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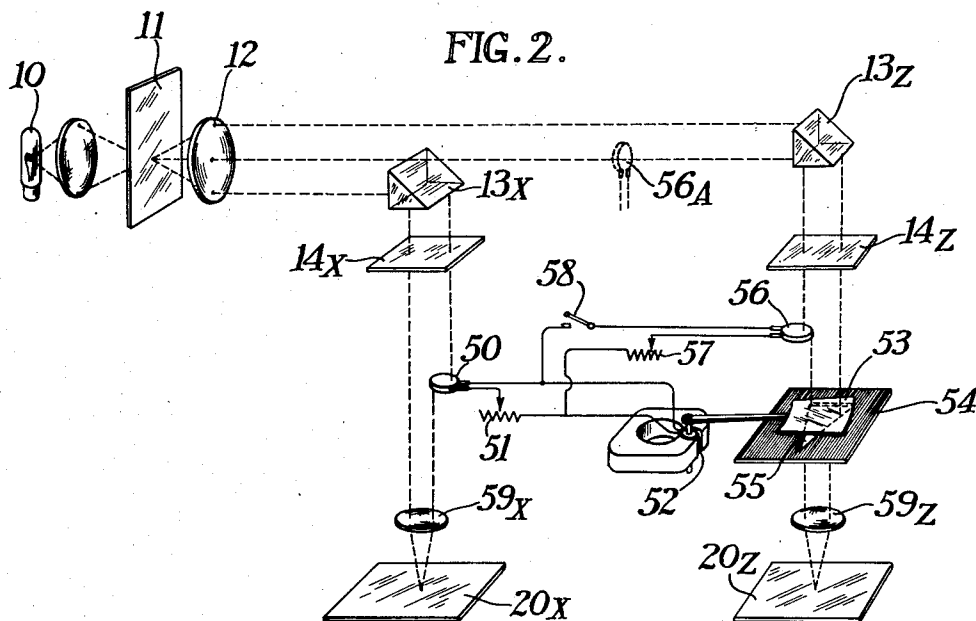
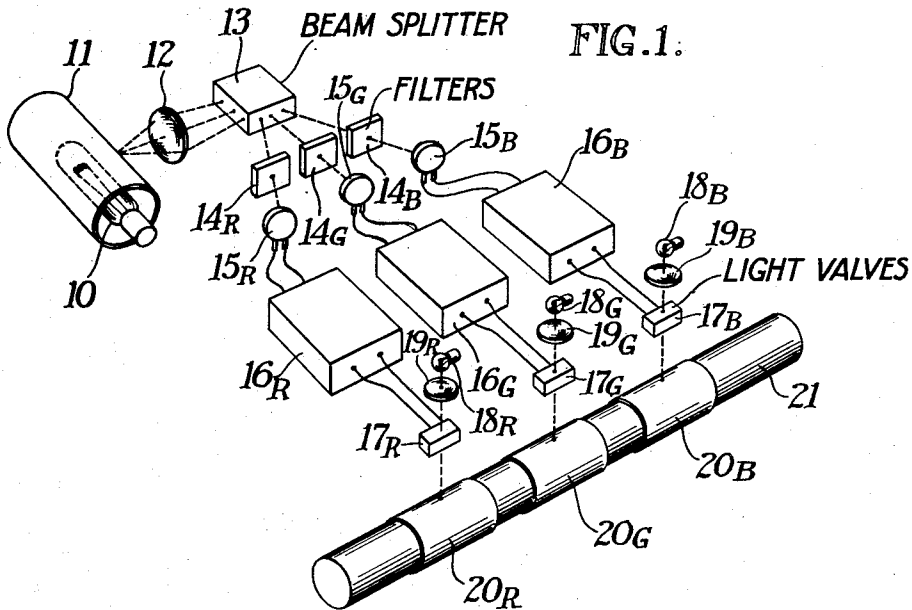
A. MURRAY ET AL

