April 13, 1943. A. C. HARDY ET AL 2,316,581

METHOD AND APPARATUS FOR MAKING SEPARATION IMAGES FOR FOUR-COLOR REPRODUCTION

Filed Aug. 5, 1941 4 Sheets-Sheet 1

Fig. 1.

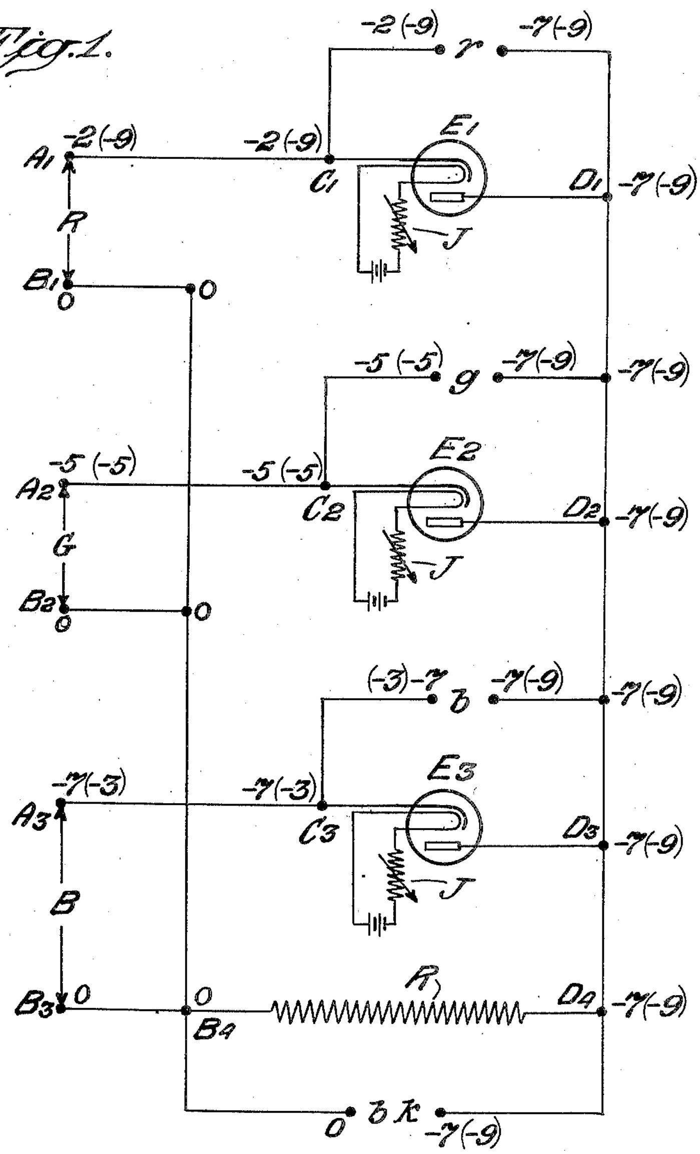

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Fig. 2.

