

Dec. 9, 1958

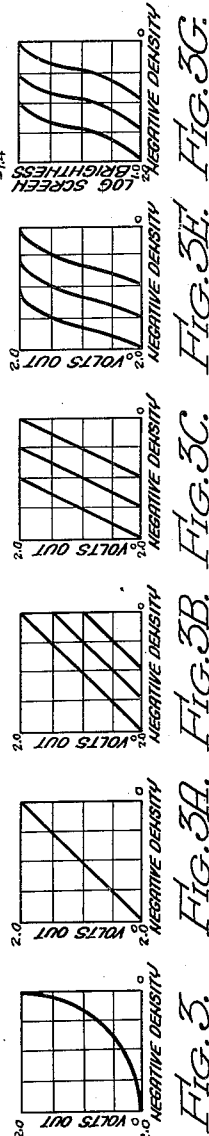
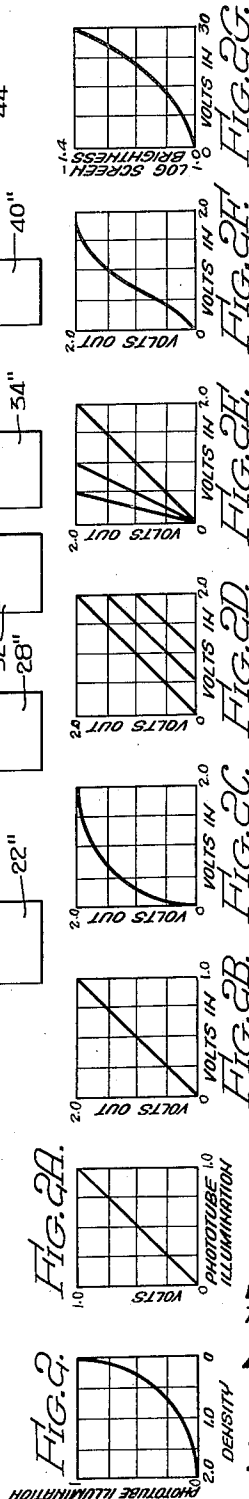
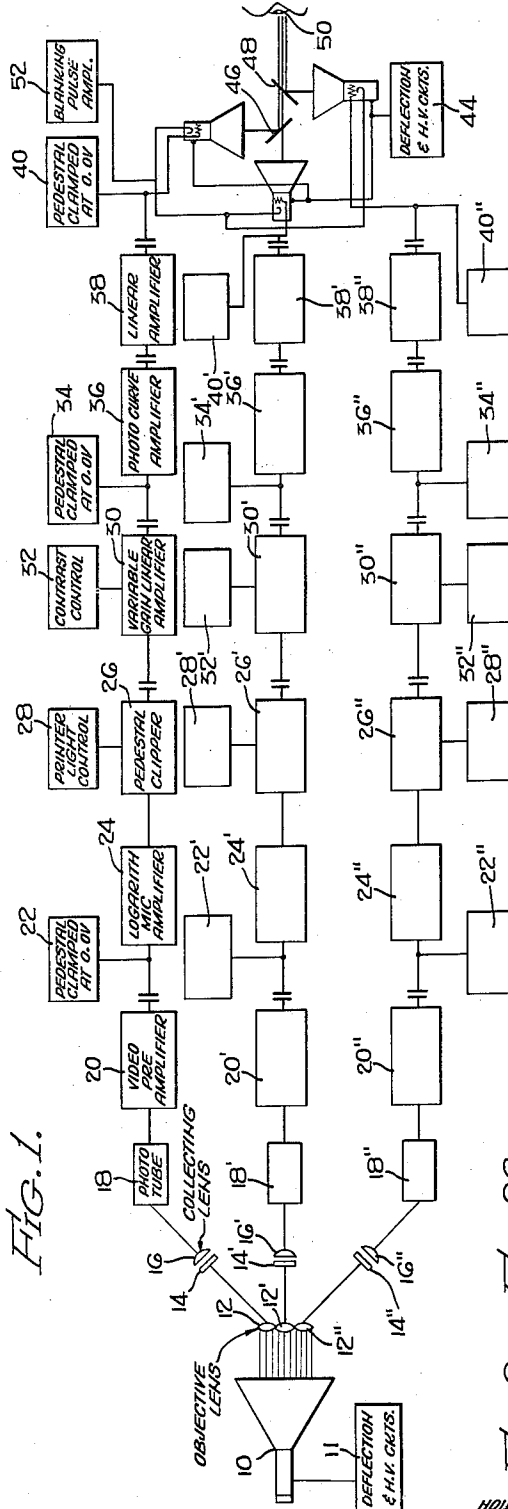
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Filed June 16, 1954

5 Sheets-Sheet 1



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FIG. 3D. FIG. 3E. FIG. 3H.

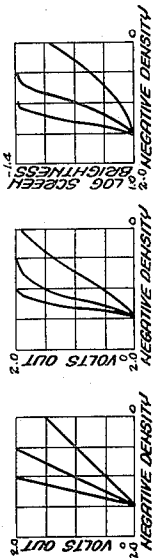


FIG. 4A. FIG. 4B. FIG. 4C. FIG. 4D. FIG. 4E. FIG. 4F.

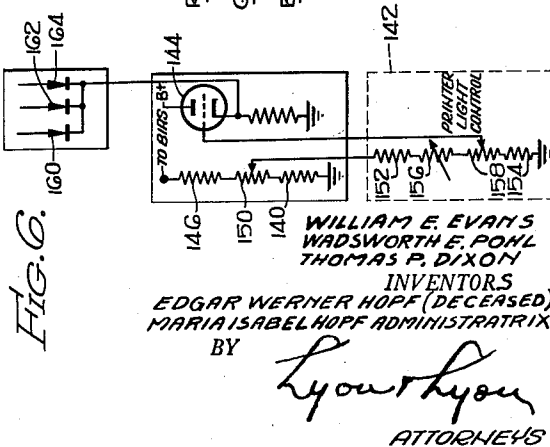
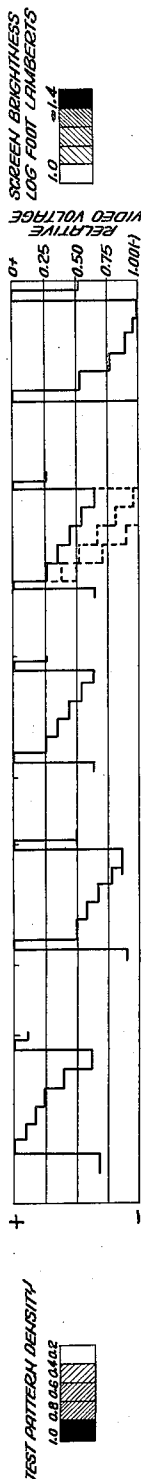


FIG. 8.