2,253,086

COLOR PHOTOGRAPHY

Filed Jan. 16, 1937

3 Sheets-Sheet 1



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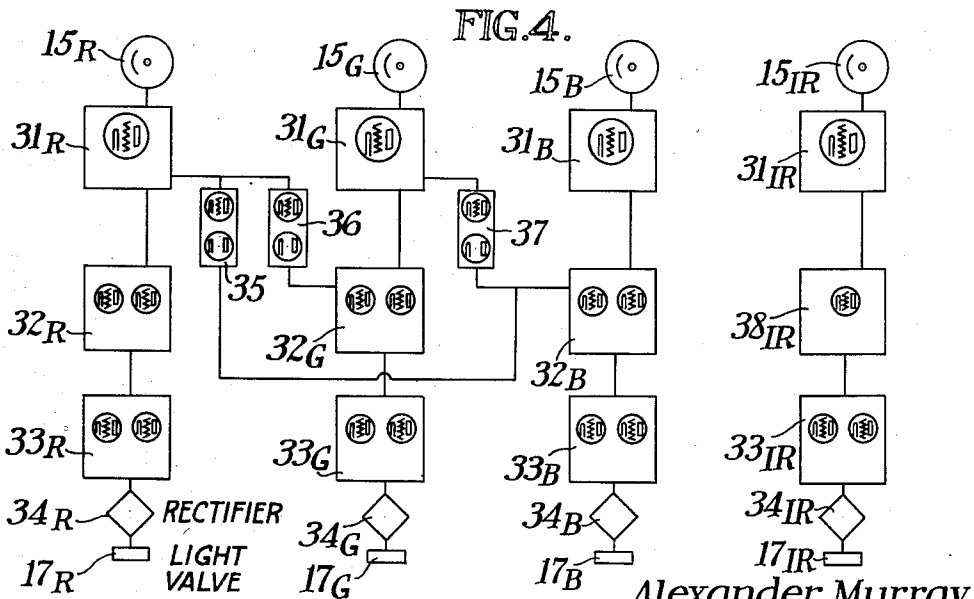
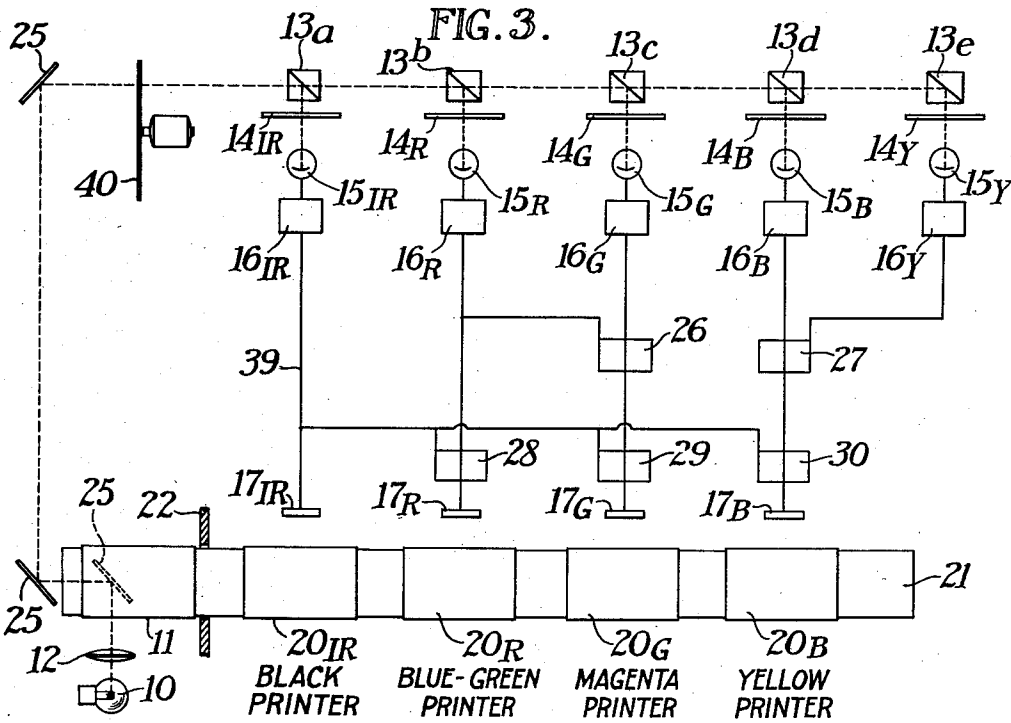
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3 Sheets-Sheet 2