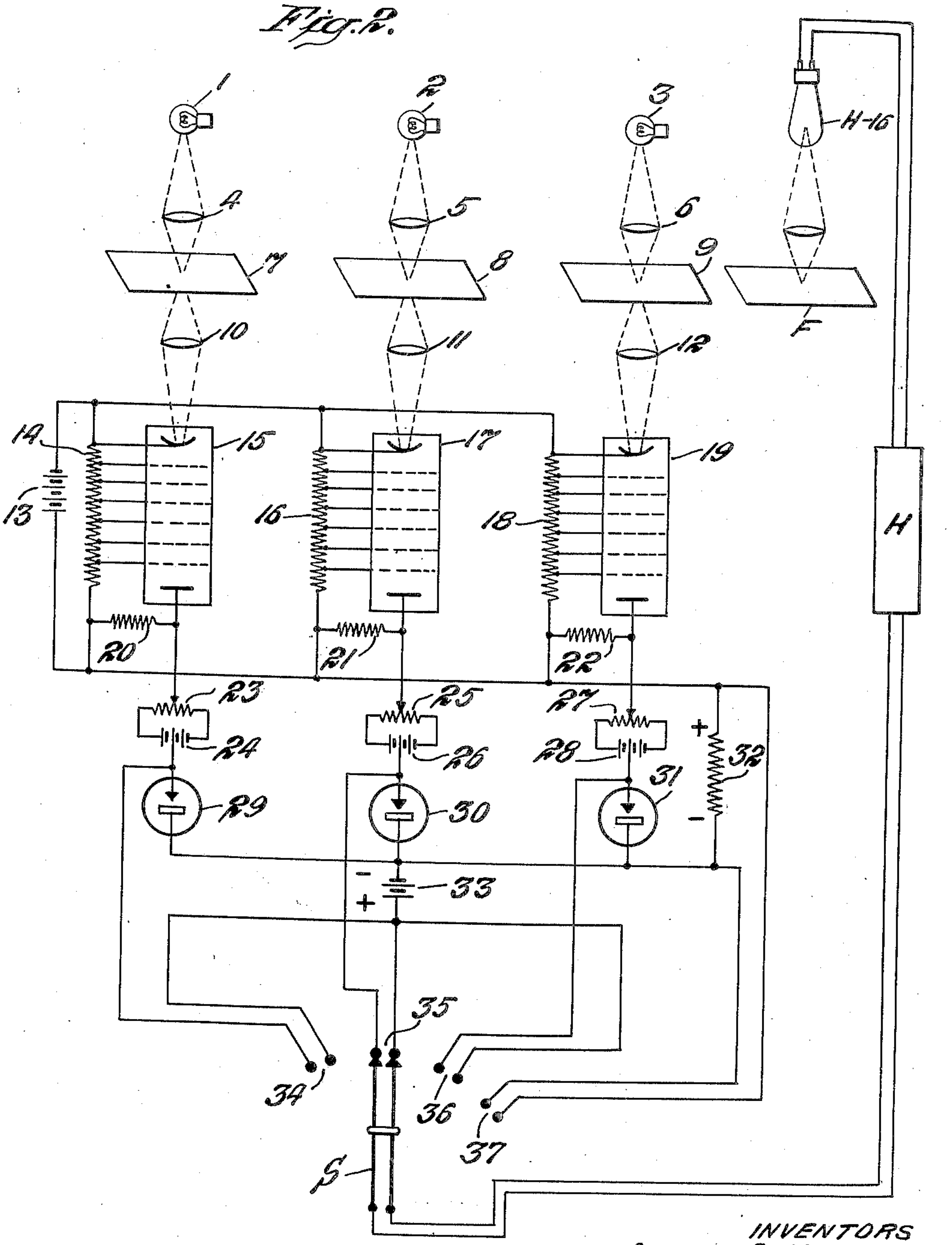

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Fig. 3.

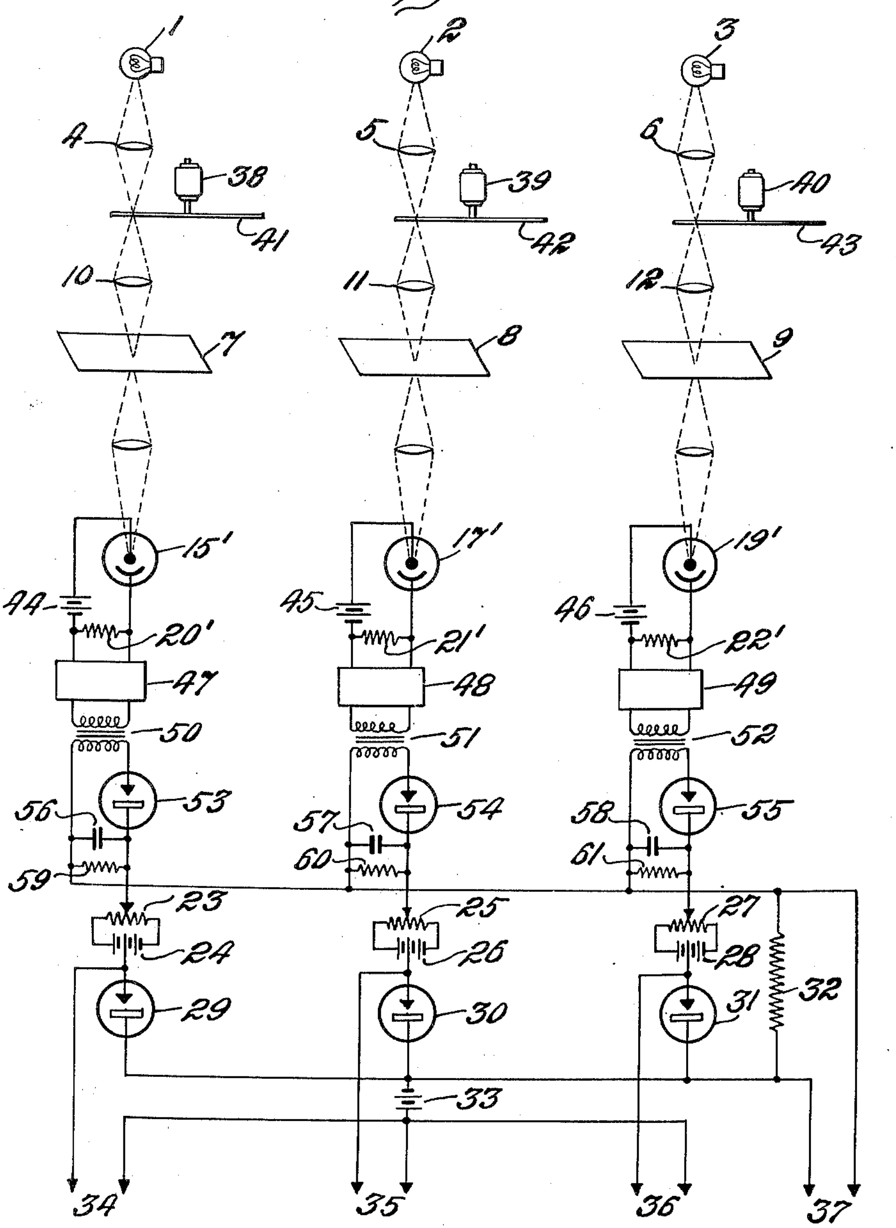

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Fig. 4.

