Nov. 9, 1937. S. D. THREADGOLD 2,098,602

COLOR PHOTOGRAPHY

Filed Oct. 19, 1935 2 Sheets-Sheet 1

Fig. 1.

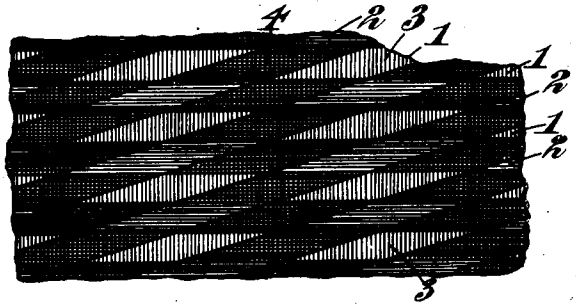
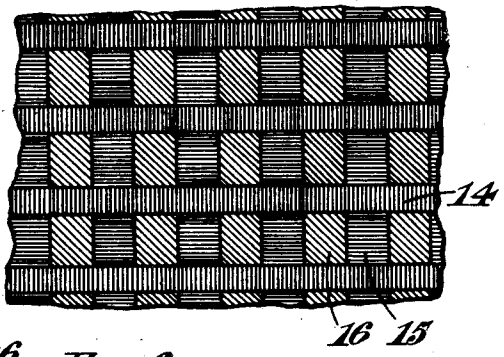


Fig. 2.



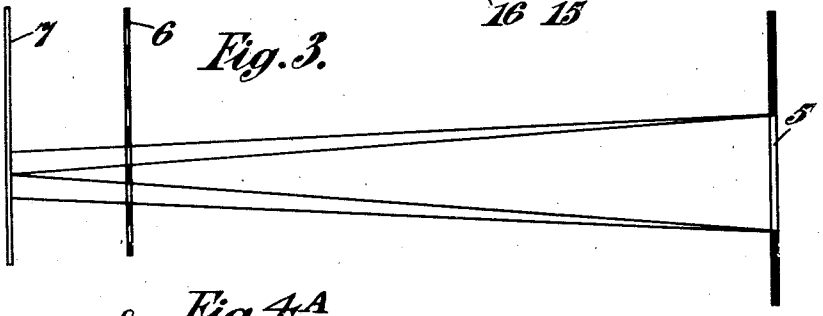


Fig. 3.

Fig. 4A.

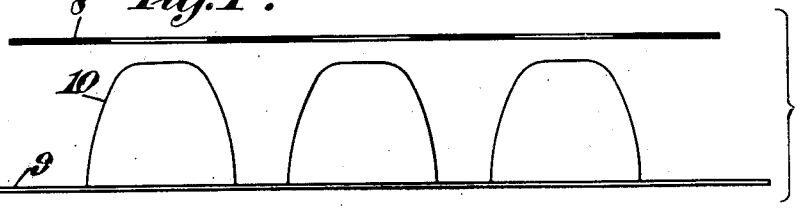
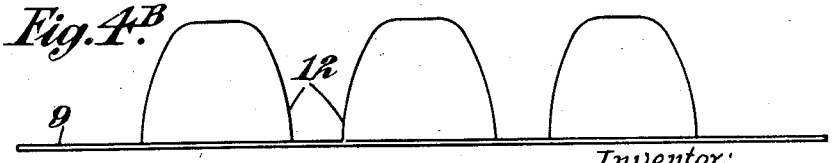


Fig. 4B.



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Fig. 5A.

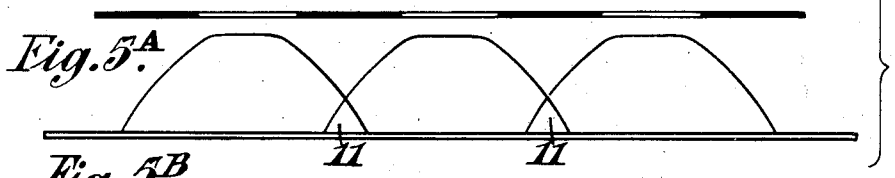


Fig. 5B.



