opposite sides two series of colored positive images, one series on each side; the images of one series being complementary to those of the other, and differently colored; and the images of the two series being centrally congruent with each other but progressively different in size from the center to the margins.

In testimony whereof I affix my signature in the presence of two subscribing witnesses.

PERCY D. BREWSTER.

Witnesses:
M. LAWSON DYAR,
S. S. DUNHAM.