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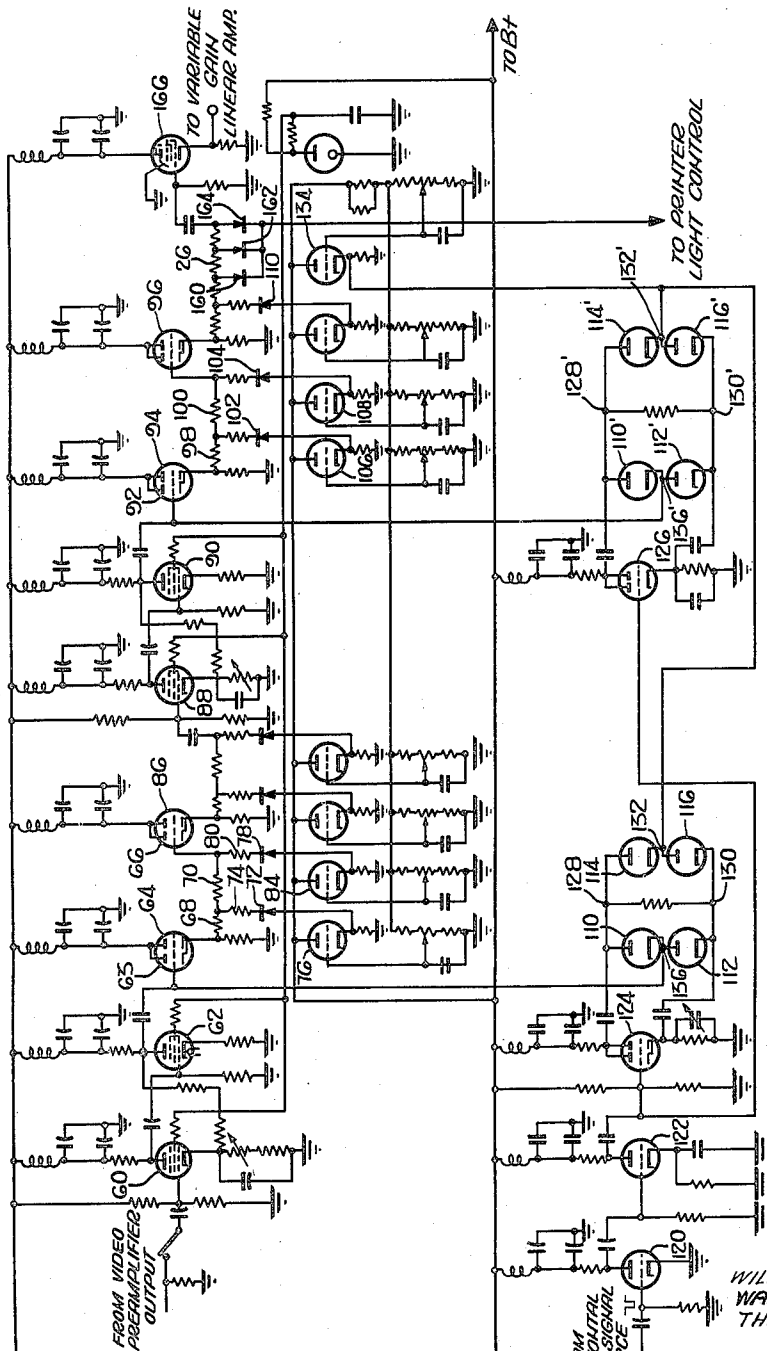
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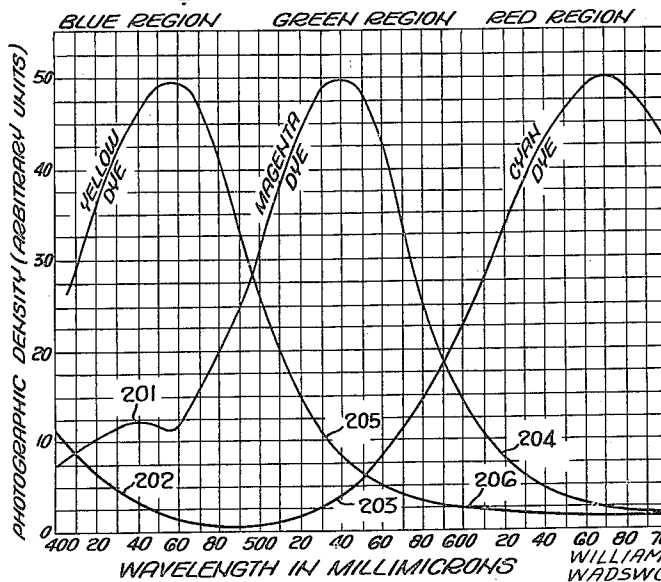
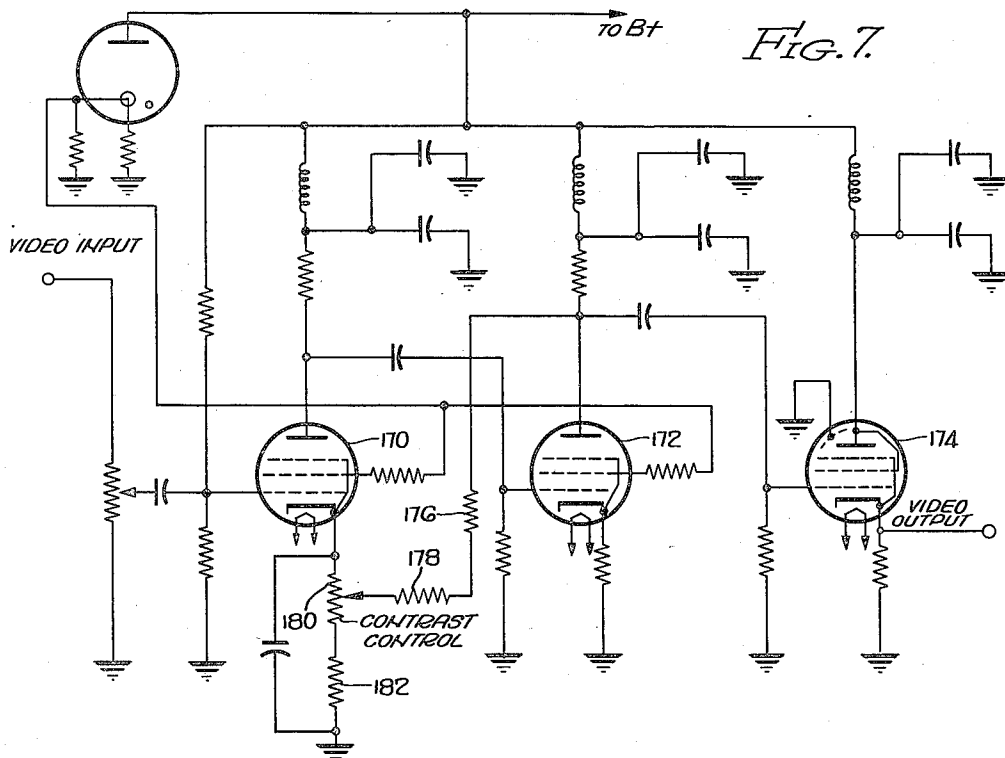


FIG. 9.