Fig. 6A.

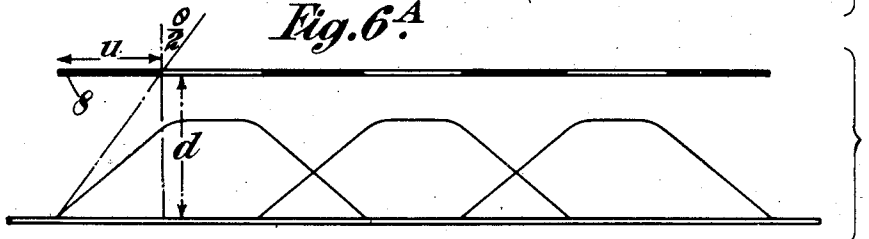


Fig. 6B.

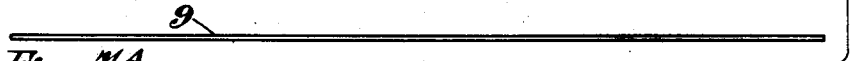


Fig. 7A.

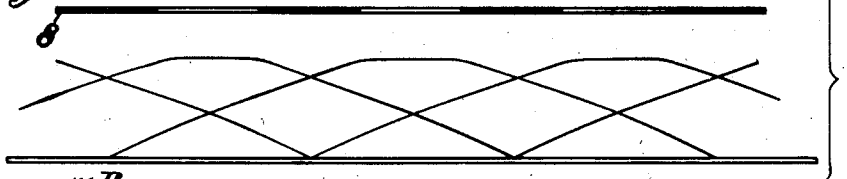


Fig. 7B.

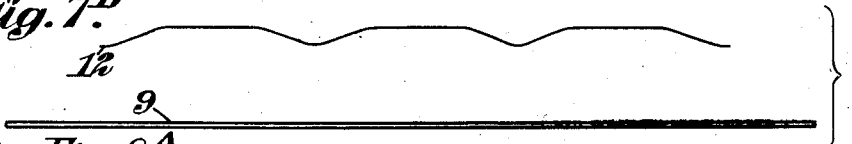


Fig. 8A.

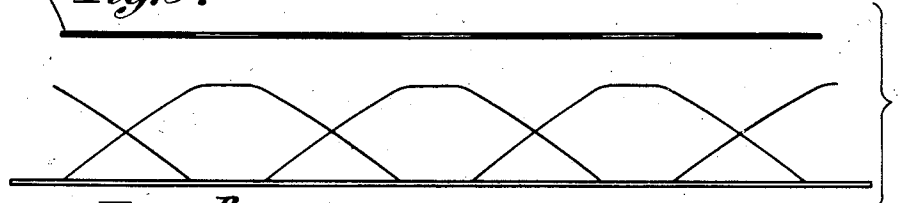
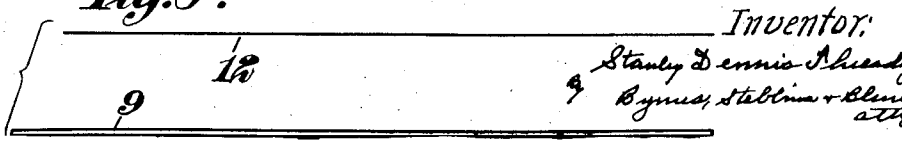


Fig. 8B.