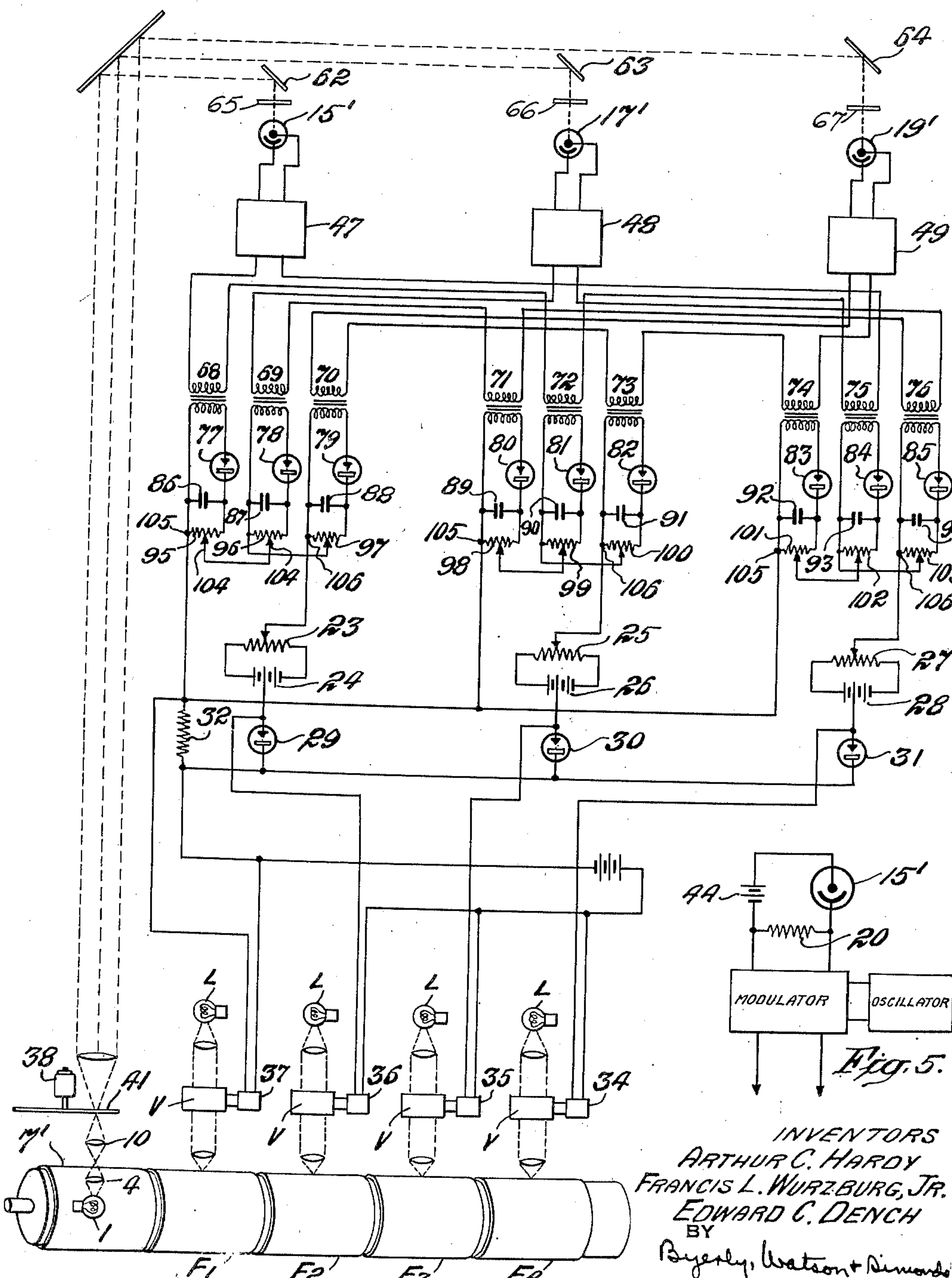

Fig. 5.

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METHOD AND APPARATUS FOR MAKING SEPARATION IMAGES FOR FOUR-COLOR REPRODUCTION

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14 Claims. (Cl. 178—5.2)

This invention relates to method and apparatus for making separation images for four-color reproduction.

The so-called four-color method of reproduction involves the use of four separation images, three of which are chromatic, while the fourth is achromatic or non-selective. In the use of the method in the graphic arts the printers made from the chromatic separation images are inked with colored inks, while the printer made from the achromatic image is inked with black ink.

The theory of the four-color method differs from that of the three-color method in that in a perfect four-color method all blacks and grays, including both the grays of areas which appear gray in the reproduction and the grays which reduce the purity of color in other areas, are obtained from the achromatic separation image, while in the three-color method all blacks and grays are obtained by combinations of three color-separation images. The four-color method presents a number of practical advantages, particularly in the graphic arts where it leads to sharper outlines and results in the saving of colored inks, which are much more expensive than black ink.

The theoretical requirements for correct three-color reproduction are known, and satisfactory methods have been developed for obtaining theoretically correct reproductions by this method. The theoretical requirements of four-color reproduction are also known, but no practical method has been developed for making four separation images which comply with the theory. As a result, the use of the four-color method in the graphic arts has been empirical and has involved a large amount of expense in hand retouching of the plates.

Our invention provides a practical method and a simple apparatus for obtaining theoretically correct separation images for the four-color method, and when applied in the graphic arts, introduces large savings in hand retouching and in colored ink.

In order to explain the theoretical requirements of four-color reproduction we shall first define the terms which we will use, as the terminology of this art has been indefinite.

(*a*) "Spectral or color component of a colored original" is the light or light flux which the original would reflect or transmit in some particular spectral region, if it were illuminated by white light. Thus, for example, the red component of a colored original is the light obtained by passing through a red filter light which has been reflected from the colored original or transmitted through the colored original, if transparent, when the colored original is illuminated by white light; or it is the light transmitted through a positive color-separation image of the colored original, which has been made in the usual manner by photographing through a red filter. The light flux of a color component is usually measured on a decimal or percentage scale, the maximum light flux from any part of the original being termed 1. or 100%.

The "tone value" of any area of an original or a reproduction is measured on a decimal or percentage scale, in which the darkest tone is designated as 1. or as 100%, and the lightest tone is designated as 0. In printed halftone reproductions, tone value is the same thing as "dot density," that is, the proportion of any small area which is covered by ink.