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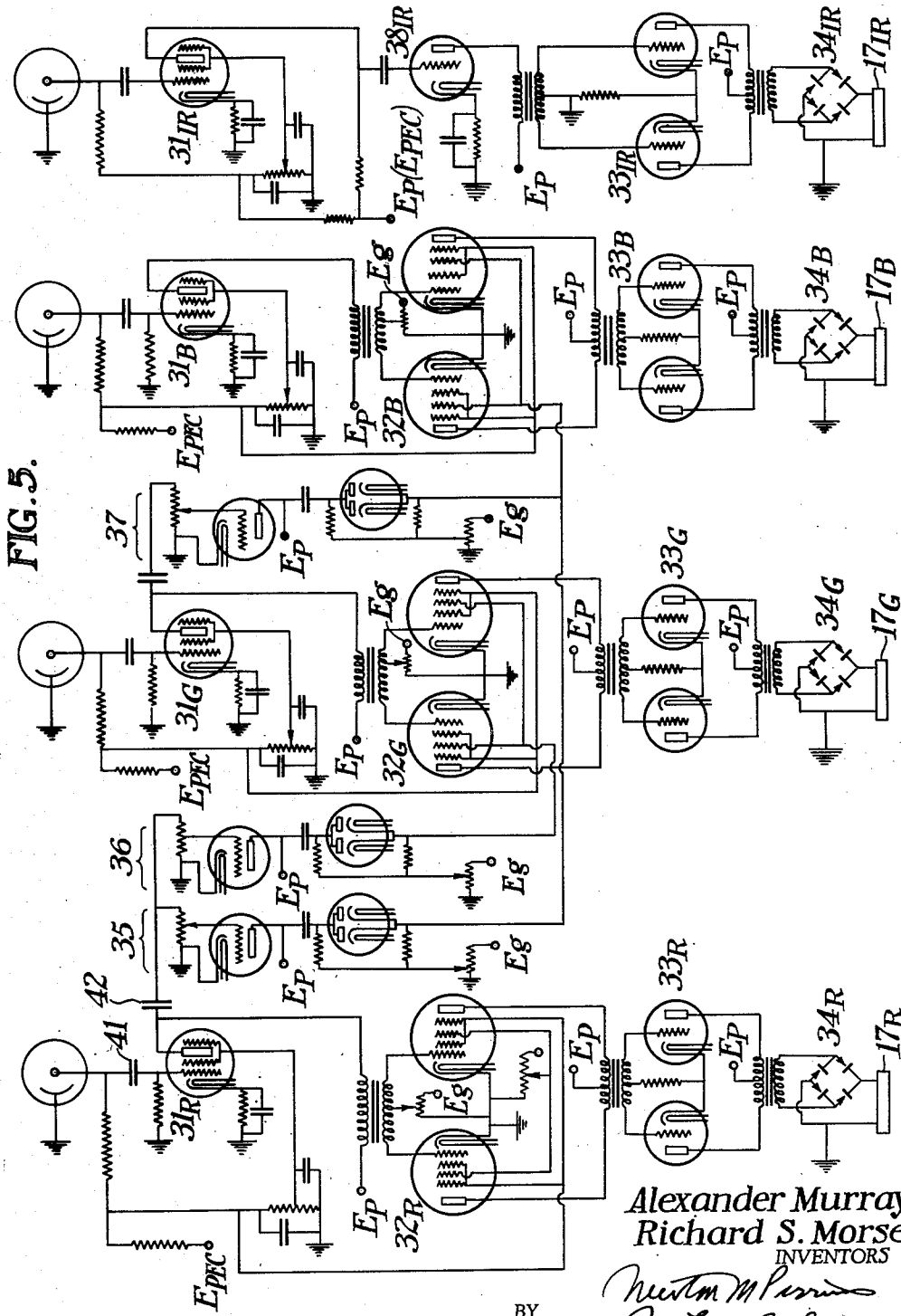
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COLOR PHOTOGRAPHY

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3 Sheets-Sheet 3



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2,253,086

COLOR PHOTOGRAPHY

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Application January 16, 1937, Serial No. 120,964

12 Claims. (Cl. 178—5.4)

This invention relates to color photography. It relates particularly to that branch of color photography wherein color separation negatives (or positives) are employed. It is customary in the art to use the term, color separation negatives, to describe black and white negatives made through color filters so that their variations in density are proportional to the density of the colors respectively associated with them.

It is an object of the present invention to provide a method of obtaining color separation negatives from a colored print or color transparency. It is a particular object of the invention to provide a method of doing this which will eliminate the necessity of photographing the original through the various color filters individually and separately.

In the operation of the invention the original color print or color transparency is scanned in a well known manner so that the reproduction of each elemental area of the original is accomplished separately. In one embodiment of the invention the scanning beam is split into a plurality of beams and each beam is passed through a color filter to a photo-electric cell which controls an electrical circuit including a light valve. Each of these light valves is used to control the intensity of a scanning beam operating in synchronism with the original scanning beam and exposing a photo-sensitive material which when developed will constitute the desired color separation negative. Another embodiment of the invention provides that the original scanning beam falls directly on the photosensitive material and thus, itself, comprises the final scanning beams.

In making plates for color press-printing, it is customary to employ three color separation negatives made through red, green, and blue filters. It is also usually desirable to use a so-called black printer which may be made in a number of ways but preferably by photographing through an infra-red filter. Definitions of "black printer" and the other terminology (such as magenta, blue-green, etc.) used in this connection will be given later in the specification.

In color press-printing it is theoretically desirable to employ inks whose color may be exactly described as "minus red, minus green and minus blue." Since straight-forward reproductions printed in available inks are always imperfect, it is necessary to employ certain methods of "color correction" many of which are well known to those skilled in the art. The "masking" method of color correction provides that the

density of magenta, for instance, printed at any point will be reduced in proportion to the density of the blue-green printed at that point and that the density of yellow printed at any point will be reduced proportional to the density of the magenta and to the density of the blue-green printed at that point. It may also be desirable to reduce the density of all three colors in proportion to the black density printed at any point.

It is a particular object of this invention to provide an electrical arrangement which will accomplish the same color correction as the masking method, or useful modifications thereof.

By this invention it is possible for the first time to carry out a color separation process and color correction simultaneously. This effects a notable reduction in the manual and photographic operations and in the elapsed time required in making color-corrected color separations.

The terminology used throughout this specification will now be defined. A red filter is one which transmits red light and, therefore, appears red. The spectral region included as red cannot and need not be exactly defined but is well known to those skilled in color photography. The terms blue filter, green filter, and infra-red filter may be similarly defined. A yellow filter is one which transmits both red and green light and absorbs the blue region of the spectrum. The terms, minus-red, minus-green, and minus-blue, may be used interchangeably with the terms, blue-green, magenta, and yellow, except when applied to the color of inks. For example, the magenta ink may not be a pure and complete minus-green, and, hence, a certain amount of color correction may be necessary when such inks are used.

Many of those engaged in color press-printing employ the terms, blue printer, red printer, yellow printer, and black printer, to mean the negatives to which the present specification refers to as blue-green printer, magenta printer, yellow printer, and black printer respectively. This latter convention is adapted here so that no confusion will arise either between the colors applying to the negatives and the colors of the light filters used or between the terms used in this specification and those employed in various branches of color photography and ordinary color press-printing.

The term "photographic" is here used in a broad sense so that "photographic layer" includes not only the silver halide type but also many similar materials such as those used as photosensitive resists.

In the recording of sound-on-film as in sound motion picture work, numerous types of electrically controlled light valves have been proposed. Since many of these and many variations of them could be adapted to the present invention, the term, light valve, will be used in this specification to include any suitable arrangement whereby the intensity or area of a light beam may be varied. A variable intensity glow lamp is equivalent to a source of light and a light valve and is included by the term "light valve."

In the following description and in the accompanying drawings, the terms used in connection with the electrical circuits are those commonly used when discussing such features. For example the symbols *Ep*, *Eg*, *Ep. e. c.* are used to mean plate potential, grid potential, and photo-electric cell potential respectively. The types of tubes (electron discharge devices) which we have found suitable are described in detail. However, it is to be understood that the present invention does not depend on the type of tubes used and that many equivalent arrangements would be satisfactory.

As is customary among those skilled in the art, the term "intelligence" is used herewith to describe the variations (in this case, the variations in color density) which are being communicated from the original to the photographic layer and being recorded thereon. The "intelligence" is spoken of as being "in" or "carried by the light beam," as being "in" or "transmitted through" the electric circuit, as comprising "luminous energy" or "electrical energy" and as being "modified" when its intensity or other characteristics are varied.

The present invention and its objects will be more fully understood from the following description when read in connection with the accompanying drawings in which:

Fig. 1 is a perspective view of a simplified arrangement which serves to illustrate the general idea involved in the invention.

Fig. 2 is a perspective view of another arrangement which in some respects is more simplified than that shown in Figure 1, but which includes means for "color-correction." The figure illustrates the broad principle of the invention and also one embodiment of it.

Figure 3 shows schematically and partially diagrammatically one form of the invention wherein three color separation printers and a black printer are made and wherein color correction is provided in all three colors for the black, in the magenta printer for the light transmitted by the red filter and in the yellow printer for the light transmitted by a yellow filter.

Fig. 4 shows schematically the electrical part of another form of the invention.

Fig. 5 is a wiring diagram showing the important details of the form of the invention which is shown schematically in Fig. 4. It will be noticed that Fig. 4 is most easily understandable by reference to Fig. 5 and that Fig. 5 may most easily be explained by reference to Fig. 4.

For convenience the following description will be confined to the employment of the invention in the making of separation negatives from a positive color transparency. It is obvious, however, that a color positive may be scanned by reflected light if necessary. Also the making of separation positives from a color negative is obviously similar. Furthermore, the making of separation positives from an original positive or the making of separation negatives from an orig-

inal color negative would require only simple and obvious alterations in the electrical circuits and/or in the construction of the light valves.

In Fig. 1 the light from a lamp 10 passes through a color transparency 11 which is rotatably mounted on a cylinder (not shown). The light then passes through an optical system shown as a simple lens 12 and through any convenient form of beam splitter 13 which produces three separate beams. Each of these beams passes through a color filter 14 (the red filter is shown as 14R, the green as 14G, and the blue as 14B) and falls on a photo-electric cell 15. Each of the three photo-electric cells 15R, 15G or 15B is associated with an electrical circuit shown as a box 16R, 16G or 16B which operates and controls a light valve 17R, 17G or 17B. The light valves 17R, etc. control the intensity of the light from three lamps 18R, etc. and their accompanying optical systems 19R, etc.

Each of the light beams whose intensity is controlled by one of the valves 17 falls on a photo-sensitive material 20 such as a photographic film mounted on a cylinder 21. The negatives 20 are labeled 20R, 20G, and 20B respectively, relating to the color of the filters through which the original scanning beam passed before falling on the photo cells 15. The rotational and transverse motions of the cylinder 21 are synchronized with the cylinder (not shown) upon which the color transparency 11 is mounted. Thus, the scanning by the light beams controlled by the light valve 17 is synchronized with the scanning of the original transparency 11.

After exposure, the films 20 are removed from the cylinder 21 and processed in the usual way to give the desired color separation negatives. No color correction corresponding to that provided by the masking method is obtainable in the simple arrangement shown in Fig. 1.

Similar reference numerals relate to similar details in each of the figures.

In Figure 2, the light source 10 and its accompanying optical system 12 provide the light beam which scans the color transparency 11 shown mounted flat in this figure. The beam splitter comprises two prisms 13x, 13z each of which accepts a portion of the beam and reflects it through a color filter (14x and 14z respectively). These two portions of the original beam are focused by optical systems 59x and 59z respectively to scan the photosensitive surfaces 20 (20x and 20z respectively). In a two color process, the two portions of the beam as modified by the color filters 14x and 14z would include complementary spectral components. The original scanning beam is shown split into only two beams in this figure. However, the principle may easily and directly be extended to include arrangements for making three or more separations.