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Patented Nov. 9, 1937 2,098,602

UNITED STATES PATENT OFFICE

2,098,602

COLOR PHOTOGRAPHY

Stanley Dennis Threadgold, Ilford, England, assignor, by mesne assignments, to Dufay-Chromex Limited, Aldwych, London, England

Application October 19, 1935, Serial No. 45,823
In Great Britain November 3, 1934

4 Claims. (Cl. 95—75)

This invention consists of improvements in or relating to color photography and relates particularly to the reproduction of multi-color photographic records (referred to as the master record) of the type associated with a regular pattern multi-color screen (referred to as the master screen) by contact printing on to a photographic light sensitive material (referred to as the copy) also associated with a multi-color screen (referred to as the copy screen) which may or may not be of regular form and may or may not be similar to that associated with the master record.

It is well known that difficulties arise with the reproduction of color photographs in this manner due to the production of moiré patterning on the copy which gives very undesirable effects on the copy picture. This moiré patterning would seem to be due to the fact that as it is impossible in practice to ensure exact registration between the elements of the same color in the master and copy screens, the elements are sometimes in phase in which case light is transmitted by the screens forming a light area, which will affect the emulsion, and are sometimes out of phase in which case no light is transmitted forming a dark area which will leave the sensitive copy emulsion unaffected. It is an object of the present invention to reduce or eliminate this effect, which is described in more detail below, without undue loss of definition.

It has been found that if the light passed by the colored elements of the master screen is distributed over the copy screen so as to give substantially even illumination of the copy screen, then the elements of the two screens cannot, in effect, become out of phase as described above and light and dark areas cannot be formed, except as dictated by the picture itself, the effect of which is neglected throughout this specification for simplicity in explanation.

If the two color screens are arranged in actual contact during printing it would appear impossible to secure this even illumination but in practice, and essentially in carrying out this invention, the screens are separated by a short distance, for example by the thicknesses of one or both their supports.

In printing multi-color photographic records of the type associated with a regular pattern multi-color screen on to copy material also associated with a multi-color screen there is employed, according to the invention, a station from which light is directed on to the master screen and at which the cross sectional area of the light beam is constrained to dimensions so co-related with the distance between the said station and the master screen, with the size of the screen elements and with the distance between the master and copy screens as to give substantially uniform illumination of the copy screen.

The cross sectional area of the light beam may be constrained by selecting a light source of suitable area or it may be constrained by inserting a mask of suitable area in the path of a beam of light.

The invention and the underlying theory will now be explained, by way of example, with reference to the accompanying diagrammatic drawings, in which:—

Figure 1 illustrates the effect produced when two screens composed of lines of two different colors are superposed slightly out of register,

Figure 2 represents a known form of three-color screen,

Figure 3 shows the arrangement of the several elements during the printing,

Figures 4*a*, 5*a*, 6*a* and 7*a* show the distribution of the light intensities on the copy screen produced by light from a light source of finite dimensions at different distances from the screen and passing through a master screen of equal transparent and opaque portions,

Figures 4*b*, 5*b*, 6*b* and 7*b* show the actual light intensities produced on the copy screen with the various arrangements shown in Figures 4*a* to 7*a* respectively, and

Figures 8*a* and 8*b* show the optimum conditions of distribution and actual intensity respectively for the case where the opaque portions of the master screen are double the width of the transparent portions.

Referring in the first place to Figure 1 which shows two superposed screens of lines of two different colors 1 and 2, say red and blue respectively, and is taken as the simplest case for purposes of explanation, it will be seen that if, as shown, the lines of the two screens are not exactly parallel, then at the places where a red line of the upper screen is over a red line of the screen underneath, as at 3, the combined screens will transmit red light. On the other hand, where a red line of the upper screen is over a blue line of the lower screen as at 4, the combined screens will be opaque to lights of all colors. If the lines of the two screens are very nearly parallel, the transparent and opaque areas 3 and 4 will be bands of considerable length, and it is these light and dark bands which give the moiré effect on the copy.

In Figure 3 the light source 5 is constituted by a mask behind which may be placed a diffusing screen, not shown, and the light passes through the master screen 6 on to the copy screen 7 and then on to the copy emulsion.