"Color tone value" is the tone value of some one color in an original or in a positive reproduction of the original. Since the amount of light from a colored original is least in the darkest areas of the original and greatest in the lightest areas of the original, the color tone value of any area is related to the color component of the original of that area by the expression,

tone value=1.—light flux of color component

where both are measured as percentages. Since the light flux of a color component produces a color separation negative when photographed directly, it is apparent that the light required to produce a color separation negative is related to the tone value of the original, or of a positive reproduction of the original, by the relationship,

light flux to produce negative=1.—tone value

"Effective color tone value" is the same thing as color tone value, except that it is measured on a scale in which 100% represents the darkness of the color in question in the blackest tone which can be produced by a combination of the three colors used in a three color reproduction. In a theoretically perfect three-color system, in which black is produced by combining the greatest tone values of each of the three colors, effective color tone value is equal to color tone value. With the colors actually used, the blackest areas are often produced by combining the three inks in different proportions. Thus, for example, if a black area is obtained in a printed half tone reproduction by a yellow printer having a dot density of 100%, a magenta printer having a dot density of 90% and a blue-green printer having a dot density of 80%, the color tone values of the three colors in this area are 100, 90, and 80; but the effective color tone value of each color is 100%, since black is produced.

With the terminology above defined, the theoretical requirements of a correct four-color reproduction are as follows:

(1) The minimum effective color tone value for each point of the reproduction must be determined. The minimum effective color tone value ($ECTV_{min}$) is the effective tone value of the one of three color separation positives for the three-color process which has the lowest effective tone value at the point in question.

(2) It is then necessary to make an achromatic separation image whose tone value at each point is equal to the minimum effective color tone value at that point.

(3) It is necessary to make three chromatic separation images whose tone values at each point are equal to the effective tone values of corresponding color separation images for the three-color process ($ECTV_R$, $ECTV_G$, $ECTV_B$) reduced by the amount of the minimum effective color tone value at the point in question. Thus, the required tone value for the red separation image for the four-color process is

$$ECTV_R - ECTV_{min}$$

Somewhat cumbersome methods have been devised for making black printers complying with the requirements of the theory, but such methods have proved of little practical value since the use of a theoretically correct black printer with color printers whose densities have not been reduced in accordance with the theory results neither in correct reproduction nor in a saving of colored ink.

Our invention avoids this difficulty and produces the four printers required for a correct and economical four-color process.

In accordance with our invention, three color components of a colored original, which could be used directly or after correction to make color-separation images for the three-color process, are so combined as to produce four separation images for the four-color process, which may be used for engraving four correct printers for the four-color process. The three components are directed on separate receptors.[1] The greatest of the three responses is selected and used to provide an achromatic separation image and the differences between the selected response and the individual response of each receptor are used to provide three chromatic separation images. While our invention is not limited to the use of color components in any particular form, we find it most desirable to communicate the intelligences of the three components to electrical circuits and to make the necessary mathematical combinations electrically.

An important feature of our invention consists of a simple electric circuit in which all the mathematical operations necessary for producing correct separation images for the four-color process are automatically and instantly performed. The circuit has three sets of input terminals on which are impressed voltages containing the intelligences of the three color components. The input terminals are connected through separate rectifiers to a common resistor. The voltage drop occurring across this resistor contains the intelligence required for the black printer or achromatic separation image, while the voltage differences occurring across the three rectifiers contain the intelligences required for the three chromatic separation images of a four-color process.

In order that our invention may clearly be understood, we will describe the apparatus embodying it which is shown in the accompanying drawings, in which:

Fig. 1 shows our new selector circuit in its simplest form;

Fig. 2 shows a direct current device for producing the separation images for a four-color process from three color-separation positives;

Fig. 3 shows an alternating current device for the same purpose;

Fig. 4 shows a device for producing color-corrected separation images for the four-color process directly from a colored original; and

Fig. 5 shows an alternative method for producing an alternating current containing the intelligence of a color component, which may be substituted for the flicker discs shown in Figs. 3 and 4.

When the intelligence of a color component is communicated to an electric circuit by a scanning operation in which a color component of a colored original is directed on a photo-electric cell, the response of the photo-electric cell is greatest where the color tone value is least, that is, at the points where the least ink of the color in question should be printed. It follows that, when the intelligences of three color components are communicated to electric circuits, the maximum electric signal, Sig_{max} (that is, the signal of the one of the three circuits which is greater than the other two at any moment) corresponds to the minimum color tone value, CTV_{min}. By reference to the requirements of a correct four-color reproduction method stated in col. 1 of this page, it will be seen that, in all cases where the color tone value of each of the three colors used is equal to the effective color tone value, the maximum electric signal at any moment corresponds to the tone value which should be used in the achromatic separation negative for the black printer; and the differences between the maximum signal and the signal actually present in the color component circuits correspond to the tone values which should be used in the three chromatic separation images for the four-color process.

The selector circuit shown in Fig. 1 provides a simple means for indicating at each moment of a scanning operation the tone value required for the achromatic image and for each one of the chromatic images for four-color reproduction. We shall first describe the operation of this circuit and then show its application in various specific apparatus for making separation images for the four-color process.

The circuit shown in Fig. 1 has three sets of input terminals A_1B_1, A_2B_2, A_3B_3 on which are impressed three variable voltages R, G, B containing the intelligences of the three color components of a colored original. The three sets of input terminals are connected through separate rectifiers E_1, E_2, E_3 to a common resistor R. The three rectifiers are all turned in the same direction. In the form shown in Fig. 1, each rectifier has its anode connected to the resistor R, but this is not essential, as the circuit may be operated with the cathodes of the three rectifiers connected to the common resistor.

[1] A "receptor" is a material or device which undergoes some change when subjected to radiant energy in the form of light and thus may serve to record or indicate the amount of light which it receives.