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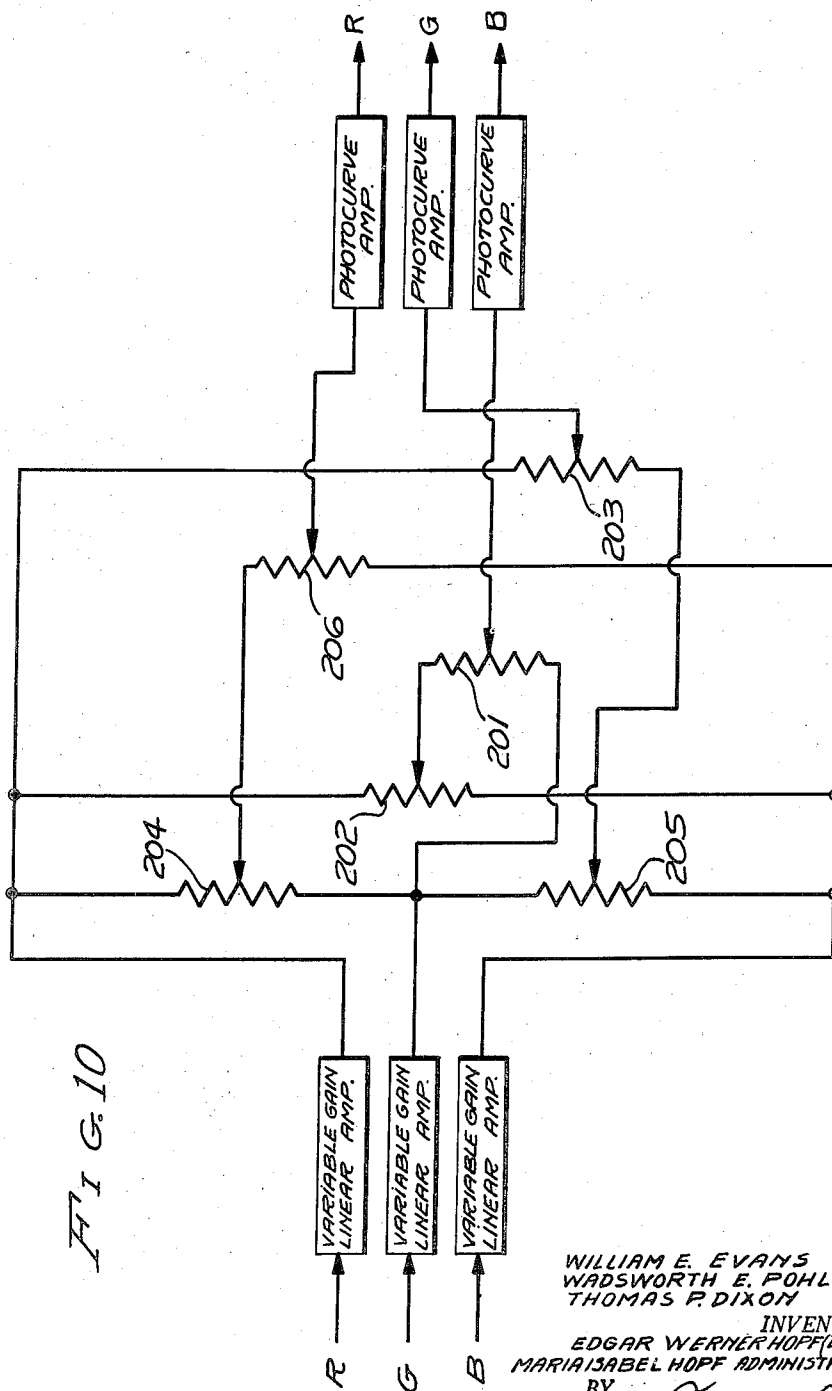
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Application June 16, 1954, Serial No. 437,258

21 Claims. (Cl. 178—5.4)

This invention relates to apparatus for reproducing images on one medium which are recorded on another. More particularly, the invention relates to apparatus which employs electronic control and monitoring devices for determining printing parameters when it is desired to reproduce an image on a recording medium and such medium differs in its characteristics from the medium from which the image is obtained.

A specific adaptation of the invention is in the field of color motion picture photography wherein the imbibition printing method is employed. In such a method, as more fully described in United States Patent No. 1,707,699, issued to W. E. Whitney on April 2, 1929, the original photographic record of a scene consists of three silver separation negatives, each corresponding to one of the three primary image aspects of a color scene. From these three negatives are printed three corresponding matrices; these matrices, each of which carries a dye of proper color, are employed to print, in sequence, and in proper registration, three-color, subtractive primary components of the image upon a film to form the final positive print.

In such process it is essential that the three image aspects be balanced properly. Thus, in order that a final print be obtained, it is necessary that each matrix balance each of the other two matrices. This requirement makes the step of printing matrices from separation negatives difficult and time consuming. Since not only may the separation negatives themselves be unbalanced with respect to each other, but also the density characteristics of the negatives and matrices may differ, the result is that, in the conventional practice of the imbibition process, proper exposure for matrix printing is in large measure determined empirically. Thus, the operator can only examine the three negatives and, from past experience, select what he believes to be an appropriate exposure for printing each of the three matrices. Next, the proper dyes are applied to each matrix and an actual positive print is made. This print is then examined for color deficiencies; based upon such examination, the exposures of the printers are corrected and the entire process is repeated. This trial and error method is continued until a satisfactory print is obtained. While the experience of the operator will determine, in large measure, the number of corrections which must be made, even the most skilled of operators will normally be required to make several corrections to the original printing times chosen. The result is that the determination of the proper exposure for matrix printing is a time-consuming and expensive operation.

In accordance with the present invention, means are provided whereby a visual image in color, corresponding to the final print, is obtained electronically from the photographic negatives. Various circuits having the proper characteristics are employed, such that the operator may balance the three-color components at the desired density levels to obtain a visual picture on a cathode-ray monitor of the desired quality. From the position of the control elements for the various circuits employed,

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the exposure for each of the three matrix printers may be obtained directly, with the result that the trial-and-error method heretofore employed may be avoided.

The response characteristics of the various circuits incorporated are such as to compensate for the different characteristics of the various media employed, in order that information as to the photographic parameters sought can be obtained directly from the electronic equipment employed.

Accordingly, it is the general object of the invention to provide an electronic device for obtaining transfer parameters when it is desired to record on a particular medium a record contained on a different medium having different characteristics.

It is a further object of the present invention to provide such a device wherein several components of a composite image must be balanced each with respect to the other and wherein an optical presentation of the composite image is produced.

It is a more specific object of the invention to provide a device for color photography whereby the image aspects of the component colors can be balanced and adjusted by visual inspection of an electronically obtained optical image.

Another object of the present invention is to provide apparatus to simulate electronically the photographic process of printing to provide thereby data on parameters involved in the performance of the photographic process.

Still another object of the present invention is to provide an electronic system wherein a positive picture in color is presented from silver separation negatives or integral tripack color negatives.

These and other objects of this invention are achieved by providing a system wherein signals representative of the optical transmission of discrete areas of a color record are generated and applied to separate channels, each of which is associated with a different color image aspect. In each channel the signals are converted to density representative signals. The average level of the density representative signals is then established by a controllable peak-clipping circuit. The peak-clipping circuit output is applied to a linear contrast control amplifier whose gain is controllable. The output of the linear amplifier is applied to a photo-curve amplifier, which modifies the signals applied to it in accordance with a desired relationship between density and cathode-ray tube screen brightness and also to compensate for nonlinearities in the brightness transfer characteristics of a cathode-ray tube employed at the output. In one embodiment the signals from each of the photo-curve amplifiers are respectively applied to a cathode-ray tube at the output of each channel. Each of these has a screen phosphor which provides an additive color corresponding to the color represented by the color image aspect associated with the channel.

The images on the cathode-ray tube screens are superimposed to present a composite picture in color. The contrast of each color and, thereby, that of the composite picture is controlled by varying the gain of the linear amplifier. The brightness of each color and, thereby, the color balance of the picture may be controlled by clipping the signals in each channel at different levels with the peak-clipping circuit. Calibrated controls are associated with each of these circuits, so that, after varying these controls to establish a picture having a desired color balance and contrast, the calibrations may be read to provide information as to the proper contrast and printer-light illumination required to provide a positive photographic print having substantially the same contrast and color balance. In the event that there is overlap in the color characteristics of the

dyes used to make the positive print, circuit means are provided between and in each channel to simulate the same type of overlap reproduction in the electronically presented positive picture.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

Figure 1 is a schematic diagram of one embodiment of the invention;

Figures 2 through 2G are curves representative of the transfer characteristic of the apparatus used in the embodiment of the invention shown in Figure 1;

Figures 3 through 3H are curves of the transfer characteristics of the system at various points in a channel;

Figure 4 is a test negative;

Figures 4A through 4E are video waveforms taken at various points in a channel when the test negative is scanned;

Figure 4F shows the positive, corresponding to the negative shown in Figure 4, presented on a cathode-ray tube at the output of a channel;

Figure 5 is a circuit diagram of a logarithmic amplifier, peak clipper, and clamp used in the embodiment of the invention;

Figure 6 is a circuit diagram of the printer-light control used in the embodiment of the invention;

Figure 7 is a circuit diagram of a variable linear amplifier and contrast control used in the embodiment of the invention;

Figure 8 is a circuit diagram of a corrective network;

Figure 9 shows curves of density versus wavelength for typical dyes used in color photography; and

Figure 10 is a circuit diagram of another and preferred embodiment of a corrective network.