Turning now to Figures 4*a* to 7*a* and 4*b* to 7*b*, and still considering the case of the simple two-line screen of red and blue bands of equal width, the master screen may be represented by alternate opaque and clear portions so far as either red or blue light is concerned and is illustrated in this way at 8 (Figure 4*a*) where the clear portions are taken as the red bands transmitting red light and the opaque portions as the blue bands transmitting substantially no red light.

If now the screen 8 is illuminated with parallel light perpendicular to its plane and considering only the light transmitted by the red bands, this light will produce, on the copy screen 9, red bands of the same width as the master bands and the conditions described in relation to Figure 1 will be produced, giving moiré effects.

If, however, a light source of finite dimensions giving diffused light is employed at a suitable distance, the red bands formed on the copy screen will be of greater width than the master bands, and the effect will be as shown in Figure 4*a* where the curves 10 represent the intensity of the light on the copy screen, and it will be seen that this intensity is a maximum at the centre and diminishes in intensity towards the edges. The width of the bands formed on the copy screen and the intensity across the bands will vary with the angle subtended by the light source at the master screen elements, and Figures 4*a* and 7*a* represent the effect for different angles which increase from Figure 4*a* to Figure 7*a*.

In the cases illustrated in Figures 5*a* to 7*a* the bands formed on the copy screen by the light transmitted by adjacent master bands overlap as shown at 11 in Figure 5*a*, and the sum of the intensities of light across the copy screen is shown in Figures 4*b* to 7*b* where in each case 9 represents the copy screen and 12 a curve giving the intensity of light at any point across the copy screen.

In the arrangement shown in Figures 6*a* and 6*b* the resultant intensity, as shown by the curve 12, is constant over the copy screen, and this is the theoretically correct condition for avoiding moiré.

Figures 8*a* and 8*b* show the theoretically correct conditions when the transparent elements are half the width of the opaque elements.

Although this description has been directed to the light transmitted by the red bands, the same conditions will of course apply for the light transmitted by the blue elements of the master screen.

It is found in practice that the best conditions are produced when the angle subtended by the light source at the master screen is slightly less than the theoretically ideal arrangement shown in Figures 6*a*, 6*b* and 8*a* and 8*b*, since, for the sake of simplicity, certain factors have been neglected and also the loss of definition will be reduced without appreciably increasing the moiré. The best conditions are found by trial and error by making slight experimental variations from the conditions shown in these figures.

In practice it has been found that using films $\frac{1}{10}$ mm. thick arranged back to back, thus making the separation between the master and copy screens $\frac{1}{5}$ mm., and having a three-color screen as shown in Figure 2 and composed of a series of longitudinal red lines 14 of one unit width separated by a space of two units width divided transversely into equal blue and green rectangles 15 and 16 and each 1½ units deep, (a complete pattern unit forming a square $\frac{1}{20}$ x $\frac{1}{20}$ mm.), a mask having a rectangular aperture 28 mm. x 18 mm. located at a distance of about 10 cms. from the film and with its long side perpendicular to the lines of the screen, gives satisfactory results.

The correct orientation of the mask may be found by trial and error by rotating it in its own plane and, as explained above, the best position by moving it to and fro in a direction perpendicular to the plane of the film until the best effect is obtained.

The mask is illuminated uniformly over its area, for example by means of an ordinary diffusing screen uniformly illuminated by any type of light source—filtered with narrow cut filters or otherwise or, for example, produced by the method described in United States Patent No. 2,024,522, issued December 17, 1935.

If, as indicated in Figure 6*a*, the separation between the two screens is "*d*" and "*u*" is the distance on either side of the element under consideration over which the light is to be spread, then the half angle

$$\frac{\theta}{2}$$

subtended by the light source at the master screen for the ideal conditions is easily obtained for any given circumstances from the expression

$$\tan \frac{\theta}{2} = \frac{u}{d}$$

from which

$$\theta = 2 \tan^{-1} \frac{u}{d}$$

Thus for any given conditions the angle to be subtended at the screen by the light source may easily be calculated and therefore the dimensions of the light source for a given distance or the distance for given dimensions may easily be found. When the screen is unsymmetrical, as shown in Figure 2, the dimensions of the light source may be calculated to give the desired result in each direction. It will be appreciated that in the case of a screen such as that shown in Figure 2, having a series of elements of different size, there will be a slight unevenness in the illumination from the larger units if the illumination is made even for the smaller units. On a screen having a red line, one unit wide and a green and blue line 2 units wide, the size of the aperture necessary to spread the red line evenly over the blue area and the green area, to meet the spread of light from the next adjacent red line, as shown in Figures 6*a* and 6*b*, will be larger than that required to spread the light from the blue and green elements to form a uniform illumination over the red line and in the case of the green and blue units this will produce a slight unevenness of illumination in a direction perpendicular to the red lines, similar to that shown in Figures 7*a* and 7*b*. In actual practice, however, this unevenness is very slight and is unnoticeable in the final print.

I claim:—

1. Apparatus for the contact printing of multi-color photographic master originals of regular pattern multi-color screen type on to photographic copy material of multi-color screen type which comprises a source of diffused light spaced from the master, photographic copy material spaced from the master to receive light from the

light source passing through the master; the effective diffusion area of the light source, its distance from the master, and the spacing of the master and copy being such that an image of each screen element of one color on the master is enlarged on the photographic copy to overlap adjacent color elements and overlap adjacent images of the same color to the extent that the sum of the light intensities at the overlapping portions of the images substantially equals the intensity at the central portions of the images, thus producing substantially even illumination over the whole copy surface.

2. Apparatus for the contact printing of multi-color photographic master originals of regular pattern multi-color screen type on to photographic copy material of multi-color screen type which comprises a source of diffused light spaced from the master, a mask determining the effective diffusion area of the light source, and photographic copy material spaced from the master to receive light from the light source passing through the master; the effective diffusion area of the light source as determined by the mask, its distance from the master, and the spacing of the master and copy being such that an image of each screen element of one color on the master is enlarged on the photographic copy to overlap adjacent color elements and overlap adjacent images of the same color to the extent that the sum of the light intensities at the overlapping portions of the images substantially equals the intensity at the central portions of the images, thus producing substantially even illumination over the whole copy surface.

3. Apparatus for the contact printing of multi-color photographic master originals of regular pattern multi-color screen type on to photographic copy material of multi-color screen type which comprises a source of diffused light spaced from the master, and multi-color screen photographic copy material spaced from the master to receive light from the light source passing through the master; the area of the light source, the distance of the light source from the master, and spacing of the master and copy being such that an image of each screen element of one color on the master is enlarged on the photographic copy to overlap adjacent color elements and overlap adjacent images of the same color to the extent that the sum of the light intensities at the overlapping portions of the images substantially equals the intensity at the central portions of the images, thus producing substantially even illumination over the whole copy surface.

4. Apparatus for the contact printing of multi-color photographic master originals of regular pattern multi-color screen type on to photographic copy material of multi-color screen type which comprises a source of diffused light spaced from the master, and photographic copy material spaced from the master to receive light from the light source passing through the master; the dimensions of the effective diffusion area of the light source, its spacing from the master and the spacing of the master and copy being substantially in accordance with the formula

$$\theta = 2 \tan^{-1} \frac{u}{d}$$

where θ is the angle subtended by the light source at the point on the master screen perpendicularly opposite to the center of the light source, u is taken to be the distance to either side of the element under consideration over which the light passed by that element must spread in order that the marginal portions of adjacent images of each color may overlap to such extent that the sum of the light intensities at the overlapping portions substantially equals the intensity at the central portions of the images thus producing substantially even illumination over the whole copy surface and d is the separation between the master and copy screens.

STANLEY DENNIS THREADGOLD.