In the operation of this circuit, the greatest of the three voltages impressed upon the three pairs of input terminals at any moment appears across the resistor R and at the output terminals *bk* which may be connected to a recorder for the achromatic separation image. The voltage which appears across the rectifier E_1 and at the output terminals *r* is the difference between this maximum voltage and the voltage R impressed at the terminals A_1B_1. The voltage across the rectifier E_2 and at the output terminals *g* is the difference between the maximum voltage and the voltage G impressed on the terminals A_2B_2, and the voltage across the rectifier E_3 and the terminals *b* is the difference between the maximum voltage and the voltage B impressed at the terminals A_3B_3. One of these three voltages is always zero, since one of them necessarily is the difference between two equal quantities. The output terminals *r, g, b* may be connected to recorders for the three chromatic images required for use with the achromatic image recorded from the terminals *bk*.

The reason for this operation may most simply be explained by the use of numerical examples. As a first example, it may be assumed that the terminals B_1, B_2, B_3 and B_4 are grounded and that the impressed voltages at the terminals A_1, A_2, A_3 are −2, −5 and −7 respectively. (Negative voltages are used in order to correspond with the direction of flow of electrons through the rectifiers.) The maximum impressed voltage, −7 impressed at A_3 will appear at C_3 and will cause a flow of electrons through the rectifier E_3 until a voltage of −7 appears at D_3 and D_4, so that the voltage drop in the resistor R is 7 and a voltage of 7 appears across the output terminals *bk*. Since there is a flow of current through the rectifier E_3 no appreciable difference in voltage appears across the output terminals *b*.

The input voltage of −5 at A_2 appears at C_2, but, as the voltage at D_2 is −7 (because D_2 is directly connected to D_4), there is no flow through the rectifier E_2 and a voltage difference of 2 is developed between the output terminals *g*. In the same way a voltage difference of 5 (7−2) occurs across the output terminals *r*. The voltages in the above example are indicated in Fig. 1.

As a second example, it may be assumed that the voltage impressed at A_1 is −9, at A_2 −5 and at A_3 −3. The voltage figures for this example are indicated in parentheses in Fig. 1, and it will be seen that, as before, the maximum voltage, which is now 9, appears across the terminals *bk*, while the voltage differences 9−9=0, 9−5=4 and 9−3=6 appear across the output terminals *r, g* and *b*.

It is apparent from this explanation that the simple selector circuit which has been described combines the intelligences of three color components in such a way as to indicate the intelligences of the four separation images theoretically required for a perfect four-color process.

In constructing the circuit shown in Fig. 1 certain precautions must be taken in order to secure accurate operation of the circuit. If vacuum tube rectifiers are used at E_1, E_2, E_3, and it is most desirable that such rectifiers should be used, the rectifiers should be operated at cathode temperatures substantially below those ordinarily used in vacuum tube rectifiers in order to avoid, so far as possible, any electron emission from the filaments of the rectifiers when no voltage is impressed across the rectifiers. The specific rectifiers E_1, E_2, E_3 shown in Fig. 1 facilitate such operation as they are two-element vacuum tubes with indirectly heated cathodes containing rheostats J in their cathode-heating circuits. Furthermore the impedance of the resistor R should be made very large in comparison with the impedances of the rectifiers in order that substantially all the voltage drop in a circuit containing a rectifier and the resistor may appear across the resistor.

The simple form of selector circuit shown in Fig. 1 presents certain inconveniences which may be easily eliminated:

(1) It provides no means for regulating the voltages R, G, B, and consequently if its input terminals are connected directly to photo-electric cells its output will be in strict accordance with the theoretical requirements stated on page 2, col. 1, only in cases where the color tone value of each color used is the same as the effective color tone value of this color.

(2) It results in recording the achromatic separation image as a negative and the chromatic separation images as positives. The reason for this is apparent from Fig. 1. The voltage across the output terminals *bk* is

$$V_{bk}=Sig_{max}=1-CTV_{min}$$

which is proportional to the light flux required to produce a separation negative (see page 2, col. 2). The voltage across one of the output terminals *r, g, b*, for example, that across the terminals *r*, is

$$\begin{aligned} V_r &= V_{bk-R} \\ &= (1-CTV_{min})-(1-CTV_R) \\ &= CTV_R-CTV_{min} \end{aligned}$$

which is the tone value of a positive separation image.

A manner in which these inconveniences may be eliminated is shown in Figs. 2, 3, and 4 which illustrate practical scanning devices making use of the selector circuit shown in Fig. 1.

The apparatus shown in Fig. 2 includes three lamps **1**, **2**, **3** of fixed intensities arranged to scan three color-separation positives **7**, **8**, **9** and to impinge upon three light-sensitive, electron multiplier tubes **15**, **17**, **19** so that the light flux impinging on each multiplier is, in effect, one of the three color components of the colored original from which the color-separation positives **7**, **8**, **9** were made. The multipliers are provided with the usual voltage dividers **14**, **16** and **18**. A battery **13** connected to the three multipliers supplies them with a common operating voltage. Voltages directly proportional to the light flux impinging on the three multipliers are developed across the load resistors **20**, **21**, **22** of the multipliers.

The terminals of the load resistors **20**, **21** and **22** are the input terminals of a selector circuit similar to that shown in Fig. 1, which connects the three pairs of input terminals through rectifiers **29**, **30**, **31** to a common resistor **32**, corresponding to the rectifiers E_1, E_2, E_3 and the resistor R of Fig. 1. Since the source of the voltages impressed on the selector circuit are voltage drops in resistors, it is necessary to the correct operation of the selector circuit that the impedance of the common resistor **32** be made many times as high as the impedances of the resistors **20**, **21** and **22**, so that the flow of current in the selector circuit required to develop the desired voltage drop in the resistor **32** does not appreciably affect the pre-existing voltage drops in the load resistors **20**, **21** and **22**. This can easily be arranged since the electron multipliers produce currents of sufficient amperage so that their load resistors need not have very high impedances in order to provide sufficient input voltage for the selector circuit, and the resistor 32 of the selector circuit may, and most desirably should, have an impedance fifty times as high as that of each load resistor.