Reference is now made to Figure 1, which shows in schematic form an embodiment of this invention. A flying-spot scanner tube 10 is used to provide a scanning light beam. This is split into three scanning beams by three objective lenses 12, 12', 12''. The three beams are directed onto corresponding areas of three separation negatives 14, 14', 14'', respectively representing red, green, and blue. These separation negatives are made by well-known photographic techniques and need not be described here. The three scanning beams of light scan the three negatives in such manner that the discrete area covered by each beam at any one time on each negative corresponds to that on the other negatives.

The output from each negative is collected by means of a lens 16, 16', 16'' and directed to fall upon a separate phototube 18, 18', 18''. Each phototube generates a signal whose amplitude is representative of the transmission of the light beam through the negative of the discrete area upon which the light impinges. Each phototube output is then applied to a video preamplifier 20, 20', 20'' which amplifies the signal and provides a negative-going signal at its output.

A flying-spot scanner tube, phototube pickup, and preamplifier of a suitable type are well known in the television field and may be found described, for example, in *Television Engineering*, page 91, et seq., by Fink, published by the McGraw-Hill Book Company. These are referred to as a "flying spot camera." The flying-spot scanner tube may have its beam deflected in accordance with the United States commercial television standards; namely, 525 lines in 60 fields or 30 frames per second, although these scanning ratios are by no means critical.

Since the flying-spot scanner is being deflected in accordance with standard television practice, the signal obtained at the output of the video preamplifier will be, for each line, a video signal accompanied by a pedestal

signal. The type of signal obtained is shown in Figure 4A. The pedestal signal occurs during the retrace interval required between the time the beam of the scanner tube reaches the end of one line and is turned off until it is positioned at the beginning of the next line. It should be noted here that each color image aspect has associated therewith a separate channel which includes the phototube pickup for that aspect, a cathode-ray tube at the end of the channel, and intervening apparatus. Each channel contains substantially similar apparatus, and, accordingly, only one will be described. However, it should be understood that the description of one applies to each channel except where otherwise noted. A clamp 22, 22', 22'' is used to restore the peak level of the pedestal to a desired value, which, in this instance, is zero voltage.

The video preamplifier output, after being clamped, is then applied to a logarithmic amplifier 24, 24', 24''. This consists of an amplifier whose output is proportional to the logarithm of its input over the major portion of its range, as may be seen by a plot of its transfer characteristic in Figure 2C.

Referring now to Figure 2, the curve shown is a plot of the transfer characteristic of a negative. It shows how much light is transmitted to a phototube through a negative of varying density. Figure 2A is a curve of the transfer characteristic of the phototube 18, 18', 18''. This shows that the output is linearly related to the input, or the output voltage is linearly related to the phototube illumination. Similarly, the video preamplifier 20, 20', 20'' has linear characteristics as shown by the curve in Figure 2B, which consists of a plot of the input versus the output voltage. The curve in Figure 2C is the plot of the transfer characteristics of the logarithmic amplifier 24, 24', 24'' and shows that the output voltage is substantially proportional to the logarithm of the input voltage.

The output of the logarithmic amplifier is applied to a pedestal clipper 26, 26', 26''. This circuit enables clipping of the pedestal of a video signal at a desired D. C. level, and the fact that the level is variable can be seen from the rectangle shown coupled thereto which is called the printer-light control 28, 28', 28''. The printer-light control includes a calibrated indicator variable therewith. The reason for the name "printer-light control" will be explained subsequently. The transfer characteristic is shown in the curve in Figure 2D. Three different clipping level curves are shown, and it will be seen that for a given setting of the pedestal clipper no voltage output is provided until the level set is exceeded. After this the output varies linearly with the input for the signal in excess of the clipping level. As may be observed from the curve, the pedestal clipper enables lateral translation of the characteristic curve. The pedestal clipper output is then applied to a variable-gain linear amplifier 30, 30', 30''. Its gain is variable and controllable, as may be seen from the rectangle connected thereto, which is designated as a contrast control 32, 32', 32''. The contrast control includes a calibrated indicator coupled to the amplifier-gain control. The reason for designating it as a contrast control will be subsequently explained. The amplifier output is linearly related to its input, as may be seen by the transfer characteristic curve shown in Figure 2E. The three different curves shown are for three different settings for the contrast control, just as the three different curves shown in Figure 2D are for three different settings of the printer-light control. It will be seen that the slope of the input versus output curve varies with each setting of the contrast control.

The output of the variable-gain linear amplifier is again clamped by means of a clamping circuit 34, 34', 34''. The clamping level selected is zero volts. The signal from the linear amplifier is then applied to a photo-

curve amplifier 36, 36', 36''. This consists of an amplifier which serves a twofold purpose. First, a desired relationship between signal amplitude and cathode-ray tube screen brightness is determined. As will be shown later, the signals presented to the photo-curve amplifier in effect represent the density of the negative being scanned. Photographically speaking, for any given set of parameters, the brightness of a positive at any particular point is determined by the density of the corresponding negative at the same point. This relationship may readily be plotted as a curve. Since it is desired to present a positive picture on a cathode-ray tube screen from density representative signals, a curve, which is an electronic analogue of the density versus positive brightness curve, may be established in which the parameters are respectively density representative signal amplitude versus screen brightness. Since it is the output of the photo-curve amplifier which is to be used to drive the cathode-ray tube, then the transfer characteristic of the photo-curve amplifier is made to have the characteristics shown to be required by the density signal versus screen brightness curve, only, of course, the transfer characteristic curve is input voltage versus the output voltage required to drive the cathode-ray tube grid (through the subsequent linear amplifier) to obtain the required brightness. Since the transfer characteristic of the cathode-ray tube (i. e., signal at grid-to-screen brightness) is not linear, the transfer characteristic of the photo-curve amplifier is further determined to take these departures from linearity into consideration. The transfer characteristic of the photo-curve amplifier is substantially as shown in Figure 2F. This curve of the relationship between the voltage input to the voltage output represents both the desired relationship between screen brightness and negative density as well as the correction or predistortion required to compensate for the cathode-ray tube transfer characteristic.

The photo-curve amplifier output is applied to a fixed-gain linear amplifier 38, 38', 38'' whose input is linearly related to its output. The fixed-gain linear amplifier output signal then again has its pedestal clamped to zero volts by another pedestal clamping circuit 40, 40', 40''. This signal is applied to the grid of a cathode-ray tube 42, 42', 42''. This cathode-ray tube is biased so that zero signal represents maximum illumination, and the more negative the signal, the less the illumination of the screen. The curve showing the transfer characteristic of the cathode-ray tube is represented by Figure 2G. It is a curve of logarithm of the screen brightness against the input voltage. The cathode-ray tube at the output of each channel has a screen whose color is determined by the primary color with which the color separation negative for the channel is associated. Accordingly, the three cathode-ray tubes may provide red, green, and blue light. The three cathode-ray tubes have a common deflection voltage source 44 synchronized with the deflection circuits 11 of the flying-spot scanner. The reason for this, of course, is that it is desired that the cathode-ray beams for three tubes be substantially simultaneously positioned and deflected at all times with the flying-spot scanner beam. The three tubes are positioned as shown. Two mirrors 46, 48 are used which are at 45° angles with respect to the tube opposite which they are placed. The two mirrors are also positioned so that the light from the two tubes may reach the eye 50 of an observer at the same time and in the same position as the light from the third tube which is being directly observed through the two mirrors.