To provide color correction, i. e. to reduce the amount of light which falls on the photo sensitive material 20z by an amount proportional to the amount of light in the other portion of the beam i. e. falling on 20x, a photo-electric cell 50 receives a portion of the light passing through the filter 14x. A variable resistance 51 adjusts the output of the photo-electric cell 50 which controls the deflection of a galvanometer 52 whose index pointer carries a light shield 53 which cooperates with a mask 54 having an aperture 55 to cut off a portion of the light beam passing through the filter 14z. Obviously the response function of the galvanometer 52 and the relative shapes of the light shield 53 and the

aperture 55 determine the amount of color correction and the rate of change of this amount with the intensity of the light falling on the photo-electric cell 50 (i. e. color correction function).

In cases where this color correction function is not linear, it is sometimes desirable to provide a different ratio of correction depending on the intensity of the color being corrected. For this purpose a second photo-electric cell 56 is positioned to receive part of the light beam passing through the filter 14z. An adjustable resistance 57 determines the degree to which the output of this photo-electric cell affects the galvanometer circuit and a switch 58 is provided by which its effect may be eliminated from the circuit. If it is desirable to control the amount of color correction in proportion to the total intensity of the original light beam, a similar arrangement may be used wherein a photo-electric cell is placed at the position marked 56A in the figure.

The variable diaphragm comprising the light shield 53 and the aperture 55 together with its control galvanometer 52 may be replaced by any other suitable type of light valve.

In connection with the following figures, three- and four-color processes are discussed wherein color correction is accomplished when the intelligence (i. e. the variations in color) is in the form of electrical energy being transmitted through a circuit. However similar results can be obtained by using an arrangement similar to that shown in Fig. 2 wherein the color correction is applied to the intelligence in the form of luminous energy.

In the embodiment of the invention shown in Fig. 3, the light source 10 and its accompanying optical system 12 are positioned outside of the cylinder upon which the color transparency 11 is mounted. In the arrangement shown in this figure the same cylinder 21 supports the color transparency 11 and the photo sensitive materials 20. Thus, synchronism of the original and final scanning beams is conveniently insured. The original scanning beam passes through the color transparency 11 and is reflected by a series of mirrors 25 to the beam splitter 13. One convenient form of beam splitter is shown which consists of four semi-transparent mirrors 13A, 13B, 13C, 13D, and a mirror 13E. Many types of beam splitters would be equally suitable and since the invention does not require the formation of real images, the beam splitter may be of a very simplified form such as that shown in Figure 2.

In order to gain the advantages of alternating current amplification in the subsequent electric circuits, an interrupter 40 is placed in scanning beam preferably somewhere between the source 10 and the beam splitter 13. We have found that interruption of the beam at a frequency of about 4000 per second is satisfactory. This carrier frequency may be provided in any suitable well-known manner and may have any suitable value.

The five beams provided by the beam splitter 13 pass through color filters 14 (labeled IR, R, G, B, and Y to refer to infra-red, red, green, blue, and yellow). The light of these beams is then accepted by the photo-electric cells 15 which control their accompanying electrical circuits 16. In the figures the solid lines 39 are used to indicate connections between the various parts of the electrical circuits. However these lines 39 are merely schematic and do not necessarily indicate electrical conductors.

The output of the infra red circuit 16 IR operates the light valve 17 IR. Also, by means of electrical modifying devices (circuits) 28, 29, and 30, it modifies the output of the red, green and blue circuits (16R, 16G and 16B respectively).

The output of the red circuit 16R as modified by the device 28 operates the "red" light valve 17R. By means of a device 26 it also modifies the output of the green circuit 16G. Thus, the output of the green circuit 16G is modified both by the output of the red circuit 16R through modifier 26 and the output of the infra red circuit 16 IR through the modifier 29.