The selector circuit shown in Fig. 2 differs from that shown in Fig. 1 only in two particulars:

(1) variable bias circuits consisting of potentiometers 23, 25, 27 and batteries 24, 26, 28 are introduced between the input terminals and the rectifiers to permit adjustment of the voltages at the rectifiers by adding or subtracting a constant voltage to that introduced at the input terminals. This permits adjusting the voltages containing the intelligences of the three color components to levels corresponding to effective rather than absolute color tone values.

(2) A battery 33 is introduced across the output terminals 34, 35, 36 which correspond to the output terminals *r*, *g* and *b* of Fig. 1. The voltage of this battery is equal to the maximum voltage developed across any one of the resistors 20, 21 or 22 when the minimum tone of one of the separation images is being scanned. The voltages developed at the different terminals 34, 35 and 36 are, therefore, not those indicated in Fig. 1, but in each case the difference between the voltage indicated in Fig. 1 and the voltage produced by the maximum light. The output terminal voltages, therefore, contain the intelligences required for recording negatives of the color-separation images, that is to say, these voltages are proportional to the light flux required to produce separation negatives. The voltage appearing at the output terminals 37 connected across the resistor 32 contains the intelligence required for recording a negative of the black achromatic separation image, as in Fig. 1.

Any known type of recording means may be connected to the four sets of output terminals to produce negatives from which the three color printers and the black printer may be obtained. Fig. 2 illustrates diagrammatically recording means for producing contrast negatives, such as half-tone negatives, which may be used directly for engraving printing plates. Any one of the four sets of output terminals may be connected by a double-pole switch S to a recording circuit H, such as that shown in Hardy Patent 2,136,340 intermittently operating a glow lamp H—16 directed through a suitable optical system upon a recording film or plate F. This film is mounted for movement corresponding to that given to the separation positives 7, 8, 9 in the scanning operation, for example, by placing the separation positives and the recording film on the tables of a flat-bed scanning machine such as that shown in Wurzburg Patent 2,185,189. With this equipment, the scanning operation is repeated four times—first with the switch S on the output terminals 34, then with the switch S on the output terminals 35, etc. The purpose of recording the four separation negatives in four separate scanning operations is to permit varying the direction of the scanning lines to avoid moiré effects as explained in Wurzburg Patent 2,185,189.

While the electron multipliers shown in Fig. 2 provide a convenient means for obtaining signal currents of sufficient amperage to permit the use of load resistors of comparatively low impedance, the use of electron multipliers is not necessary for this purpose.

Fig. 3 shows a scanning apparatus in general similar to that shown in Fig. 2 except that ordinary photo-electric cells 15′, 17′, 19′ are substituted for the electron multipliers 15, 17, 19 of Fig. 2. Separate batteries 44, 45, 46 are provided for the photo cells. The load resistors 20′, 21′, 22′ of the photo cells are necessarily of much higher impedance than the load resistors of the electron multipliers shown in Fig. 2 because of the weakness of the currents produced in the photo cells. In order to obtain the benefits of alternating current amplification, flicker discs or light choppers 41, 42, 43 operated by motors 38, 39, 40 interrupt the beams of light from the lamps 1, 2, 3. A. C. amplifiers 47, 48, 49 are connected to the load resistors 20′, 21′, 22′, and step-down transformers 50, 51, 52 are connected to the outputs of the amplifiers. These transformers have two functions. In the first place, they increase the signal currents so that the required signal voltages can be obtained in load resistors of comparatively low impedance. In the second place, they serve to isolate the photo cells from the selector circuit and thus prevent the selector circuit from in any way modifying the action of the photo cell circuits.

The secondaries of the transformers 50, 51, 52 are connected through rectifiers 53, 54, 55 to load resistors 59, 60, 61, and filter condensers 56, 57, 58 are placed in parallel with these load resistors. The rectified current in the load resistors 59, 60, 61 (which because of the use of the amplifiers and transformers may be made of moderate impedance) develops voltage drops proportional to the light flux of the color components.

The terminals of the load resistors 59, 60, 61 are the input terminals of a selector circuit precisely like that shown in Fig. 2, and as in Fig. 2 the output terminals 34, 35, 36, 37 of the selector circuit may be connected to convenient recorders of any type to produce negatives for the four color printers.

The devices shown in Figs. 2 and 3 do not provide for making the color corrections required in the three-color process. Consequently, in the use of this apparatus, it is desirable that the color-separation positives which are scanned be color-corrected color-separation positives in order to secure correct printers for the four-color process.

Where it is desired to use color-separation images which have not been color-corrected, or to work directly from a colored original, apparatus for making color corrections may conveniently be used with our selector circuit, particularly where the transformers of Fig. 3 are used.

Fig. 4 shows a device for making color-corrected separation images for the four-color process directly from a colored original. In Fig. 4 light from a lamp 1′ is directed through a transparent colored original 7′, past a flicker disc 41, and then to a beam splitter (which may consist of three mirrors or reflecting prisms 62, 63, 64). The beam splitter directs the light from the colored original through three color filters 65, 66, 67 upon three photo cells 15′, 17′ and 19′, which are provided with batteries and load resistors as in Fig. 3. The photo cell voltages are amplified by A. C. amplifiers 47, 48, 49, as in Fig. 3.

In order to provide for making color corrections by modifying the intelligence in each color circuit by the intelligences in the other two color circuits, each of the amplifiers 47, 48, 49 is connected to three transformers. As shown in Fig. 4, the output terminals of the amplifier 47 are connected to the primaries of transformers 68, 72 and 75, while the amplifier 48 is connected to the transformers 69, 71 and 76 and the amplifier 49 to the transformers 70, 73 and 74.

