PATENT SPECIFICATION

Convention Date (United States): Feb. 24, 1930.

360,274

Application Date (in United Kingdom): Jan. 16, 1931. No. 1541/31.

Complete Accepted: Nov. 5, 1931.

COMPLETE SPECIFICATION.

Improvements in Color Photography.

We, TECHNICOLOR MOTION PICTURE CORPORATION, a corporation of Maine, United States of America, of 110, Brookline Avenue, Boston, Massachusetts, United States of America, assignees of EASTMAN ATKINS WEAVER, a citizen of the United States of America, of Winchester, County of Middlesex, Commonwealth of Massachusetts, United States of America, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to the art of color photography and more particularly to color separation.

One of the most important problems in the art of color photography where separate records of different color aspects of an object are made, is the selection of the parts of the spectrum to be recorded on each of the separate color records. The time of exposure should be as short as possible especially in the case of color cinematography which demands the highest possible light intensity, and on the other hand, the color separation has to be as perfect as possible, taking also in account the fact that in certain systems of color photography, only part of the spectrum is used, as for instance in two color photography with the primary colors green and red-orange, where the blue color is largely omitted. It will be apparent to any one skilled in the art that a perfect reconciliation of these requirements is impossible However, we have found a solution of this problem which fills practical requirements to a satisfactory degree, by taking into account the tints of the principal objects to be photographed, in selecting the spectral ranges of the several color records.

The objects of our invention are the following ones:

To provide a system of color photography which reconciles optimum effective light intensity with satisfactory color separation.

To provide a method of separating the spectral colors which renders one of the prominent colors substantially neutral, whereas the other prominent colors are well separated and a favorable light intensity is obtained.

To provide a set of corresponding color filters which permits the practical application of our system of color separation.

The invention will be explained, in connection with the appended drawings, as applied to a two color photography system using red and green filters. It is however understood that it can be modified to any other color combination and that it can not only be applied to color separation with filters but also with emulsions sensitized for certain colors, or to combinations of both, as for instance in so-called monopacks, bipacks, etc.

In the accompanying drawings,

Fig. 1 is a diagram showing the intensity of the light of various wave lengths, as reflected from human skin;

Fig. 2 is a diagram corresponding to Fig. 1 for the light reflected from foliage;

Fig. 3 is a diagram showing the ratio of the reflection coefficients of human skin and of foliage and the range of filters according to our invention, in relation to this diagram; and

Fig. 4 is a diagram showing the spectral distribution of the light coming from a blue sky, in relation to the ranges of ordinary filters and of filters according to our invention.

In the following description the term "taking ranges" will be used for the spectral ranges into which the light coming from the objects to be photographed is separated in order to depict them again by superimposing their records printed in appropriate colors. The term "prominent colors" will be used for the colors most important in a given scene to be photographed, as for instance the blue and red in the American flag.

As mentioned above, maximum light transmission together with satisfactory color separation and a favorable rendering of those parts of the picture whose colors are not actually represented on the final record are some of the main problems encountered in the art of color photography, and especially in color cinematography, where very short periods of exposure are essential and where frequently only part of the solar spectrum is utilized. The most favorable color separation together with high light intensity could be obtained by transmitting no part of the spectrum through more than one of the taking filters, since the so-called "graying down" or "diluting" of a tint, i.e. the rendering of the clear color components of the tint together with a number of complementary components increases with the increasing overlapping of the transmission ranges of the taking filters into which that tint is separated, a fact well known in the art. A minimum amount of graying down can be achieved by utilizing only a narrow spectral band for each taking range, which however limits the effective light intensity. It is therefore desirable to widen the taking ranges, but in a manner which does not cause any undesirable graying down. In selecting the taking ranges it must furthermore be considered that existing dyes do not transmit absolutely sharp bands of the spectrum so that it is not feasible to transmit adjacent spectral regions through two filters without having an intermediate region which is at least partially transmitted by both. However this circumstance is not altogether unfavorable because a limited amount of graying down is desirable, as too intense colors must be avoided, especially if the picture is to be reproduced by projecting it onto a screen.