The output of the blue circuit 16B, which controls the "blue" light valve 17B is modified by the output of the infra-red circuit 16 IR through the modifier 30 and is also modified by means of a modifying circuit 27 by the output of a circuit 16Y which is controlled by the light passing through the yellow filter 14Y. This latter modification is equivalent to modifying the output of the blue circuit 16B by both the output of the red circuit 16R and the green circuit 16G. The latter arrangement will be discussed in connection with Figures 4 and 5. The use of a yellow filter 14Y is shown merely as a convenient alternative to the more direct method shown in Figures 4 and 5 employing modification of the output of the blue circuit by both the output of the red circuit and of the green circuit.

The beams which are controlled by the light valves 17 and which expose the films 20 are not shown in this figure.

For convenience and clarity, Figures 4 and 5 will be considered and described simultaneously.

These two figures show one form of electrical circuit with which the invention may be practiced. The light coming from the beam splitter and passing through the red, green, blue and infra-red filters is received by the photo-electric cells 15—R, 15—G, 15—B and 15—IR respectively. The alternating component of the output of the photo-electric cell 15—IR is directed through a condenser 41 to the control grid of an amplifying tube 31R shown as a tetrode. The output of this circuit including the tetrode 31R may be further amplified by electron discharge devices shown in the drawings as two variable mu pentodes in push-pull 32R. Another stage of amplification is provided by two triodes in push-pull 33R whose output is fed into a rectifier 34R which operates the light valve 17R.

The output of the red circuit 31R in addition to supplying the amplifier 32R, is coupled by a condenser 42 to two identical circuits 35 and 36 whose outputs are used to modify the green and blue circuit outputs respectively. Each of these latter circuits comprise a stage of amplification and a rectifier.

In the "green" circuit, the output of the photo-electric cell 15—G operates the amplifier 31G which in turn operates the push-pull amplifier 32G through one of the control grids in each of two electron discharge devices shown as variable mu pentodes included in this stage of the amplification. The other pair of control grids (one in each tube) are connected and attain a potential determined by the output of the modifier circuit 36. The remaining stages of amplification and rectification of the green circuit may be, as shown, identical with those of the red circuit described above.

The output of the first stage of amplification (31G) of the green circuit also operates a modi-

fier circuit 37 which is similar to the modifiers 35 and 36 and which cooperates with the modifier 35 to color correct the output of the blue circuit.

The blue circuit having three stages of amplification, 31B, 32B, and 33B, is similar to the green circuit. In this case, the second pair of control grids in the push-pull amplifier 32B receives a potential which is modified in accordance with the combined output of the modifiers 35 and 37.

This particular method of modification is described in more detail in a copending application, Serial Number 120,965 filed concurrently herewith by Richard S. Morse, one of the present inventors.

In the embodiment of the invention shown in these two Figures 4 and 5, there is no color correction of or for the black printer. Thus, the infra-red circuit comprises a photo-electric cell 15-IR, three stages of amplification 31IR, 32IR, and 33IR, a rectifier 34IR, and a light valve 17IR. In order to show one of the many possible variations of this invention, the second stage of amplification 32IR is different from the second stage of amplification of the red circuit (32R). However, either of these arrangements may be used in either the red or infra-red circuits. The use of the double control of the amplification at this stage is necessary only in the green and blue circuits since in each of these cases the modulation for color correction is introduced to the second control grid of each tube. However, since under some circumstances it may be necessary to correct all three colors for black as shown in Figure 3, it would be convenient to have the amplifier 32R comprising two pentodes in push-pull as shown rather than a triode as used in the infra-red circuit.

Having thus described several embodiments of our invention, we wish to point out that it is not confined to the specific structures shown but is of the scope of the appended claims. What we claim and wish to protect by Letters Patent of the United States is:

1. In a process for producing photographic color separation records from a colored original, the method which comprises scanning elemental areas of the original, simultaneously directing different spectral components of the scanning beam as modified by the original onto corresponding areas of different photographic layers, altering the intensity of at least one of said components in accordance with the intensity of at least one other of said components, and developing the exposed photographic layers.

