Feb. 13, 1945. W. T. HANSON, JR., ET AL 2,369,457

COLOR PRINTING

Filed June 10, 1942

Fig. 1

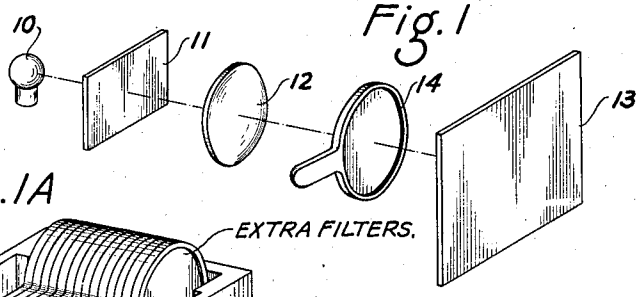
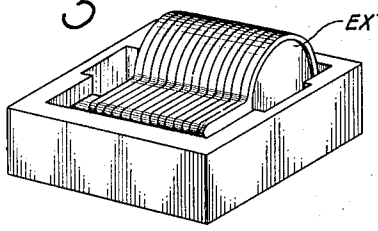


Fig. 1A



PRIOR ART

Fig. 2

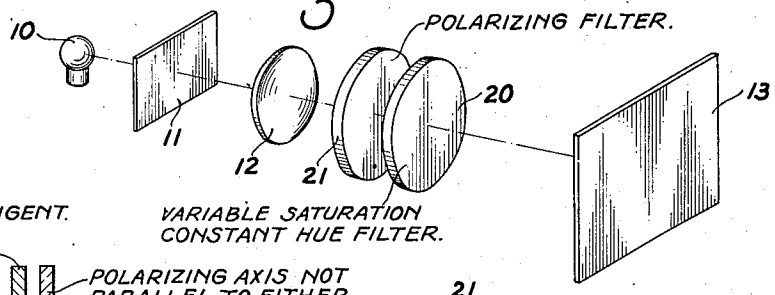


Fig. 3

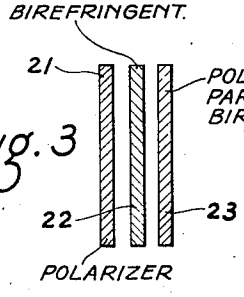


Fig. 4

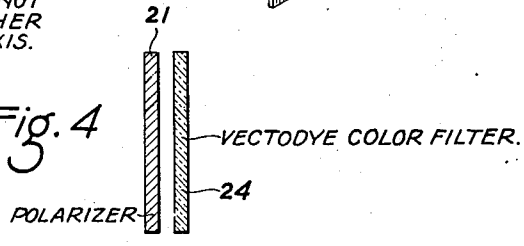
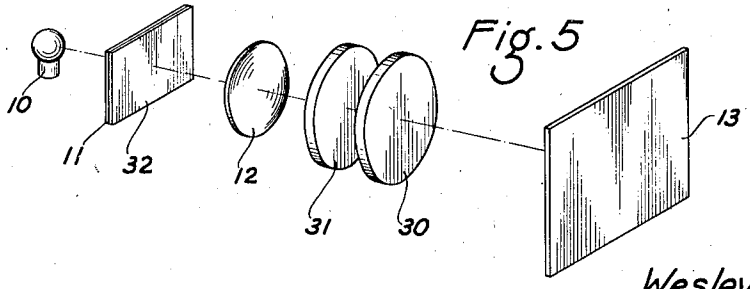


Fig. 5



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COLOR PRINTING

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Application June 10, 1942, Serial No. 446,444

2 Claims. (Cl. 95—2)

This invention relates to color printing and particularly to methods of correcting color balance when printing from a multi-colored original.

The correction of color balance is not to be confused with the type of correction obtained by masking and in fact one embodiment of the present invention relates to a combination of both types of color correction. Improper color balance may be either in the original or in the distribution of sensitivity in the sensitive material on which the reproduction is being made. Therefore, one properly speaks of the correct color balance of an original with respect to the color sensitive material being printed. In U. S. Patent 2,256,385, Evans and Luboshez describe one method of correcting color balance and the present invention may be considered as a direct improvement of that published method. It will be noted that Evans and Luboshez required a large number of color filters, but even then did not have continuous increments of color.