In order to overcome the white retrace lines of a picture which is obtained as a result of the pedestal between video signals being clamped at picture white, a blanking pulse from a blanking-pulse amplifier 52 is provided during each pedestal interval to overcome the effect of this pedestal and maintain the tube screens dark during the retrace interval. This blanking pulse may be applied

as shown to the cathode of each one of the television tubes. The amplifier 52 is also synchronized properly with the deflection circuitry. It will be appreciated that, in view of the fact that the phosphors of the three tubes are selected to provide the primary colors, these can be operated to provide white or substantially any other required colors by properly mixing the output from the three tubes. Furthermore, if desired, instead of using three tubes having three different phosphors, it is possible to use three tubes having a white phosphor and three different filters, a single tricolor tube, or a single white screen tube with rotating filters in front thereof and the signals supplied from the three channels to the tube grid on a time-sharing basis and in synchronism with the rotating filters. It would further be possible to obtain the tricolor display from the three images of three projection systems arranged to superimpose in register on a common viewing screen. These are several of the expedients used to present a color television picture and are applicable herein.

Reference is now made to Figure 3 which shows a series of curves indicative of the transfer characteristics from the input up to various points in a typical channel of the system. For example, Figure 3 is representative of the video signal output of the video preamplifier provided when a negative, of the type represented in the curve of Figure 2, which ranges from a minimum to a maximum density is scanned. Figure 3A shows the video signal output of the logarithmic amplifier 24 for this type of signal. It will be appreciated that the signals presented to the logarithmic amplifier are representative of the transmission characteristics of discrete areas of a negative. Since the

$$\text{Density } D = \log \frac{1}{\text{transmission}}$$

these signals are converted to density-representative signals by the logarithmic amplifier. Accordingly, the output of the logarithmic amplifier may be read by a linear meter in terms of density, since it represents the density of the discrete area of the negative being scanned at the particular instant of the reading. Accordingly, the system shown and included up to the output of the logarithmic amplifier for each channel may be considered an electronic densitometer.

For the three clipping levels shown in the transfer characteristic curve of Figure 2D, three different curves of negative density versus the voltage output obtained from the clipper are shown in Figure 3B although the same negative is scanned in each instance.

As stated previously, the complete video signal, as in television practice, consists of a pedestal, a negative-going video signal, another pedestal, another negative-going video signal, etc. The pedestals occur during the blanking intervals during line retrace. The pedestal clipper clips these pedestals at a desired negative level. The subsequent pedestal clamp serves to move the entire signal so that the remaining unclipped pedestal portion is clamped to zero voltage. Of course, the video signal is moved closer to zero along with its unclipped pedestal portion. Effectively, then, the pedestal clipper may be varied to move the video signal any desired value closer to zero voltage level or to leave it at its most negative position. Since, as previously described, the cathode-ray tube at the output of a channel is biased to provide its brightest light output when there are zero volts applied to its grid and to decrease its light output with increasingly negative signals applied to its grid, the pedestal clipper can be said to control or establish the brightness range for the picture resulting from the video signals being applied to the cathode-ray tube grid via the pedestal clipper. Increasing or decreasing the brightness or illumination level of a light source used to print a positive from a negative has this effect. Therefore, the control of the pedestal clipper may be calibrated in units corresponding to the level of illumination required of a printing light to achieve

the desired photographic exposure. It will also be understood that a fixed level of illumination may be used for a positive print and the time of exposure may be varied. For such a situation, the printer-light control may be calibrated in terms of time of exposure for a predetermined level of illumination.

Figure 3C is representative, for the three clipping levels shown in Figure 3B, of the output of the variable-gain linear amplifier for the input to a channel obtained from a negative whose density varies, as previously indicated. Figure 3D shows the three different curves obtained when the clipping level is held constant and the gain of the amplifier is varied. Figure 3E shows the channel transfer characteristic at the output of the photo-curve amplifier for three different clipping levels. Figure 3F shows the output of the photo-curve amplifier for one clipping level with three different gain positions chosen for the variable-gain amplifier. Figure 3G and Figure 3H, respectively, show curves of the logarithm of of the screen brightness with respect to the negative density for three different levels of the pedestal clipper and for three different positions of the gain control of the variable-gain amplifier when the pedestal clipper level is maintained constant. These last curves then represent the transfer characteristics of the channel for three different pedestal levels and for three different settings of the variable amplifier. It can be appreciated from the curves of Figure 3G how, for each different setting of the pedestal clipper, the same picture brightness range is provided although the negative density providing that range is greater or lesser—the same effect that may be obtained by increasing or decreasing the level of illumination of a printing light. The log screen brightness versus negative density curves of Figures 3G and 3H represent the characteristics of each channel. From Figure 3H it should be appreciated that, as the gain of the variable-gain linear amplifier is increased, the greater the brightness range with which a given negative density range is reproduced as a positive, and inversely a decrease in amplifier gain provides a decrease in brightness range for the reproduction as a positive of the same negative density range. This is indicated by the different curve slopes in Figure 3H. In effect, therefore, the variable-gain amplifier provides a means for controlling or determining the contrast of the positive picture shown on the face of the cathode-ray tube. Accordingly, the amplifier-gain control may be called a contrast control and may be calibrated in terms of contrast.

A further appreciation of the operation of this invention may be obtained by seeing what happens at various points in a channel to a video waveform obtained by scanning a line of a negative having the test pattern densities shown in Figure 4. The signals are shown against a scale of relative video voltage values with white or maximum screen brightness being obtained with zero volts applied to the grid and black or minimum screen brightness being obtained with a relative video voltage value of -1.00 . Figure 4A shows the video waveform obtained at the output of the video preamplifier. Figure 4B is illustrative of the video waveform obtained at the output of the logarithmic amplifier. This curve then has its pedestal clipped at a level determined by the printer-light control. The resulting signal is shown in Figure 4C. The output of the variable-gain amplifier is shown in Figure 4D for three different gain-control settings corresponding to the three settings shown in curves of Figure 3D. The output of the photo-curve amplifier for only one of the settings is shown in Figure 4E. Figure 4F shows the positive picture which is seen on the cathode-ray tube screen at the output of the channel.

It will be appreciated that the system described in using electronic techniques presents a positive picture from a photographic negative. The positive picture reproduces the colors of the original when signals, corre-

sponding to those obtained by scanning three color image aspect negatives with the flying-spot scanner, are respectively applied to the three channels. By adjusting the printer-light control and the contrast control in each channel, the color brightness and contrast of the positive picture presented, and thereby the overall color balance, may be determined. In accordance with known photographic techniques, contrast may be determined from a knowledge of the characteristics of the material on which a positive print is to be made together with the development procedure used with it. Thus, different types of positive stock may have different contrasts, or a given type of positive stock may be developed in different ways to yield different contrasts. These may be given different numbers and these numbers can be used for calibration of the contrast control. With the printer-light control and the contrast control calibrations established, the correct exposure and contrast may be obtained readily for any set of negatives by scanning them and adjusting the controls in each channel until a positive picture is presented having the desired color balance and contrast. The control settings in each channel are then read and employed in the actual printing of the positives.

A preferred manner of employing this system for providing printer exposure data for photographic printing of motion pictures is as follows: Motion pictures of a particular setting and action are taken. Separation negatives of the motion pictures taken at the set are then developed and scanned by the flying-spot scanner, and the resulting signals are applied to the respective color channels. The picture presented by the cathode-ray tube apparatus is viewed alongside of an optically projected reference of previously processed film of like character. The printer-light controls and contrast controls may then be varied until the picture seen on the cathode-ray tube apparatus has the desired color balance and contrast substantially as shown in the optically projected reference. The printer-light and contrast control settings for each channel may then be read or recorded and then used in processing, and the finished prints will have all the qualities of the reference print.

Although the embodiment of the invention has been thus far described as providing printer exposure data for photographic printing when three separate black and white color separation negatives are scanned by the flying-spot scanner, this is not to be construed as a limitation on the use of the apparatus. Actually, any means for deriving signals of the type obtained when the color separation negatives are scanned can be employed, and these signals may be applied to the respective channels to produce a color positive picture. The signals may also be obtained from any of the multilayer negatives used in color photography such as integral tripack stock of the color negative type by scanning the signal negative with a flying-spot scanner and splitting the resultant beam into three with a beam splitter and then using a different filter in front of each phototube so that only the signals representative of the color components which each channel is designed to control are applied to that channel. If preferred, dichroic mirrors may be used, in the manner well known in the art, to split the light beam after it has been passed through the negative being scanned into three beams each, representative of the color component which each of the channels is to control. Accordingly, when reference is made herein to separate negatives, the same is intended to include multiple emulsion negatives on a single base.

Without any modifications this invention may be used to provide exposure data for the three separate black and white negatives obtained from multilayer stripping film. It should be obvious that a single channel may be used for providing data and also that two channels may be used for providing data from bipack film, the cathode-ray tube screen phosphors being selected to provide the proper color, or white cathode-ray tube screens being used

with proper color filters being positioned in front thereof. It should be appreciated, therefore, that the invention is useful to provide printer exposure data from signals of the proper type regardless of the source of said signals or the original recording medium from which the signals of the proper type are generated. These signals, for example, may be recorded on magnetic tape. These signals may also be obtained by scanning color paper negatives, using reflection techniques to derive the signals. The above are just a few of the uses of this invention in both still and motion picture photography. The fact that only these are recited should not be construed as a limitation since many other uses, such as in lithography, will occur to those skilled in these arts and may still be within the spirit and scope of this invention.

As previously stated, circuits for the flying-spot scanner tube and the respective phototubes and video preamplifiers are well known in the television field and may be found described under the name flying-spot camera.

Figure 5 is a circuit diagram of the logarithmic amplifier, pedestal clamp, and pedestal clipper which are employed in the embodiment of the invention. As previously stated, the logarithmic amplifier has a transfer function wherein its output is substantially proportional to the logarithm of its input. To achieve this, "curve-fitting" techniques are employed of the general type described in Waveforms by Chance et al., page 315, and published by the McGraw-Hill Book Company. The video output from the preamplifier 20 is applied to the logarithmic amplifier input which consists of two stages of video amplification 60, 62 including two amplifier tubes with feedback between the plate of the second and the cathode of the first, in order to assure linearity. The output from the second of these two video amplification stages is applied to a first curve-fitting section 63. The first section consists of a cathode follower 64 having its cathode coupled to the grid of a succeeding cathode stage follower 66 via two resistors 68, 70 in series. A first diode 72 has its cathode connected to the junction of the two resistors 68, 70 through a third resistor 74 and its anode connected to the cathode of a cathode follower tube 76. A second diode 78 has its cathode connected through a resistor 80 to the connection with the grid of the succeeding cathode follower stage 66. This diode also has bias applied to its anode by means of a cathode follower stage 84. The output of the first curve-fitting section 63 is applied to a second curve-fitting section 86 which is similar to the first. The output of the second curve-fitting section 86 is applied to two stages 88, 90 of video amplification which have the same circuit as the first two stages 60, 62. The output is applied to another curve-fitting section 92 in similar to the first and again consisting of a cathode follower 94 whose output is coupled to a succeeding stage 96 via two series resistors 98, 100. Two diodes 102, 104 are coupled through other resistors to these two resistors and are biased by means of cathode followers 106, 108. One more "curve-fitting" diode 110 is employed at the output of the third section so that, in all, seven "curve-fitting" diodes are employed. These diodes are biased to provide a transfer characteristic as shown in Figure 2C. This is obtained by biasing the diodes increasingly negative so that, instead of a linear input versus output curve, the input versus output curve is bent by reason of the diodes permitting amplification of increases in signals in a non-linear incremental fashion. The output of the last curve-fitting section is applied to the pedestal clipping section 26, which will be described in greater detail later. Cathode followers are used to bias the respective curve-fitting diodes in order to provide the utmost in stability of said biasing and to preserve the D. C. component.

The circuit shown below the logarithmic amplifier consists of two clamping or D. C. restoring circuits. These are represented by the rectangle 22 in Figure 1. The clamping action in this instance is not passive, de-

pending on average signal value, but is active and is obtained using the horizontal sync signal. Clamps of this type may be found described in Television Engineering by Fink, pages 298-299, and published by the McGraw-Hill Book Company. This clamp uses four diode rectifiers 110, 112, 114, 116 connected in bridge fashion. The horizontal sync signal which is used to deflect the flying-spot scanner beam is amplified by two stages of amplification 120, 122. The output is applied to two separate phase-splitting stages 124, 126 whose output is respectively applied to two opposite terminals 128, 130 of each rectifier bridge. A bias is applied to a third one 132 of the remaining diagonal terminals of each bridge from a fixedly biased cathode follower stage 134. The output from the remaining diagonal 136 of one of the bridges is coupled to the grid of the first cathode follower 64 employed in the first curve-fitting section. The output from the remaining diagonal 136' of the other bridge is coupled to the grid of the cathode follower 94 following the second video amplifier section of the logarithmic amplifier. This assures that the signals being applied to the curve-fitting portions of the logarithmic amplifier are at all times clamped to the desired D. C. level since the clamping signal is renewed with each line.

Figure 6 is a circuit diagram of the printer-light control for one channel. It consists of two voltage divider networks 140, 142 followed by a cathode follower tube 144. The first voltage divider is connected across a source of bias potential. It includes two fixed resistors 146, 148 in series with a potentiometer 150. The potentiometer tap is connected in series with the second voltage divider consisting of two fixed resistors 152, 154 and two potentiometers 156, 158 in series. The potentiometer 150 in the first voltage divider is used to adjust roughly the current flowing through the second voltage divider. The potentiometers 156, 158 in the second voltage divider have their values selected to provide, respectively, coarse and fine controls for setting up the bias provided to the grid of a cathode follower tube to which the fine control potentiometer arm is connected. All the potentiometers are in the printer-light control but, in practice, once the two coarse controls are set, they are rarely adjusted further. Thus the rotation of the arm of the potentiometer 158 connected to the grid of the tube may be calibrated in well-known fashion by means of a dial (not shown) either in exposure time or in printer-light illumination level. The cathode follower 144 is used to bias the three diodes 160, 162, 164 in Figure 6, representative of the three diodes coupled between the last "curve-fitting" diode in the logarithmic amplifier and an output cathode follower tube 166. These three diodes may be considered as the pedestal clipper. The cathode of the cathode follower tube 144 in the printer-light control is coupled to the cathodes of three diodes 160, 162, 164 shown in the logarithmic amplifier of Figure 5. Thus it sets the level which a signal is required to exceed in order to be applied to the grid of the output stage 166. It should be noted that the bias diodes used in connection with the printer-light control and pedestal clipper are reversed from those used in the curve-fitting sections. The clipper control diodes are biased and connected so that if the signals applied are more positive than the bias, the diodes will conduct and thus clip off the more positive peaks of the pedestal of the video signal. This action is illustrated in Figures 4B and 4C.

The photo-curve amplifier circuit is substantially identical with the logarithmic amplifier circuit shown in Figure 5. The bias applied to the various diodes employed in the curve-fitting sections in this instance, however, is such as to provide a transfer characteristic in accordance with the curve shown in Figure 2F. Of course, no clipping section is needed for the photo-curve amplifier.