For the purpose of explanation it will be assumed that our invention, which takes account of the facts outlined above, is to be applied to a system of color photography which involves the taking of cinematographic pictures by means of color separation with a red-orange and a green filter. Our experience in color photography has shown that in a system of this kind the first of two vital considerations in connection with the problems as outlined above relates to color separation as limiting light transmission. We have found that the prominent colors of the ordinary cinematographic picture for physiological as well as psychological and esthetic reasons, are flesh tint and foliage tint. These tints have to be distinguished markedly from each other; that is, flesh colored objects have to be rendered sufficiently red-orange, the foliage colored objects have to be rendered sufficiently green, and each must be separately distinguished from the white. The second consideration relates to the fact that skies which can not be rendered correctly in a two color system not making use of the blue, should not appear too green; they will appear the more natural, the more nearly neutral they are rendered.

In order to find taking ranges in conformity with the facts and considerations discussed, we have made a spectro-photometric study of the composition of the prominent colors, i.e. of the light reflected from flesh tint and from foliage. We find in general that flesh tint is strong in wave lengths from 700 to 590 mu., weak from 590 to 530 mu., strong from 530 to 495 mu., and weak again from 495 mu. to ultra violet. Foliage is weak from 700 to 610 mu., strong from 610 to 520 mu., and weak from 520 mu. to ultra violet, although from about 490 to 460 mu. not as weak as flesh. The curves obtained in this manner are of the general configuration as shown in Figs. 1 and 2, but of course they are subject to rather wide variations according to the objects investigated in each particular case. Considering now the shape of these curves, it appears that the spectra of the two prominent colors are, generally speaking, of a complementary character, each being substantially weak where the other is strong.

In order to find out what would constitute the best possible pair of filters for reproducing a scene of this nature according to the principles explained above, we have plotted the ratio of the reflection coefficients of flesh tint and leaf tint throughout the spectrum. The resulting curve as shown in Fig. 3 is low from 700 to 600 mu., high from 600 to 520 mu., low from 520 to 480 mu., and then again higher. The parts of the spectrum where this curve is low should be transmitted by the red filter and absorbed by the green filter and vice versa for the parts where the curve is high. Thus, in the ideal case the red filter should transmit approximately from 700 to 600 mu., and from 520 to 480 mu., while the green filter should transmit from 600 to 520 mu. and from 480 to 450 mu., as schematically indicated in Fig. 3, AB and CD corresponding to the range of the green filter and BC and DE to that of the red filter.

Coming now to the second vital consideration, namely, the rendering of the blue color, it is well known in the art that sky light has a spectral distribution continuously increasing from the red to the blue, substantially as shown in Fig. 4, which gives the spectral qualities of blue sky light. Considering this fact it will be seen that a set of filters having alternative transmitting bands as above described and as schematically shown at N in Fig. 4 will give less difference of exposure on the two color records and therefore a less intense green on the final picture which is printed with green and red-orange dyes, than a pair of filters as heretofore used, which would result in a positive having a green aspect corresponding to the whole range FG of the green part of the spectrum in addition to weak part GH in the red-orange, as shown at O of Fig. 4. A positive made with our filters will only have a green aspect corresponding to A^1B^1 of Fig. 4 which, together with a red aspect corresponding to B^1C^1, and not very much weaker than the green aspect, and will print with the green and red-orange positive colors a nearly neutral sky satisfying the second consideration referred to above.

Having in mind these requirements for filters according to our invention, it is now necessary to have dyes with transmitting characteristics corresponding to these requirements. It is evident that the filter ranges as described above and shown on the drawing correspond to ideal conditions which it will not always be possible to obtain in actual practice, and that filters as actually used will often somewhat depart from this ideal, this being mostly due to the facts that available dyes do not have sharp absorption bands, that illumination conditions vary considerably, etc. However, even if somewhat departing from the ideal, filters made according to the basic principle of our invention are still more effective than ordinary filters. According to practical experience, light transmission, color separation and the rendering of the blue are still very favorable if for instance, in the embodiment described above, the green filter does not actually have two distinctly separate bands but merely transmits less light in a region approximately corresponding to the low wave length transmission band of the red filter or even if both filters extend into the blue range of the spectrum. Especially the beneficial effect of our filters upon the rendering of the blues will not be diminished even if each filter transmits a substantial part of the lower wave lengths of the visible spectrum, the main consideration being that light of these low wave lengths is to a considerable degree recorded on both color aspects, so that these blue parts are finally printed in a light neutral shade, as explained above. However, for the described application of our invention to color photography with separation of the red-orange and green colors we found the following filters suitable, as having transmitting characteristics corresponding with sufficient accuracy to the ranges described in connection with Fig. 3. For the red filter we bathe a suitable base as e.g. gelatine of a thickness of approximately .002 inches for about two minutes, at approximately 65° F. in the following dye:

Eastman yellow (glucose phenyl-osazone -*p*-p^1- dicarboxylic acid	0.24%
Rhodamine (acid rhodamine 3R, an acid triphenyl methane dye)	0.90
Sodium acetate ($CH_3.COONa$)	0.80
Water	98.06

Use one part of this to two parts of water. For the green filter, we use analogously:

Uranine (Schultz #585)	0.25%
Potassium carbonate (K_2CO_3)	2.00
Sodium acetate (CH_3COONa)	2.00
Water	95.75

Use two parts of this solution with three parts of a 2.50% solution of fast light green S (an acid triphenyl methane dye).

Although we prefer the above formulas, we have found that instead of the Eastman yellow, naphthol yellow, quinoline yellow or auramine may be used, that instead of rhodamine, rose bengal may be used, that instead of uranine (a sodium salt of fluorescein) other derivatives of fluorescin may be used, and that instead of fast light green, patent blue, guinea green or erio green may be taken, always presuming that any two of the above enumerated substances will be combined only if their nature will not cause any chemical reaction between them. We prefer to dry the dyed gelatine filters on glass in a moving air current, in from 30 to 40 minutes. We found that these filters show about 40% more exposure, give equal distinction between flesh and foliage tints and between both and neutral, and better, because paler skies, than the color filters heretofore used for these purposes.

It will be apparent to any one skilled in the art that the principle of our invention can be applied not only to the specific embodiment described above, but also to any other combination of prominent colors, with any desirable number of filters and with one or more principal spectral colors omitted, or utilizing the whole spectrum. It is also apparent that the application of the principle is not limited to color separation with filters, but that it can advantageously be used with any other means for color separation, or combination of such means as for instance in the case of the so-called bi-packs, well known in the art, where obviously a combination of emulsion-sensitization and filter absorption according to this principle would have to be used.

Having now particularly described and ascertained the nature of our said invention, and in what manner the same is to be performed, we declare that what we claim is:—

1. In the art of color photography the method of separating the colors of a scene for recordation as separate images, which

is characterized by the fact that the recorded color ranges of the color separation images correspond substantially to the color ranges reflected most strongly by the prominent objects of the scene.

2. The method according to claim 1 further characterized by the use of taking filters, the transmission bands of each taking filter corresponding substantially to the color of one prominent object of the scene.

3. The method according to claims 1 and 2 further characterized in that each taking filter transmits a band of light of a higher wave length and a band of light of a lower wave length, the bands substantially not overlapping.

4. The method according to claim 3 further characterized in that the transmission bands of each filter are substantially separated by absorption bands corresponding to transmission bands of the other filter.

5. The method according to claim 1, further characterized in that a color of the scene not represented in the reproduction colors is reproduced substantially a neutral grey, this color being recorded in the record color ranges in substantially equal amounts.

6. The method according to claim 5, further characterized in that the colors of the recorded ranges, each range including bands of low and high wave length, are reproduced only in colors substantially complementary to the high wave length bands, the colors of the scene corresponding to the low wave length bands being thereby reproduced in substantially neutral grey.

7. The method according to claim 5 further characterized by the fact that substantially neutral blue skies are obtained in the positive reproduction without using a blue taking filter, by assigning to each taking filter the transmission of a certain part of the low wave length portion of the spectrum and in printing the color separation images in colors complementary to the taking ranges without said low wave length portions.

8. As an article of manufacture, a set of coordinated taking filters for color photography, at least one of said filters having at least two regions of high spectral transmission separated by absorption bands, the regions of high transmission of the one filter corresponding approximately to absorption regions of the other filter.

9. As an article of manufacture a set of two taking filters according to claim 8 further characterized in that the first filter has a main transmission region in the high wave length part of the spectrum and a secondary transmission region in the low wave length part thereof and that a second filter has a main transmission region in the medium wave length part of the spectrum and a secondary transmission region in the low wave length part thereof.

10. An article of manufacture according to claim 9 further characterized in that one of said filters has a transmission band approximately from 700 to 600 mu., and a second band approximately from 520 to 480 mu., and that the other filter has a transmission band from approximately 600 to 520 mu. and a second band approximately from 480 to 450 mu.

11. An article of manufacture according to claim 9 further characterized in that one of said filters is stained with a dye containing Eastman yellow and acid rhodamine, and that the other of said filters is stained with a dye containing uranine and fast light green S.

Dated the 16th day of January, 1931.

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Redhill: Printed for His Majesty's Stationery Office, by Love & Malcomson, Ltd.—1931

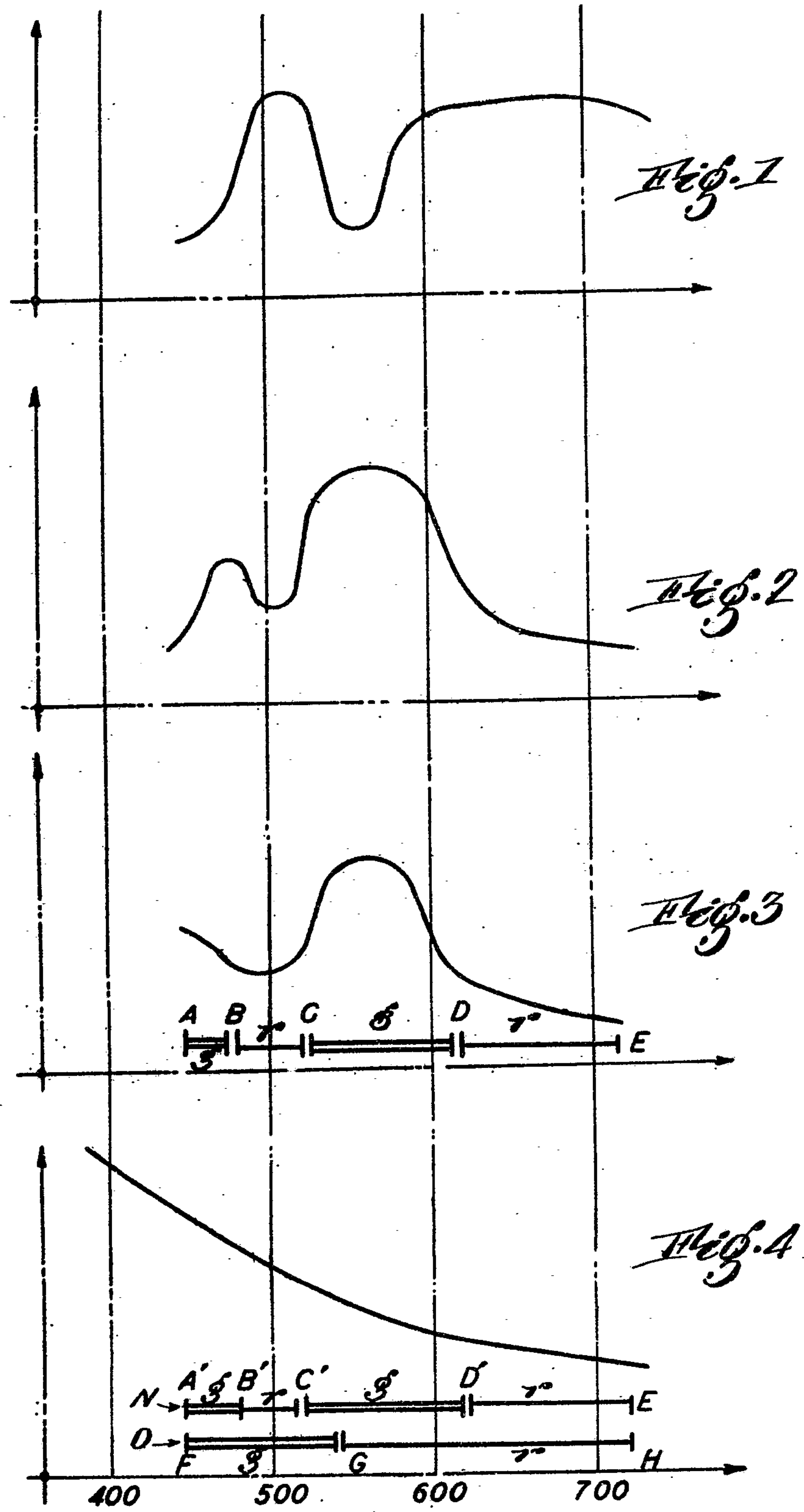
Fig. 1
Fig. 2
Fig. 3
A B C D E
Fig. 4
N A' B' C' D' E
O F G H
400
500
600
700