It is an object of the present invention to provide a method of controlling color balance when reproducing a multicolored original. It is the main object of the invention to provide such a control giving continuous increments of control.

It is also an object of the invention to eliminate the need for a large number of different filters to be used alternatively or in combination to get the various stages of control as employed in the prior art. At this point, it is noted that a wedged color filter is not satisfactory in any practical printing system because it interferes with uniformity of light distribution.

These main objects are accomplished by employing a constant hue variable saturation color filter and a preferred embodiment of the invention provides a method in which the hue can be varied from one hue, through neutral to the complementary hue.

It is a further object of a preferred embodiment of the invention to combine this method of color balance control with the control of masking taught in our copending application, Serial No. 446,445, filed concurrently herewith.

According to the present invention a multicolored original is reproduced by printing from the original onto a photosensitive surface by light which passes through a polarizing filter and through a definitely colored color filter whose color saturation varies with the orientation of polarization of light by which the filter is viewed and whose hue is constant at least over a range of said orientations. The light may pass through the two filters in either order and these filters may be anywhere between the light source and the photosensitive surface. That is, either or both may be in the beam illuminating the original, between the original and the lens if a projection system is used or between the lens and the photosensitive surface. In one particular embodiment described in detail below, the color filter must face the polarizing filter, and hence, it is turned around if the order of the two filters is reversed. Also, in the embodiment combining the present invention with that of our copending application, the order of the filters is of some importance, as will be noted. Since the color filter may come either before or after the polarizing filter in the optical system, the effective color saturation thereof is not apparent until after the light has passed through both filters. Therefore, in the above description of the invention, we refer merely to the fact that the filter has variable saturation in accordance with the light by which it is viewed rather than in accordance with the light incident thereon.

At least two entirely different types of such variable saturation color filters are well known to those skilled in the study of polarized light. It will be noted that either form is quite different from the combination of an ordinary color filter and two polarizing filters since this latter combination gives constant hue and constant saturation with variable density. One form of variable saturation filter consists of a vecto-dye filter in which the molecules or crystals of the dye are all oriented so that they absorb only light polarized at right angles thereto. Such a vectodye filter appears neutral to light polarized in the plane parallel to the transmitting plane of the dye molecules, and appears distinctly colored to light polarized at right angles thereto. Of course, intermediate planes of polarization of the viewing light give intermediate degrees of saturation, but the hue remains constant. With this arrangement there is a slight increase in density corresponding to the increase in saturation as the plane of polarization is rotated.

A second type of variable saturation filter consists of a birefringent layer in combination with a second polarizing layer whose vibration axis is oriented somewhere between the two vibration axes of the birefringent layer. Furthermore, the birefringent layer must be between the two polarizing filters. Obviously, the birefringent layer may be considered as combined with either polarizing layer, but for convenience it will be considered always with respect to one of the layers,

the combination constituting a variable saturation constant hue filter. The saturation of this latter type of filter varies, as the first filter is rotated, from a maximum saturation for one hue through neutral to a maximum saturation for the complementary hue. Of course, complementary hues may be considered as algebraically the same, one being negative with respect to the other, but it is not usual to do so. However, at least over a range of orientations of the polarization plane, such a filter has constant hue varying from zero to a maximum. With this type of filter the change from neutral through a maximum of one hue and back to neutral requires a rotation of the first polarizing filter through 90°, a second 90° carrying the color through a maximum saturation of the complementary hue. On the other hand, with the vectodye type of filter, a rotation of 180° is required to change from neutral to a maximum saturation and back to neutral.

When using the birefringent plus polarizer type of saturation filter it is preferable to have the axes of the birefringent material at 45° to the axis of the fixed or second polarizer. Of course, these axes must be at some angle to the fixed polarizer; otherwise the combination will always remain neutral and vary only in density as the first polarizer is rotated. With the vibration axes at 45° to the fixed polarizer axis, the change in density is a minimum as the first polarizer is rotated thus giving practically pure change of saturation with no change of hue or density. For color printing it is desirable to have a minimum change in density so as to have the least effect on exposure time required.

Thus, both preferred embodiments of the invention employ control filters which the saturation can be varied all the way from a maximum down to zero. In one embodiment it may be varied right through zero and to a maximum of the complementary hue which, of course, has its advantages in color printing processes in which the color balance may be off either way. The density of a vectodye filter is usually less than the combination of a birefringent layer and fixed polarizer so that this embodiment has certain advantages. On the other hand, the birefringent type can give complementary hues and that form of birefringent type having the vibration axes at 45° to the fixed polarizer axes the density as well as the hue remains practically constant as the first polarizer is rotated.

In practice the polarizer and the variable saturation filter are rotated relative to one another to give the saturation which corrects the color picture relative to the photosensitive surface on which a print is being made. Of course, additional color filters may be included in the optical system but the saturation of these filters is, of course, independent of orientation of any polarizing filter and for theoretical purposes such additional fixed color filters may be considered as contributing to the balance of the color sensitivity of the sensitive layer upon which the reproduction is being made.

In our above mentioned copending application, a vectograph mask is combined with a multicolored original so that the degree of masking may be varied by adjusting the orientation of the printing light. That invention may be readily combined with the present invention by first adjusting the polarizing filter relative to the vectograph mask to give the degree of masking required and then adjusting the variable saturation color filter relative to the polarizing filter to give the saturation required to correct the color balance of the combination of the original and its mask relative to the sensitivity of the photosensitive surface upon which a print is being made. In this combination of the two inventions, the polarizer should be between the mask and the variable saturation color filter. That is, if the polarizing filter is between the source and the masked original, the color filter should be between the source and the polarizing filter; if the polarizing filter is between the masked original and the sensitive layer, the color filter should be between the polarizing filter and the sensitive layer.

The invention and its advantages will be fully understood from the following description when read in connection with the accompanying drawing in which:

Figs. 1 and 1A illustrate one form of the prior art.

Fig. 2 illustrates a preferred embodiment of the invention.

Figs. 3 and 4 show two forms of variable saturation color filters.

Fig. 5 illustrates a combination of the present invention and that of our copending application, Serial No. 446,445, filed concurrently herewith.

In Fig. 1 light from a source 10 passes through a multicolored transparency 11 to print therefrom by projection by a lens 12 onto a photosensitive surface 13 which may be developed to a natural color reproduction of the transparency 11. The transparency 11 may be either a negative or a positive and similarly the photosensitive layer 13 may be processed either directly or by reversal. If the color balance of the transparency 11 or the balance of the sensitivity of the material 13 is incorrect, one with respect to the other, this may be corrected by inserting a color filter 14 having the correct hue and saturation. In practice it is desirable to make this correction very accurately, and hence, as illustrated by Fig. 1A, the filter 14 is usually selected from a large number of slightly different color filters. Even with as large a number of filters as is practical, the exact degree of correction required may fall between two of the filters or combinations of filters. This is overcome by the present invention which gives a continuous variation in saturation.

In the embodiment of the present invention shown in Fig. 2, the printing light passes through a polarizing filter 21 and a constant hue variable color saturation color filter 20, which filters are rotatable relative to one another. The filters are shown immediately adjacent to the lens 12, but either may be anywhere in the optical system between the source 10 and the photosensitive surface 13. If no color balance correction is required, the filters are rotated relative to one another to give a neutral hue. Adjustments from this setting may be made to any desired saturation, up to the maximum available, by rotating either filter.

One form of variable saturation filter is illustrated in Fig. 3 and consists of a second polarizing filter 23 and a birefringent layer 22 between this second polarizer 23 and first polarizer 21. In the arrangement shown, the color filter follows the polarizing filter 21, but if it were placed optically ahead the polarizer 21, it should be turned around so that the birefringent layer 22 follows the polarizer 23 and therefore comes be-

tween the two polarizers. Of course, if the polarizing axis of the polarizer 23 were parallel to either of the birefringent axes, the birefringent material would have no effect and rotation of the polarizer 21 would only vary the density. Therefore, the polarizing axis of the polarizer 23 must not be parallel to either birefringent axis. Of course, either polarizer may be considered as forming part of the color filter, but for convenience we refer to the second polarizer 23 as being part of the color filter and we describe it with respect to the condition in which its vibration axis is fixed relative to those of the birefringent layer. Although, this fixed polarizing axis may have any orientation not parallel to either birefringent axis, it is preferable to orient it at 45° to either, i. e. halfway between both birefringent axes. This preferred embodiment provides a minimum change in density as the first polarizer 21 is rotated to change the color saturation.

In Fig. 4, the variable saturation filter consists of a vectodye filter having the color absorbing molecules oriented to operate practically entirely only on light polarized in one azimuth and not on light polarized at right angles thereto. Therefore, rotation of the polarizer 21, or at least relative rotation of this polarizer 21 and the color filter 24 gives a variation from neutral up to a maximum saturation of the hue of the filter. Such a color filter does not in general have as high a density as the combination polarizer and birefringent material illustrated in Fig. 3 but the latter permits variation from one hue through neutral to a maximum of the complementary hue.

In Fig. 5 the original 11 is masked by a vectograph mask 32 in accordance with the invention of our copending application mentioned repeatedly above. In this figure a polarizer 31 is rotated relative to the vectograph 32 to give the degree of masking required. A variable saturation color filter 30 is adjusted relative to the polarizer 31 to give the color balance control required, and hence, the polarizer 31 acts to give both controls, i. e. the control of masking and the control of color balance.

Birefringent materials which appear colored when placed between two polarizers and operate as described above are well known, for example, the transparent wrapping material now marketed under the name "Cellophane."

In practice, each color process is generally susceptible to only one form of incorrect color balance; for example, it may have a tendency to go too blue. This may be corrected by a variable saturation yellow filter. Even a process which may go either too blue to too yellow may be corrected by a single filter of the type discussed above to give complementary hues. In a few cases, however, it may be desirable to have two or more variable saturation filters to be used alternatively (or in series, one being balanced to neutral if the correction can be obtained entirely by the other). Two such filters, one to balance green against magenta and the other to balance blue against yellow or red are sufficient used alternatively for practically all printing processes. Any system using two such filters in series must take into account their mutual effect or else the two systems must be independent each with its own polarizer and separated from each other by a depolarizer.

In this specification the terms "Hue, Saturation and Brightness" are employed in the accepted and approved manner for describing the three attributes of color. Zero staturation refers to neutral gray or white.

Having thus described the preferred embodiments of our invention and the preferred manner of combining it with our copending application, we wish to point out that the invention is not so limited but is of the scope of the appended claims.

What we claim and desire to secure of Letters Patent of the United States is:

1. The method of reproducing a multicolored original masked by a vectograph mask containing a color correction image of and for the original which comprises printing from the combination onto a photosensitive surface through a polarizing filter oriented relative to the mask to give color correcting contrast to the mask and through a definitely colored color filter whose color saturation varies with the orientation of polarization of the light by which it is viewed and whose hue is constant at least over a range of said orientations, said color filter being adjusted relative to the polarizing filter to correct the color balance of said combination relative to the photosensitive surface.

2. The method of reproducing a multi-colored transparency which comprises printing a vectograph mask from the transparency by light whose color is that required to give a color correcting mask, holding said mask in masking register with the transparency, orienting a polarizing filter in optical alignment with the combination of transparency and mask to adjust the contrast of the mask to that required for color correction, orienting also in said optical alignment and relative to the polarizing filter a definitely colored color filter whose color saturation varies with the orientation of polarization of the light by which it is viewed and whose hue is constant at least over a range of said orientations, the latter orienting being to the saturation required to correct the color balance of said combination relative to a given color sensitive layer and the polarizing filter being optically between the mask and the color filter, and printing onto said color sensitive layer from said combination through said adjusted filters.

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