July 25, 1961 G. S. J. ALLEN ET AL 2,993,954

COLOUR OR TONAL REPRODUCTION

Filed Sept. 29, 1958 3 Sheets-Sheet 1

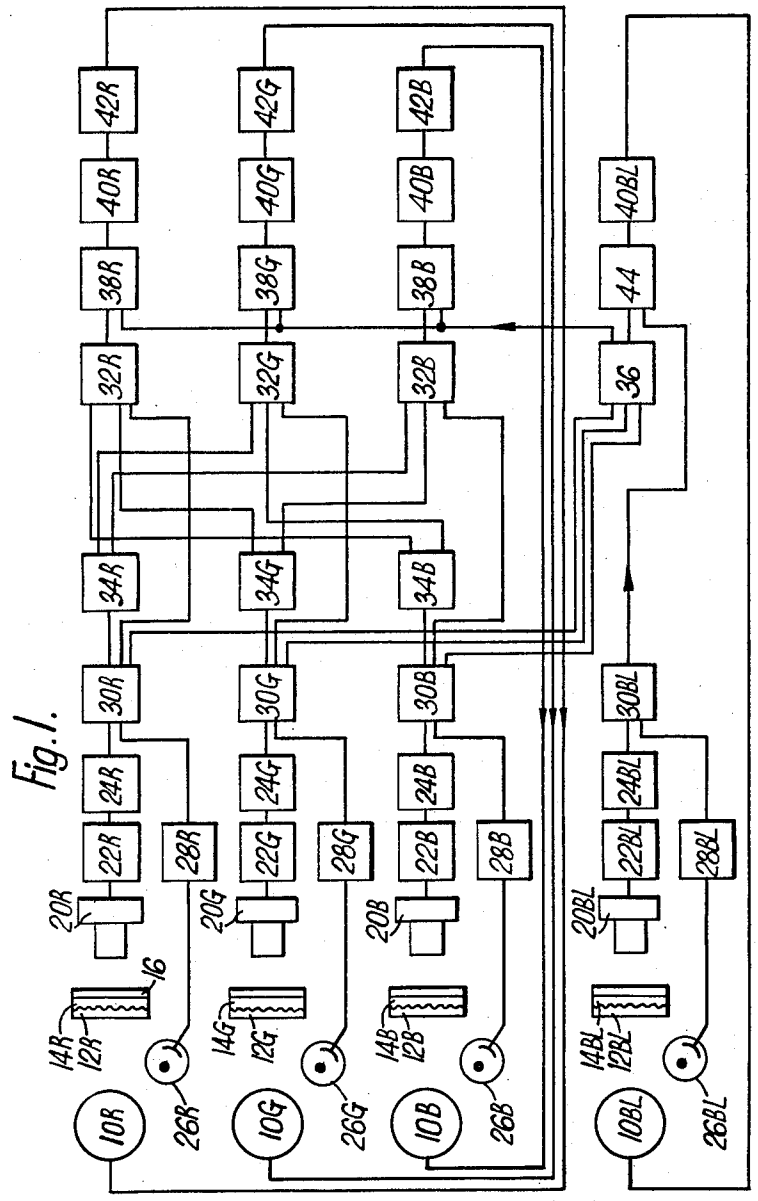


Fig. 1.

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Fig. 2.

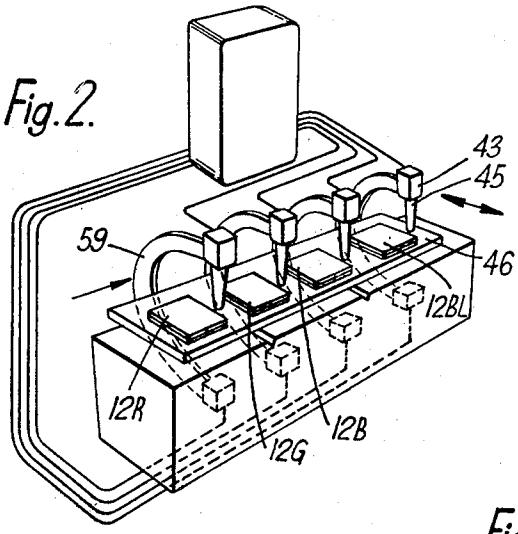


Fig. 3.

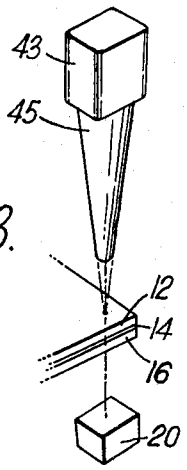
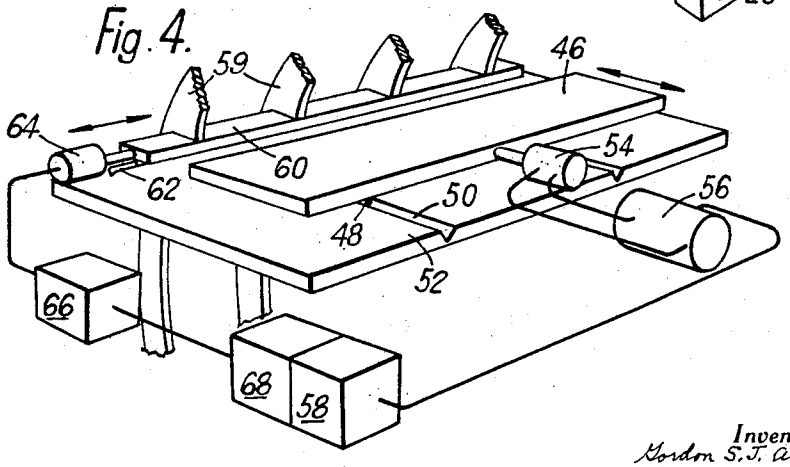


Fig. 4.



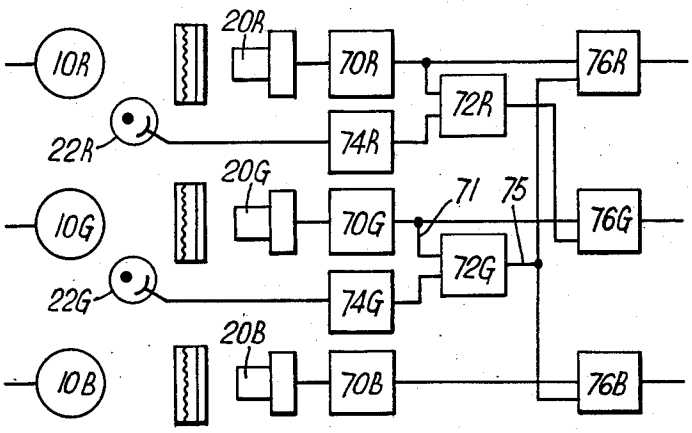
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Fig. 5.



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United States Patent Office 2,993,954
Patented July 25, 1961

2,993,954

COLOUR OR TONAL REPRODUCTION

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Filed Sept. 29, 1958, Ser. No. 764,094
11 Claims. (Cl. 178—5.2)

This invention relates to a scanning system for use in colour and tonal reproduction. The invention is particularly, but not exclusively, concerned with colour correction in the production of separation negatives or positives for use in colour reproduction.

In our co-pending application Ser. No. 654,408 there is claimed a method in which a single light source, modulated in accordance with the output of an electrical computer, serves both to scan uncorrected transparencies to provide information from which the required correction can be computed and to expose an emulsion in accordance with corrected information. Separate scanning beams from the light source are transmitted through a number of uncorrected transparencies and fall on a number of light-sensitive devices, the modulated electric signals from which are applied to the electrical computer which computes the required correction from the signal variations. The emulsion to be exposed is placed behind the uncorrected transparency for which the correction has been computed, so that light passing through the latter to the associated light-sensitive device also passes through the emulsion to be exposed. This system has the advantage that the emulsion which is being exposed is in contact with, or closely adjacent to, its associated uncorrected transparency. In this specification, the term "transparency" is intended to mean a negative or positive black and white image.

According to the present invention, a number of light sources, at least one of which is modulated in accordance with output signals from an electrical computer, are used to scan respectively a number of uncorrected transparencies to provide information from which the required correction can be computed. The modulated light source or sources serve also to expose a photographic emulsion or emulsions in accordance with corrected information derived from the computer. Scanning beams from the light sources are transmitted through the uncorrected transparencies and fall on a number of light-sensitive devices behind the transparencies, the modulated electric signals from the light-sensitive devices being applied to the computer, which then computes the required correction from the signal variations. The unexposed photographic emulsion or emulsions are placed behind the corresponding uncorrected transparency or transparencies for which a correction has been computed, so that light passing through one of these uncorrected transparencies to the associated light-sensitive device also passes through the photographic emulsion to be exposed.

In the preferred form of the invention, the computer determines the correction required for each of the uncorrected transparencies and generates different output signals which modulate accordingly the light sources associated with the uncorrected transparencies. The photographic emulsions to be exposed by means of these uncorrected transparencies are then placed behind the latter, respectively, and are exposed at each point in accordance with the corrected light values.

The scanning of the uncorrected transparencies by the light sources can conveniently be achieved by arranging for the transparencies to be mounted in a common frame which can be moved with respect to the light sources, or for the light sources to be moved in unison with respect to the transparencies. In a further form, the transparencies are mounted in a frame which is given an oscillatory movement in opposite directions and the light sources are mounted on a common member which is given an oscillatory movement in directions perpendicular to that of the transparencies.

In order that the invention may be better understood, embodiments thereof will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 shows diagrammatically the general arrangement of the scanning system and the circuit diagram of the apparatus;

FIGURE 2 shows diagrammatically the mechanical details of the apparatus;

FIGURE 3 is an enlarged view of the optical system associated with each transparency in FIGURE 2;

FIGURE 4 shows in greater detail the mechanical construction of the scanning system; and

FIGURE 5 is a circuit diagram of an alternative form of the apparatus.

In FIGURE 1 four light sources **10**R, **10**G, **10**B and **10**BL, each consisting of a crater lamp together with an optical system, are arranged to scan three separation negatives **12**R, **12**G and **12**B, and a fourth negative **12**BL, respectively. The fourth negative **12**BL is a "white light" negative, obtained by the exposure of the multicolor original to white light. The photographic layers **14**R, **14**G, **14**B and **14**BL to be exposed are placed immediately behind the corresponding negatives with the emulsion surfaces in contact, and are backed by filters **16** such that they pass only light to which the unexposed photographic emulsions are insensitive. These filters thus prevent the transmission to these photographic layers of light to which they are sensitive, and thereby prevent unwanted exposure of these emulsions due to light reaching the latter through the back surface of the photographic plates. Assuming the photographic emulsions to be sensitive only to the blue end of the spectrum, the backing filters **16** absorb blue light but transmit light in the remainder of the spectrum.

Light from the source **10**R which passes through the separation negative **12**R and the backed photographic plate **14**R—**16** is collected by a photomultiplier **20**R which provides at any instant an output signal corresponding to the transmittance value of the element of the separation negative **12**R which is being scanned. Similarly the photomultipliers **20**G, **20**B and **20**BL receive light from the light sources **10**G, **10**B and **10**BL, respectively, modulated by the associated transparencies. It is arranged that the four negatives are scanned in unison by the four light sources so that the output signals from the four photomultipliers **20**R, **20**G, **20**B and **20**BL include information representing at any instant the transmittance values of corresponding elements of the four negatives.

The signals from the four photomultipliers are applied respectively through cathode follower circuits **22**R, **22**G, **22**B and **22**BL to logarithmic circuits **24**R, **24**G, **24**B and **24**BL which provide, respectively, output signals representing the logarithms of the signals provided by the three photomultipliers. Each photomultiplier provides signals which are proportional to the product of the brightness of the corresponding light source and the transmission factor of the element of the corresponding uncorrected negative which is being scanned at the instant in question. The output of each logarithmic circuit therefore represents the sum of the logarithms of the brightness of the light source and the transmission factor of the scanned element of the corresponding separation negative. The logarithm of the transmission factor is proportional to the inverse density of the negative.

To enable the modulation which is due to the intensity variations of the light sources to be removed from the photomultiplier signals, four photoelectric cells (or

photomultipliers) 26R, 26G, 25B and 26BL are exposed directly to the four light sources and their output signals are passed through logarithmic circuits 28R, 28G, 28B and 28BL and are then subtracted from the four photomultiplier signals, respectively, in subtraction circuits 30R, 30G, 30B and 30BL. The output signals from these latter circuits therefore represent the logarithms of the transmission factors of the scanned elements of the four negatives, that is to say the inverse densities of the scanned elements. The first three of these output signals are therefore suitable for the preparation of yellow, cyan and magenta printers for the subtractive printing process.

The output signals from the subtracting circuits are applied directly to masking circuits 32R, 32G and 32B and also to inverting and attenuating circuits 34R, 34G and 34B. The inverting and attenuating circuit in each channel applies an output signal, suitably attenuated, to each of the two masking circuits in the other channels. Thus, considering the blue filter signal (yellow printer) the signal from circuit 30B, which represents the inverse density of the uncorrected negative or the density of the required printer (neglecting correction), is applied to the masking circuit 32B in which it is combined with inverted and attenuated signals from the green and red filter channels.

The colour channel signals from the subtraction circuits 30R, 30G and 30B are applied to a minimum-signal selection circuit 36, which provides an output signal the amplitude of which equals at any moment that of the minimum of the three colour channel signals. This output signal is used for the production of the black printer. A signal representing the colour contributed by the black printer is applied from the circuit 36 to each of the summing circuits 38R, 38G and 38B and is there combined with each of the masked colour channel signals from the circuits 32R, 32G and 32B. These signals are used to reduce the intensity of the light sources and the addition of the black printer signal to the colour channel correction signals therefore constitutes undercolour removal.

The colour channel signals from the circuits 38R, 38G and 38B are applied through anti-logarithmic circuits 40R, 40G and 40B, which provide output signals representing the anti-logarithms of the input signals, to limiting circuits 42R, 42G and 42B. These limiting circuits prevent the brightness of the light sources from increasing beyond a certain level, and their output signals are used to control the modulation of the light sources 10R, 10G and 10B, respectively.

The modulation which reaches each photomultiplier therefore represents the transmission factor of the scanned elements of the associated separation negative, modified by the intensity variation of the corresponding light source, representing the correction required for that negative.

The E.H.T. supply to the photomultiplier is preferably pulse-modulated so as to provide pulsating output signals for convenience in the subsequent computing circuits.

In an alternative embodiment, the photoelectric cells 26R, 26G and 26B are omitted and the demodulating signals to be applied to the subtraction circuits 30R, 30G and 30B are obtained directly from the output signals from the limiter circuits.

The black printer signal from the circuit 36 is applied to a subtraction circuit 44. In this circuit, the signal from the circuit 30BL, which represents the density of the "white light" negative 12BL through which the black printer is exposed, is subtracted from the black printer signal. The resultant signal, after passing through a logarithmic circuit 40BL is used to control the intensity of the lamp 10BL. Thus the density values of the "white light" negative do not affect the total exposure of the black printer, this negative being used only to provide the sharpness which results from a contact printing operation.

FIGURES 2, 3 and 4 show the mechanical arrangement of a scanning system suitable for use in the apparatus of FIGURE 1. As is shown in FIGURE 3, each light source consists of a crater lamp 43 to which is affixed an optical system 45 arranged to produce a spot of light in the plane of the transparency 12. This light passes through the transparency and the underlying photographic emulsion 14 and backing 16 to the photomultiplier 20. Referring again to FIGURE 2 the four transparencies 12R, 12G, 12B and 12BL, with their underlying unexposed photographic emulsions, are mounted in apertures on a common table 46. As is shown in greater detail in FIGURE 4, this table is mounted on balls 48 which run in grooves 50 in a base 52, and the table is given oscillatory movement in the direction of these grooves by a hydraulic piston in a cylinder 54 controlled by a flow control valve 56 connected to an oil pressure unit 58. This arrangement enables the uncorrected transparencies and the unexposed photographic emulsions to be moved in unison in oscillatory manner with respect to the four light sources. To enable the light spot to complete the scanning of each uncorrected transparency, relative movement between the light sources and the transparencies in a direction perpendicular to the oscillatory movement of the table 46 must be provided, and this is achieved by mounting the light sources on arms 59 attached to a common arm 60 which is mounted on balls in a groove 62, perpendicular to the grooves 50, in the base 52. The position of the arm 60 is governed by a hydraulic piston within a cylinder 64, under the control of a flow control valve 66 connected to an oil pressure unit 68. The operation of the flow control valves is such that the table 46 is given an oscillatory movement in the direction of the grooves 50 which is rapid compared with that which is given to the arm 60. In this way a scanning raster is built up on each transparency, the movement of the table 46 being responsible for the line scan of the raster and the movement of the arm 60 for the frame scan. The four photomultipliers are also attached to the arms 59 and move in unison with the lamps.

Instead of removing from the colour channel signals the modulation due to the variation of the brightness of the light source by subtracting from each composite signal a signal derived from a photoelectric cell exposed to the corresponding light source, the colour correction in a given colour channel can be achieved by subtracting from a transmission factor signal in that channel a transmission factor signal of another channel, representing a colour which is to be used to correct the first colour, and in this way at the same time removing to a certain extent the modulation due to the variation of brightness of the light sources. The magenta printer signal is corrected by subtracting from it a part of the cyan printer signal, and the cyan and yellow printer signals are each corrected by the subtraction of a part of the magenta printer signal. A diagrammatic representation of the circuit for a single colour channel is given in FIGURE 2 of our co-pending application Ser. No. 654,408. By subtracting the correcting colour signal from the signal representing the colour to be corrected in this way (both signals including information representing the transmission factors of the corresponding uncorrected transparencies) the modulation due to variation in the intensity of the light source in the channel to be corrected is removed to a certain extent, and it is found that this degree of removal of the modulation is sufficient for most purposes.

The method according to the invention can be used to carry out the electronic equivalent of a photographic technique which may be called successive two-stage masking. Considering the masking of the yellow printer by the magenta printer, in the photographic process a first corrected yellow positive is made by combining the uncor-

rected yellow negative with a mask which has previously been made by combining the uncorrected yellow negative and the uncorrected magenta negative. The first corrected yellow positive is registered with the uncorrected magenta negative to produce a further mask, which is registered with the uncorrected yellow negative to make a second corrected yellow positive. This process can go on indefinitely, the amount of the correction carried out becoming progressively less at each stage.

FIGURE 5 shows an embodiment of apparatus in which the method according to the present invention is applied to this process. The signals from the yellow printer (blue filter) and magenta printer (green filter) photomultipliers **20**B and **20**G are passed through logarithmic circuits **70**B and **70**G. A subtraction circuit **72**G subtracts from the logarithmic magenta channel signal on conductor **71** a signal from the photoelectric cell **22**G which has passed through a further logarithmic circuit **74**G. In this way the magenta channel signal is demodulated to remove the effect of the "correcting" variations in the brightness of the corresponding light source. The resulting signal on conductor **75**, representing density values of the uncorrected magenta printer negative, and the yellow channel signal from the logarithmic circuit **70**B, representing density values of the corrected yellow printer negative (the modulation due to the light source being still present) are fed to a subtraction circuit **76**B, the output of which, after passing through antilogarithmic and limiting circuits, is used to control the intensity of the corresponding light source **10**B.

The uncorrected magenta printer signal is also combined with the corrected cyan printer (red filter) signal in a subtraction circuit **76**R to provide the correction signal for the cyan channel. The correction signal for the magenta channel is obtained by subtracting, from the "corrected" magenta printer signal provided by the logarithmic circuit **70**G, an "uncorrected" cyan printer signal from the subtraction circuit **72**R, which is obtained by demodulating the output of the photomultiplier **70**R to remove the effects of variations of intensity of the corresponding light source.

The method according to the invention can also be applied to the production of screened positives and negatives, using the methods described in our co-pending application Ser. No. 654,408. Alternatively, the photographic plates which are used may already have a screen image exposed on them.

In some circumstances it may be desirable to insert a mask between the uncorrected transparency and the emulsion to be exposed, for example to modify a picture or compensate for a variation in density in the picture, or to remove part of a picture.

It will be appreciated that other forms of light source can be used in place of the crater lamps which have been shown. If cathode ray tubes are used as the light source, the necessity for a mechanical scanning system is removed, since the scanning of the uncorrected transparencies can be effected as a result of applying suitable potentials to the deflection electrodes of the cathode ray tubes.

If desired, a rotating scanner system can be employed. In one example, the uncorrected transparencies are wrapped around a hollow transparent cylinder, side by side and axially spaced along the latter. A film bearing the emulsion to be exposed is placed behind each negative, a stationary light source is arranged outside the cylinder in front of each uncorrected transparency, and a stationary photomultiplier is arranged inside the cylinder behind each emulsion to be exposed, these positions being reversible. The cylinder is then given a helical movement to cause the light spot from each light source to scan the whole of the corresponding transparency.

Although the invention is primarily concerned with colour correction, it can also be used for tone correction of the separation transparencies used in the production of a multicolor print, or for the improvement of resolution in such transparencies.

We claim:

1. Apparatus for reproducing visual images, comprising a plurality of transparencies, a light source for each transparency, means for effecting simultaneous synchronous relative movement between said light sources and transparencies for scanning said transparencies element by element, light-sensistive devices behind said transparencies which convert the light passing through the transparencies into electric signals of corresponding magnitude, means including an electrical computer for generating from said signals the electric correction signal required for the scanned element of at least one of said transparencies, means driven by said correction signal for modulating the brightness of the corresponding light source, and an unexposed light-transmitting photographic layer placed immediately behind and substantially in contact with said transparency for which the correction has been computed, whereby light which passes through said transparency to the associated light-sensitive device also passes through said photographic layer and exposes it in accordance with corrected light values.

2. Apparatus for reproducing visual images, comprising a plurality of transparencies, a light source for each transparency, means for effecting simultaneous synchronous relative movement between said light sources and transparencies for scanning said transparencies element by element, light-sensitive devices behind said transparencies which convert the light passing through the transparencies into electric signals of corresponding magnitude, means including an electrical computer for generating from said signals the respective electric correction signals required for the scanned elements of said transparencies, means driven by each correction signal for modulating the brightness of the corresponding light source, and a plurality of unexposed light-transmitting photographic layers one placed immediately behind and substantially in contact with each transparency, whereby light which passes through a transparency to the associated light-sensitive device also passes through said associated photographic layer and exposes it in accordance with corrected light values.

3. Apparatus according to claim 2, including a common base, in which said transparencies are mounted and a common member on which said light sources are mounted, said scanning means including driving means whereby relative scanning movement takes place between said common base and said common member.

4. Apparatus according to claim 3, in which said common base is arranged for linear oscillatory movement in opposite directions, and said common member is arranged for linear oscillatory movement in directions perpendicular to the first, said directions and the rates of movement being selected so that the light spot from each light source follows a scanning raster covering the whole of the associated transparency.

5. Apparatus according to claim 2, including screening means whereby a screen pattern is produced on each of said photographic layers.

6. Colour correction apparatus comprising a plurality of colour separation transparencies, a common base on which said transparencies are mounted, a light source for each transparency and a common member on which said light sources are mounted, driving means for effecting relative movement of said common base and said common member whereby said transparencies are scanned by light spots from said light sources simultaneously and in synchronism, element by element, light-sensitive devices behind said transparencies which convert the light passing through the transparencies into electric signals of corresponding magnitude, means including an electrical computer for generating from said signals the respective electric correction signals required for the scanned elements of the said transparencies, means driven by each correction signal for modulating the brightness of the corresponding light source, and a plurality of unexposed

light-transmitting photographic layers one placed immediately behind and substantially in contact with each transparency, whereby light which passes through a transparency to the associated light-sensitive device also passes through said associated photographic layer and exposes it in accordance with corrected light values.

7. Apparatus according to claim 6, in which each transparency is a colour separation transparency, in which said electrical computer comprises, for each separation transparency, subtraction means effective to subtract from the electric signal from the light-sensitive device associated with said transparency an electric signal from the light-sensitive device associated with the correcting separation transparency.

8. Colour correction apparatus comprising three colour separation transparencies, three light-transmitting photographic layers one placed behind and substantially in contact with each said transparencies, respectively, a fourth photographic layer to constitute a black printer, four light sources arranged to form a light spot on each of said three transparencies and on said fourth photographic layer, respectively, means for effecting relative movement between said transparencies and said photographic layers, on the one hand, and said light sources, on the other hand, whereby said transparencies and said fourth photographic layer are scanned by said light spots simultaneously and in synchronism, element by element, light-sensitive devices behind said three separation transparencies and their associated photographic layers for converting the light passing through said transparencies into electric signals of corresponding magnitude, means including an electrical computer for generating from said signals a black printer electric signal and further electric signals representing the corrections required for the scanned elements of the separation transparencies combined with the undercolour to be removed, means responsive to said black printer signal for modulating the light source associated with said fourth photographic layer, and means driven by each of said further signals for modulating the brightness of the corresponding light source, whereby light which passes through a separation transparency to the associated light-sensitive device also passes through said associated photographic layer and exposes it in accordance with corrected light values and said fourth photographic layer is exposed to the brightness variations of said fourth light source.

9. Apparatus according to claim 8, in which a further transparency is placed in front of and substantially in contact with said fourth photographic layer, said apparatus further comprising a fourth light-sensitive device behind said fourth photographic layer and demodulating means for reducing said black printer signal by an amount corresponding to the density values of said further transparency.

10. Colour correction apparatus, comprising a plurality of transparencies, a light source for each transparency, means for effecting relative movement between said light sources and said transparencies for scanning said transparencies by light spots from said light sources simultaneously and in synchronism, element by element, light-sensitive devices behind said transparencies for converting the light passing through the transparencies into electric signals of corresponding magnitude, a further light-sensitive device positioned to receive light directly from each light source and providing a corresponding electric signal, demodulating means for removing from said signals from said light-sensitive devices behind said transparencies the modulation represented by the signals from said further light-sensitive devices to provide signals modulated only in accordance with the density values of the scanned elements of said transparencies, means including an electrical computer for generating from said signals the respective electric correction signals required for the scanned elements of said transparencies, means driven by each correction signal for modulating the brightness of the corresponding light source, and an unexposed light-transmitting photographic layer placed immediately behind and substantially in contact with each transparency, whereby light which passes through a transparency to the associated light-sensitive device also passes through said associated photographic layer and exposes it in accordance with corrected light values.

11. Colour correction apparatus comprising a common base, three colour separation transparencies to be corrected mounted on said base, a common member, a light source for each transparency, driving means for effecting relative movement of said common base and said common member, whereby said transparencies are scanned by light spots from said light sources simultaneously and in synchronism, element by element, light-sensitive devices behind said transparencies which convert the light passing through the tranparencies into electric signals of corresponding magnitude, demodulating means for removing from each of said signals the modulation due to variation in brightness of the light source, means including an electrical computer for subtracting from the corresponding signal, in which said modulation due to the variation in brightness of the light source is still present, a signal from another light-sensitive device from which the said modulation has been removed, means driven by the resultant signals from said electrical computer to modulate the brightness of the corresponding light sources, and an unexposed light-transmitting photographic layer placed immediately behind and substantially in contact with each transparency, whereby light which passes through a transparency to the associated light-sensitive device also passes through said associated photographic layer and exposes it in accordance with corrected light values.

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