Figure 7 is a circuit diagram of the variable-gain linear amplifier 30 and also shows the contrast control 32. The amplifier consists of two stages of video amplification 170,

172 and an output cathode follower stage 174. The gain of the amplifier is carefully controlled by controlling the feedback between the anode of the second video stage and the cathode of the first video stage. This controlled feedback is obtained by connecting the anode of the second video stage 172 through two series-connected resistors 176, 178 to a potentiometer 180. The potentiometer resistance has one end connected to the cathode of the first stage 170 and the other end connected to a resistance 182 which in turn is connected to ground. The variable arm of the contrast control potentiometer 180 is coupled to an indicator (not shown) in well-known fashion. This is then calibrated in terms of contrast versus amount of potentiometer arm rotation.

A circuit diagram for a fixed-gain linear amplifier is not shown since video amplifiers having the required qualities of linearity are well known. The variable-gain linear amplifier, the circuit of which is shown in Figure 7, can be and has been used for this purpose. Once its controls are set at the proper gain level, they are not adjusted further. The pedestal clamp 34 associated with the linear amplifier may be of the same type shown in the circuit diagram in Figure 5.

Power supplies, deflection circuits, and blanking circuits for the flying-spot scanner and the three cathode-ray tubes represented by rectangles are not shown in detail since these are well known in the television art and are commercially purchasable.

Any system using negatives from which color positives are to be made can employ the embodiment of the invention shown here. It is required merely that electrical signals be generated representative of either the optical transmission or optical density of the negatives from which a colored positive picture is to be made. These optical transmission signals can then be employed in the manner taught herein to produce a positive color picture. Optical density signals can be applied to the system after the logarithmic amplifier to achieve the desired results.

Another feature of this invention can be seen by referring to Figure 8. Figure 8 shows a resistance network which, if required, may be connected between and in channels at the output of the variable-gain linear amplifier. This network broadly serves the purpose of effectively modifying the positive picture obtained with this system so that it more accurately represents either the picture with which it is being compared or the results to be obtained with the finished positive picture.

An analysis of color prints indicates that colors, especially saturated colors formed by dyes used in a subtractive system, tend to be degraded in purity and reduced from their proper relative brightness because the dyes of one primary color have residual absorption within the wavelength region of the other primaries. Figure 9 shows typical spectral absorption curves of three subtractive dyes used in making positive pictures. The curves represent photographic density versus the wavelength in millimicrons and the regions of overlap of the curves are quite apparent. It can be seen therefore how much density or darkening each dye of a typical subtractive system produces within the wavelength region of the other dyes. To compensate for the darkening effect of the dyes within each other's wavelength region, the circuit shown in Figure 8 may be employed to simulate the cross-channel subtractions found in the dye system. The circuit permits feeding controlled amounts of signal where the voltage crossfeed is proportional to negative density from one channel to each of the others. It will be recalled that each channel derives its original signal modulation from a photographic negative; that is to say, where the negative has low density the corresponding signal is large, and this must drive the cathode-ray tube dark in order to correctly produce a positive picture. Accordingly, increasing a signal by adding thereto goes in the direction of darkness, and the cross-

channel exchange of signals works in the desired direction to simulate dye overlaps in the subtractive print.

It will be noted that each channel is connected to every other channel through two resistive circuits, each consisting of a resistor 201'—206' in series with a potentiometer 201—206. If it is assumed that the first channel will present the color red at its output, the second channel the color green, and the third channel the color blue, then the crossfeeds from one channel to the other control the simulation of the absorption effects as follows: potentiometer 201—blue absorption by magenta dye; potentiometer 202—blue absorption by cyan dye; potentiometer 203—green absorption by cyan dye; potentiometer 204—red absorption by magenta dye; potentiometer 205—green absorption by yellow dye; potentiometer 206—red absorption by yellow dye.

The curves in Figure 9 bear similar reference numerals to the potentiometers which are used to correct for the overlap effect which they represent.

The potentiometers in the cross-channel connections are adjusted in accordance with the information derived from the spectral-absorption curves to provide the proper amount of cross-channel signal for a given amplitude channel signal and confirmed by visual appraisal of color qualities. In addition, adjustable attenuators 207, 208, 209 are inserted in series in each channel. The purpose of these is to adjust the over-all signal voltage of each channel to the same level it would have if there were no crossfeed. These are substantially the same as contrast controls. If one of them should be set to zero (i. e., no attenuation) and the signal level of that channel should be increased by the contribution from another channel, the electronic color picture would be found to exhibit increased contrast since the brightness swing would be greater because of the other contributed signals. It is necessary, therefore, to adjust these controls to compensate for the voltage built up by crossfeed. Once all of the controls, both crossfeed and attenuation, are adjusted, these settings remain fixed so long as the equipment is required to reproduce pictures made by a given subtractive dye system. New settings are required to match pictures of a different color process. If a number of different color processes are employed, these networks may be made up as separate items which are preset and either plugged or switched in, in accordance with the systems in use.

Figure 10 is a circuit diagram of a preferred resistance network arrangement which achieves the same results as are achieved with the network shown in Figure 8 but does not produce the variations in contrast which require the use of the attenuators 207, 208, and 209. The potentiometers in Figure 10, which function to control the same respective crossfeeds, bear the same reference numerals as the potentiometers shown in Figure 8. The adjustment of these potentiometers is accomplished in the same manner as is described for the adjustment of the crossfeed potentiometers in Figure 8. However, in view of the cascade connections of the crossfeed potentiometers in Figure 10, i. e., each potentiometer 202, 203, 205 is connected between a different two channels and the respective third potentiometers 201, 203, 206 are each connected between the remaining channel and the potentiometric arm of a potentiometer connected across two channels, from the series connection shown in Figure 8, no contrast changes occur and the channel signal levels need not be attenuated by a separate set of attenuators. Sets of plug-in units of this potentiometer arrangement may also be made up for each different color process, if desired.

Accordingly, there has been shown and described a novel and useful system for reproducing electronically, in color, positive pictures from information derived from signals corresponding to the transference of color separation negatives. By employing the novel principles and structure described and shown herein, it will be apparent

that information for timing and processing the chemical development of color pictures, both for still and motion picture photography, may be obtained.

What is claimed is:

1. An image translating system comprising means to generate electrical signals representative of the light transmission of discrete areas of a photographic negative, electronic means responsive to said electrical signals to present the corresponding positive picture of said image, means to control the contrast of said positive picture, and means to control the brightness of said positive picture.

2. An image translating system as recited in claim 1 wherein said means to control the brightness of said positive picture includes an indicator variable therewith and calibrated in terms of exposure.

3. An image translating system comprising means to generate electrical signals representative of the light transmission of discrete areas of color image aspect negatives of said image, electronic means responsive to said signals to present a corresponding positive picture in color of said image, means to control the positive contrast of each primary color in said picture, and means to control the color balance of said picture.

4. An image translating system as recited in claim 3 wherein said means to control the color balance of said picture includes an indicator controlled by said means and calibrated in terms of exposure.

5. An image translating system comprising means to generate electrical signals representative of the optical density of discrete areas of different color image aspect negatives, and electronic means to convert said signals to point-by-point variations of colored light sources corresponding to the colors represented by the different color image aspect negatives to present a colored positive picture of said image, said last named means including means to control the contrast of each color of said colored positive picture, and means to control the brightness of each color in said colored positive picture.

6. A system for presenting a positive picture of an object with cathode-ray tube apparatus from signals representative of the optical density of discrete areas of a photographic negative of said object comprising means to modify said signals in accordance with a desired relationship between negative density and screen brightness of said cathode-ray tube apparatus, and means to apply said modified signals to said cathode-ray tube apparatus to present a picture of said object.