The secondary of each of the nine transformers is connected through a rectifier to a load resistor as in Fig. 3. The result is to provide three independent sets of three load resistors having voltage drops corresponding to the light flux of the three color components. Thus the voltage drops in the first set of load resistors 95, 96, 97 correspond respectively to the light flux passing the three filters 65, 66, 67. The same thing is true of the second set of load resistors 98, 99, 100 and also of the third set of load resistors 101, 102, 103.

The signal voltages in the three resistors of each set are used to modify one another so as to produce a resulting voltage containing the intelligence of a color-corrected color component. While any type of correction may be introduced, we prefer to use the additive and subtractive type of correction described and explained by one of us in U. S. Patent No. 2,193,722, issued Mar. 12, 1940, and U. S. Patent No. 2,165,168, issued July 4, 1939. This may be done very simply by providing each load resistor with a variable contact 104 like that of a potentiometer and by providing cross connections between the contacts 104 and output terminals 105, 106 such that the voltage between the output terminals 105, 106 of each set of transformers is the algebraic sum of fractions of the three voltages in the three load resistors of that set.

The output terminals 105, 106 of each of the three sets of load resistors constitute the input terminals of a selector circuit which is identical with that shown in Figs. 2 and 3 and operates in the same manner. The selector circuit being supplied with voltages containing the intelligences of three corrected components regulated by the potentiometers 23, 25, 27, to levels corresponding to effective color tone values produces at its output terminals 34, 35, 36, 37 the intelligences for four color-corrected printers.

As shown in Fig. 4, the output terminals may be connected with recording devices for recording the four separation negatives simultaneously. The four recording devices shown in Fig. 4 consist of light valves V controlling recording lights L, focused on four recording films F_1, F_2, F_3, F_4, carried on the same cylinder as the colored original 7'.

Thus the apparatus in Fig. 4 directly scans a colored original and effects all the mathematical operations necessary to produce simultaneously the four negatives required for making the four printers of the theoretically correct four-color process. Such printers, as we have pointed out, give a reproduction as correct as can be obtained from a theoretically correct three-color process, and at the same time use a minimum amount of colored ink. All the blacks and grays, whether occurring by themselves or in connection with colors, are produced by black ink.

In order to use the A. C. amplifying system shown in Figs. 3 and 4, it is not necessary to use the flicker discs or light choppers shown in these figures. An alternative arrangement for obtaining an alternating current containing the intelligence of a color component consists in omitting the flicker disc and using direct current from a photo-electric cell to modulate an alternating current obtained from an oscillator. This arrangement, which is shown in Fig. 5, may be used in the apparatus shown in Figs. 3 and 4 in the circuit for each color component, instead of using the flicker discs shown in these figures.

What we claim is:

1. An electro-optical circuit comprising three channels respectively bearing signals corresponding to three color components of a colored original, a fourth channel connected to each of the three channels and means responsive to the intensities of the signals for rendering conductive into the fourth channel only the channel carrying the signal whose intensity is the greatest of the three, and fifth, sixth and seventh channels each one of which is connected to the output of one of the first three channels and to the output of the fourth channel and means for establishing in each one of the fifth, sixth and seventh channels a signal equal to the difference between the signals in the two channels to which it is connected.

2. An electro-optical circuit comprising three channels respectively bearing signals corresponding to three color components of a colored original, a fourth channel connected to each of the three channels and means responsive to the intensities of the signals for rendering conductive into the fourth channel only the channel carrying the signal whose intensity is the greatest of the three, means for producing light-flux variations corresponding to the signals in the fourth channel, and means for producing light-flux variations corresponding to the difference between the signal intensity in the fourth channel and the signal intensity in each one of the first three channels.

3. The method of making separation images for a four-color reproduction process, which comprises directing three different spectral components of a colored subject to three separate photo-electric receptors, adjusting the electric responses of the receptors to correspond to the effective color tone values of a three color reproduction, selecting at each instant the greatest of the three adjusted responses, utilizing the selected responses to provide an achromatic separation image, and utilizing the differences between each selected response and the concurrent individual adjusted response of each photo-electric receptor to provide three chromatic separation images.

4. Apparatus for making separation images for a four-color reproduction process, comprising an electric circuit having three pairs of input terminals, three rectifiers, a resistor, conductors connecting corresponding electrodes of the three rectifiers to one end of the resistor, conductors connecting one terminal of each of the three pairs separately to the other corresponding electrodes of the rectifiers and a conductor connecting the other terminals of the three pairs to the other end of the resistor, means for impressing on the three sets of input terminals variable voltages containing the intelligence of three different spectral components of a colored subject, and means for utilizing the variations in the voltage drop occurring across the resistor and the variations in the voltage differences occurring across each one of the three rectifiers to produce four separation images.

5. Apparatus for making separation images for engraving the printers for a four-color reproduction process, comprising an electric circuit

having three pairs of input terminals, three rectifiers, a resistor, conductors connecting corresponding electrodes of the three rectifiers to one end of the resistor, conductors connecting one terminal of each of the three pairs separately to the other corresponding electrodes of the rectifiers and a conductor connecting the other terminals of the three pairs to the other end of the resistor, means for impressing on the three sets of input terminals variable voltages containing the intelligences of three different spectral components of a colored subject, means for recording the variations in the voltage drop occurring across the resistor to provide an achromatic separation image for engraving a black printer, and means for recording the variations in the voltage differences occurring across each one of the three rectifiers to provide three separation images for engraving the color printers to be used with the black printer.