2. In a process for producing color separation records from a colored original the method which comprises scanning the original, forming from the scanning beam as modified by the original a plurality of spectral components each carrying its corresponding intelligence, transforming at least part of the energy of at least one of said components into electrical energy, modifying the intelligence in at least one other of the components in accordance with said electrical energy, controlling light valves in accordance with each intelligence, exposing photographic layers by scanning beams whose intensity is controlled in accordance with said light valves and developing the exposed photographic layers.

3. In a process for producing a color separation record from a colored original, the method which comprises scanning the original, forming from the scanning beam as modified by the original a plurality of spectral components each car-

rying its corresponding intelligence transforming at least part of the intelligence energy of at least one of said components into electrical energy, modifying the intelligence of at least one other of the components in accordance with said electrical energy, exposing a photographic layer by a scanning beam whose intensity at said layer is controlled in accordance with said intelligence as modified and developing the exposed photographic layer.

4. In a process for producing color separation records from a colored original, the method including scanning the original, dividing the scanning beam into different spectral components, controlling a plurality of light valves each according to the intelligence in one of said components, modifying the intelligence in one of the components reaching one of said light valves in accordance with the intelligence in at least one other of the components and scanning a photographic layer with light whose intensity at said layer is controlled by said light valve.

5. In a process of the character described for producing color corrected color-separation records from a colored original, the steps which comprise communicating at least part of the intelligence of at least one of the spectral components to an electrical circuit and modifying the intelligence intensity in at least one other of the spectral components in accordance with the output of said electrical circuit.

6. A device of the character described including means for scanning a colored original, a beamsplitter, color filters cooperating with said beamsplitter to distribute a plurality of spectral components of the scanning beam, electrical means for modifying the intelligence intensity in at least one of said components in accordance with the intelligence intensity in at least one other of said components and means for exposing a photographic layer to a scanning beam whose intensity is proportional to the intelligence intensity as modified.

7. A device of the character described including means for scanning a colored original, a beamsplitter, light filters cooperating with said beamsplitter to distribute a plurality of spectral components of the scanning beam, means for communicating the intelligence in each of said components to an electrical circuit, means for modifying the intelligence intensity in at least one of said components in accordance with the intelligence intensity in at least one other of said components and means for exposing a photographic layer to a scanning beam whose intensity is proportional to the intelligence intensity as modified.

8. In an electro optical system for the reproduction of natural color pictures, and having channels carrying intelligences corresponding to different color components of the original, color correcting means comprising means for modifying the output of at least one of said channels in accordance with the intensity of the intelligence in at least one other of said channels.

9. In a process for reproducing a colored original, the method of color correction which comprises scanning the original, forming from the scanning beam as modified by the original a plurality of spectral component channels each carrying its corresponding intelligence, transforming at least part of the energy in at least one of said channels into electrical energy and modifying the intelligence in at least one other of said

channels in accordance with said electrical energy.

10. The method of making a color-separation image for use in color reproduction, which comprises directing different spectral components of light emitted by a colored subject to separate photoelectric receptors, subtracting from the response of the first receptor to the variation in intensity of a spectral component of said light from point-to-point of the subject, a constant fraction of the response of the second receptor to the variation in intensity of a different spectral component of said light from the same point to the same point of the subject and making a record of the subtraction to provide an image of the subject whose point-to-point variation corresponds to the difference between the corresponding point-to-point variations in a function of the intensity of one spectral component of the light emitted by the colored subject and the variation in the same function of the intensity of another of the spectral components.

11. In a process of the character described for producing color corrected color-separation records from a colored original, the steps which com-

prise communicating at least part of the intelligence of at least one of the spectral components from a point of the original to an electric circuit whose response is a non-reciprocal function of the intensity of said intelligence and subtracting from the same non-reciprocal function of the intelligence intensity in at least one other of these spectral components, the response of said electric circuit.

12. In a process of a character described for producing color corrected color-separation records of a colored original, the steps which comprise communicating at least part of the intelligence of at least one of the spectral components from a point of the original to an electric circuit whose response is proportional to the intensity of the intelligence and modifying by the response of said electric circuit the intelligence intensity in at least one other of the spectral components, the modification being substantially the subtraction of quantities logarithmically proportional to said intensities.

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