7. A system for presenting a positive colored picture of an object with cathode-ray tube apparatus from signals representative of the optical density of discrete areas of color image aspect negatives of said object comprising means to modify said signals in accordance with a desired relationship between negative density and screen brightness of said cathode-ray tube apparatus, and means to apply said modified signals to said cathode-ray tube apparatus to present a positive picture of said object in color.

8. A system for presenting a positive picture of an object with cathode-ray tube apparatus from signals representative of the optical transmission of discrete areas of a photographic negative comprising means to modify said signals to be representative of the density of said negative, means to modify said density representative signals in accordance with a desired relationship between negative density and screen brightness of said cathode-ray tube apparatus, and means to apply the output of said last named means to said cathode-ray tube apparatus to present said positive picture.

9. A system for presenting a positive picture of a colored object with cathode-ray tube apparatus from signals representative of the point-by-point optical transmission of discrete areas of photographic separation negatives made from the colored object comprising means to modify said signals to be representative of the density of said negative, means to modify said density representative signals in accordance with a desired relation-

ship between negative density and screen brightness of said cathode-ray tube apparatus, and means to apply the output of said last named means to said cathode-ray tube apparatus to present said positive picture in color.

10. A system for presenting a positive picture of a colored object with cathode-ray tube apparatus from signals representative of the optical transmission of discrete areas of color image aspect negatives made from the colored object comprising an image translating channel for each different color image aspect each of which includes means to modify said signals to signals representative of the density of said negative, means to modify said density representative signals in accordance with a desired relationship between negative density and screen brightness of said cathode-ray tube apparatus, said cathode-ray tube apparatus including a cathode-ray tube for each channel, each tube having a screen providing illumination having the color associated with the negative providing signals for the channel, means in each channel to apply said modified density representative signals to the cathode-ray tube in the channel, and means to superimpose the light outputs from all the cathode-ray tubes to provide a positive colored picture of said object.

11. A system for presenting a positive picture of an object with cathode-ray tube apparatus from signals representative of the light transmission of discrete areas of a negative of said object comprising means to apply a logarithmic correction to said signals to obtain signals representative of the optical density of said negative, means to control the average value of said density representative signals to determine the brightness of the positive picture, means to amplify the output of said average value controlling means, means to control the gain of said means to amplify, to determine the contrast of said positive picture, means to modify the output of said means to amplify in accordance with a desired negative density to cathode-ray tube screen brightness characteristic and to compensate for the transfer characteristic of said cathode-ray tube apparatus, and means to apply the output of said means to modify to said cathode-ray tube apparatus to present a positive picture of said object.

12. A system as recited in claim 11 wherein said means to control the average value of said density representative signals includes an indicator coupled to said means to be variable therewith, said indicator being calibrated in terms of printing exposure required for said negative.

13. A system for presenting a positive colored picture of an object with cathode-ray tube apparatus from signals representative of the light transmission of discrete areas of color image aspect negatives of said object comprising a separate channel for the signals from each negative, each channel having a logarithmic network to which said signals are applied, means to clip at a desired level the pedestal of the output signals from said logarithmic network to control the color brightness of the output from a channel, an amplifier to which the output of said means to clip is applied, means to control the gain of said amplifier to control the contrast of the output from said channel, and means to modify the output of said means to amplify in accordance with a desired negative density to cathode-ray tube screen brightness characteristic and to compensate for the transfer characteristics of said cathode-ray tube apparatus; and means to apply said modified signals from each channel to said cathode-ray tube apparatus to present a positive colored picture.

14. A system as recited in claim 13 wherein said means to clip at a desired level includes an indicator coupled to vary with the desired clipping level, said indicator being calibrated in accordance with printer-light illumination units required to provide a positive print having substantially the same color brightness.

15. In a system for electronically presenting a positive colored picture of an object from signals representative of the light transmission of discrete areas of three

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color image aspect negatives where the signals for each color are translated in a separate channel to control cathode-ray tube apparatus to provide an additive picture presentation, means to modify said additive picture presentation to resemble a desired subtractive color picture presentation comprising network means coupled between channels to feed signals therebetween to simulate the overlap effects on one another of primary color dyes used in said desired subtractive color picture, said network means including a first potentiometer means coupled between a first and second of said signals, a second potentiometer means coupled between said first and a third of said separate channels, and a third potentiometer means coupled between said second and third of said channels.

16. A system for presenting a positive colored picture of an object with cathode-ray tube apparatus from signals representative of the optical density of discrete areas of color image aspect negatives of said object comprising a separate channel for the signals for each different color image aspect negative, network means coupled between channels to feed signals therebetween having an amplitude to achieve effects on the signals in the channels representative of the overlap effects of primary color dyes used in a desired subtractive system on one another, means in each channel to modify the signals in said channel in accordance with a desired relationship between negative density and screen brightness of said cathode-ray tube apparatus, means to modify the signals in each channel to compensate for the transfer characteristics of said cathode-ray tube apparatus, and means to apply said doubly modified signals of all the channels to said cathode-ray tube apparatus to present a positive picture of said object in color.

17. A system as recited in claim 16 wherein each channel includes means to attenuate the signal levels in each channel to compensate for the signals fed between said channels.

18. A system for presenting electronically a positive colored picture of an object with cathode-ray tube apparatus from signals representative of the light transmission of discrete areas of color image aspect negatives comprising a separate channel for the signals from each color image aspect negative, each of said channels including a logarithmic circuit to which said signals are applied, a peak clipping circuit coupled to the output of said logarithmic amplifier, means to control the clipping level of said peak clipping circuit to determine the color balance of the picture finally presented, an amplifier, means to control the gain of said amplifier to control the contrast of the picture finally presented, network means coupled between said three channels at the output of said amplifier in each channel to feed signals therebetween representative of the overlap effects of primary color dyes to be used for a subtractive representation of said colored picture, attenuator means in each channel to compensate the signal levels for the effects of said network means, means in each channel to modify the output of said attenuator in accordance with a desired negative density to cathode-ray tube screen brightness characteristic; and means to apply the output of each said means to modify circuit means to said cathode-ray tube apparatus to present a positive colored picture.

19. A system for presenting electronically on cathode-ray tube apparatus a positive colored picture of an object from color image aspect negatives made from said

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object comprising a separate channel for each color image aspect negative each including means to generate signals representative of the light transmission of corresponding discrete areas of each negative, a logarithmic amplifier, means to apply said signals to said logarithmic amplifier to obtain signals representative of the density of said discrete areas, a pedestal clipper, means to apply said density representative signals to said pedestal clipper, means to control the clipping level of said pedestal clipper to determine the color balance of the picture finally presented, calibrated means controlled by said means to control the clipping level and calibrated in terms of illumination intensity required for obtaining a positive print of similar color brightness from the negative associated with said channel, a variable-gain linear amplifier coupled to receive output from said pedestal clipper, means to control the gain of said linear amplifier to determine the contrast of the picture finally presented, photo-curve amplifier means to provide an input to output characteristic representative of a desired relationship between negative density to cathode-ray tube screen brightness and the compensation required for a cathode-ray tube transfer characteristic, means to couple the output of said linear amplifier to said photo-curve amplifier means, and a cathode-ray tube coupled to receive output from said photo-curve amplifier means, said cathode-ray tube having a screen providing a color corresponding to the primary color represented by the color image aspect negative associated with said channel, and means to combine the images displayed on each cathode-ray tube screen into a single colored picture of said object.

20. A system as recited in claim 19 wherein said means to apply the output of said variable-gain linear amplifier to said photo-curve amplifier means includes a resistance network coupled between each of said channels to feed signals therebetween representative of the overlap effects of primary color dyes to be used for a subtractive representation of said colored picture.

21. A system as recited in claim 20 wherein said resistance network includes a different first potentiometer connected across a different two of said channels and a different second potentiometer connected between one of said channels and the potentiometric arm of a different one of said first potentiometers which is not connected to said one channel.

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