6. Apparatus for making separation images for a four-color reproduction process comprising an electric circuit having three pairs of input terminals, three rectifiers, a resistor having an impedance many times as great as that of the rectifiers and conductors connecting the terminals to the resistor through the rectifiers, means for impressing on the three sets of input terminals variable voltages containing the intelligences of three different spectral components of a colored subject, regulatable means for adding a fixed voltage to the voltage impressed upon each set of terminals, a pair of output terminals at opposite ends of the common resistor, and a pair of output terminals at opposite sides of each rectifier.

7. Apparatus for making separation images for a four-color reproduction process from three color components of a colored original, comprising an electric circuit having three load resistors, a common resistor having an impedance many times as great as that of any one of the load resistors, three rectifiers, conductors connecting the load resistors to the common resistor through the rectifiers, means for passing through the load resistors currents varying with the point-to-point variation of the three spectral components, and means for recording the variations in the voltage drop occurring across the common resistor.

8. Apparatus for making separation images for a four-color reproduction process from three color components of a colored original, comprising an electric circuit having three load resistors, three rectifiers, a common resistor having an impedance many times as great as that of any one of the load resistors, conductors connecting the load resistors to the common resistor through the rectifiers, means for passing through the load resistors currents varying with the point-to-point variation of the three spectral components, and means for recording the variations in the voltage drop occurring across the common resistor, and for recording the variations in the voltage differences occurring across each one of the rectifiers.

9. Apparatus for making separation images for a four-color reproduction process, comprising three photo-electric receptors, means for directing different spectral components of the light from a colored original upon said receptors, three load resistors, means for directing the current response of each receptor through one of the load resistors, a common resistor having an impedance many times as high as that of any of the load resistors, three rectifiers, conductors connecting the load resistors to the common resistor through the rectifiers, four recorders, conductors connecting one recorder across the common resistor and connecting each of the other three recorders across one of the rectifiers, and a source of constant potential inserted in the connection between these three recorders and the three rectifiers.

10. Apparatus for making separation images for a four-color reproduction process, comprising means for establishing three alternating currents containing the intelligences of three color components of a colored original, an A. C. amplifier for amplifying each of said alternating currents, a step-down transformer connected to each amplifier, three load resistors, means for rectifying the current from each transformer and directing it through one of the load resistors, a common resistor connected to the three load resistors through three separate rectifiers, and having an impedance many times as great as any of the load resistors, and means for recording the variations in the voltage drop occurring across the common resistor and the variations in the voltage differences occurring across each one of the rectifiers.

11. Apparatus for making color-corrected separation images, comprising means for establishing three alternating currents containing the intelligences of three color components of a colored original, three sets of transformers, three sets of load resistors, means for passing each of said alternating currents through the primaries of transformers of a plurality of said sets of transformers, means for rectifying the output current from each transformer and passing it through one of the load resistors so as to provide three sets of a plurality of variable voltages, the voltages of each set containing the intelligences of a plurality of color components of the colored original, and means for combining the voltages of each of the three sets to provide three voltages corresponding to three color-corrected color components.

12. Apparatus for making color-corrected separation images for a four-color reproduction process, comprising means for establishing three alternating currents containing the intelligences of three color components of a colored original, three sets of transformers, three sets of load resistors, means for passing each of said alternating currents through the primaries of transformers of a plurality of said sets of transformers, means for rectifying the output current from each transformer and passing it through one of the load resistors so as to provide three sets of a plurality of variable voltages, the voltages of each set containing the intelligences of a plurality of color components of the colored original, means for combining the voltages of each of the three sets to provide three voltages corresponding to three color-corrected color components, a selector circuit having three sets of input terminals connected through separate rectifiers to a common resistor, means for impressing the three voltages corresponding to color-corrected color components upon the three sets of input terminals, and means for recording the variations in voltage drop across the common resistor and the variations in the voltage differences across the three rectifiers.

13. Apparatus for making color-corrected separation images for a four-color reproduction process directly from a colored original compris-

ing means for scanning the colored original with an interrupted light beam and splitting the beam into three parts, three color filters through which the three parts of the beam are passed, three photo-cells receiving the three parts of the beam passed through the filters, an A. C. amplifier connected to each photo-cell, a plurality of step-down transformers connected to each amplifier, three sets of load resistors, means for rectifying the current from each transformer and passing it through one of the load resistors so as to provide three sets of plurality of variable voltages, the variations in the voltages of each set corresponding to the point-to-point variations in a plurality of the color components of the original, means for combining the voltages of each of the three sets to provide three voltages corresponding to three color-corrected color components, a selector circuit having three sets of input terminals connected through separate rectifiers to a common resistor, means for impressing the three voltages corresponding to color-corrected color components upon the three sets of input terminals, and means for recording the variations in voltage drop across the common resistor and the variations in the voltage differences across the three rectifiers.

14. In scanning apparatus, the combination of means for scanning a colored original with an interrupted light beam and splitting the beam into three parts, three color filters through which the three parts of the beam are passed, three photo-cells receiving the three parts of the beam passed through the filters, an A. C. amplifier connected to each photo-cell, a plurality of step-down transformers connected to each amplifier, a plurality of sets of load resistors, means for rectifying the current from each transformer and passing it through one of the load resistors so as to provide three sets of plurality of variable voltages, the variations in the voltages of each set corresponding to the point-to-point variations in a plurality of the color components of the original, and means for combining the three voltages of each of the three sets to provide three voltages corresponding to three color-corrected color components.

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CERTIFICATE OF CORRECTION.

Patent No. 2,316,581. April 13, 1943.

ARTHUR C. HARDY, ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, first column, line 11, for "variable" read --Variable--; line 62, for "this equipment" read --this recording equipment--; page 7, second column, line 20-21, for "volttages" read --voltages--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 8th day of June, A. D. 1943.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal)