

July 6, 1971

D. M. NEALE
METHOD OF PRINTING POSITIVES FROM COLOR NEGATIVES WHOSE
SUBJECTS INTEGRATE TO BLUE

3,591,375

Filed July 15, 1968

4 Sheets-Sheet 1

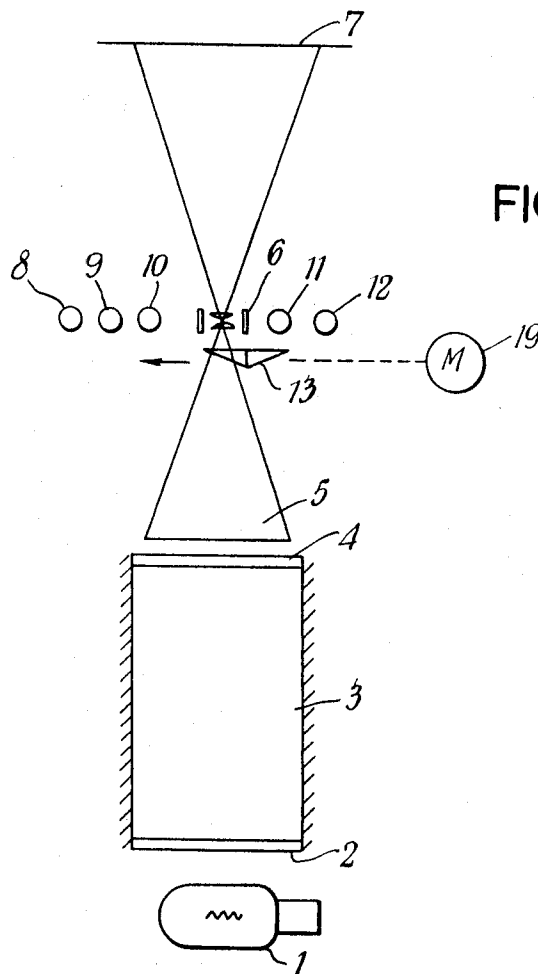


FIG. 1

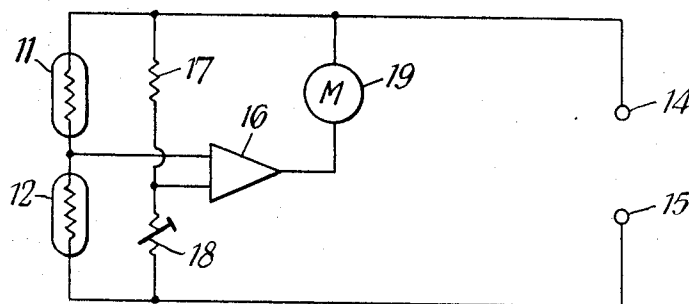


FIG. 2

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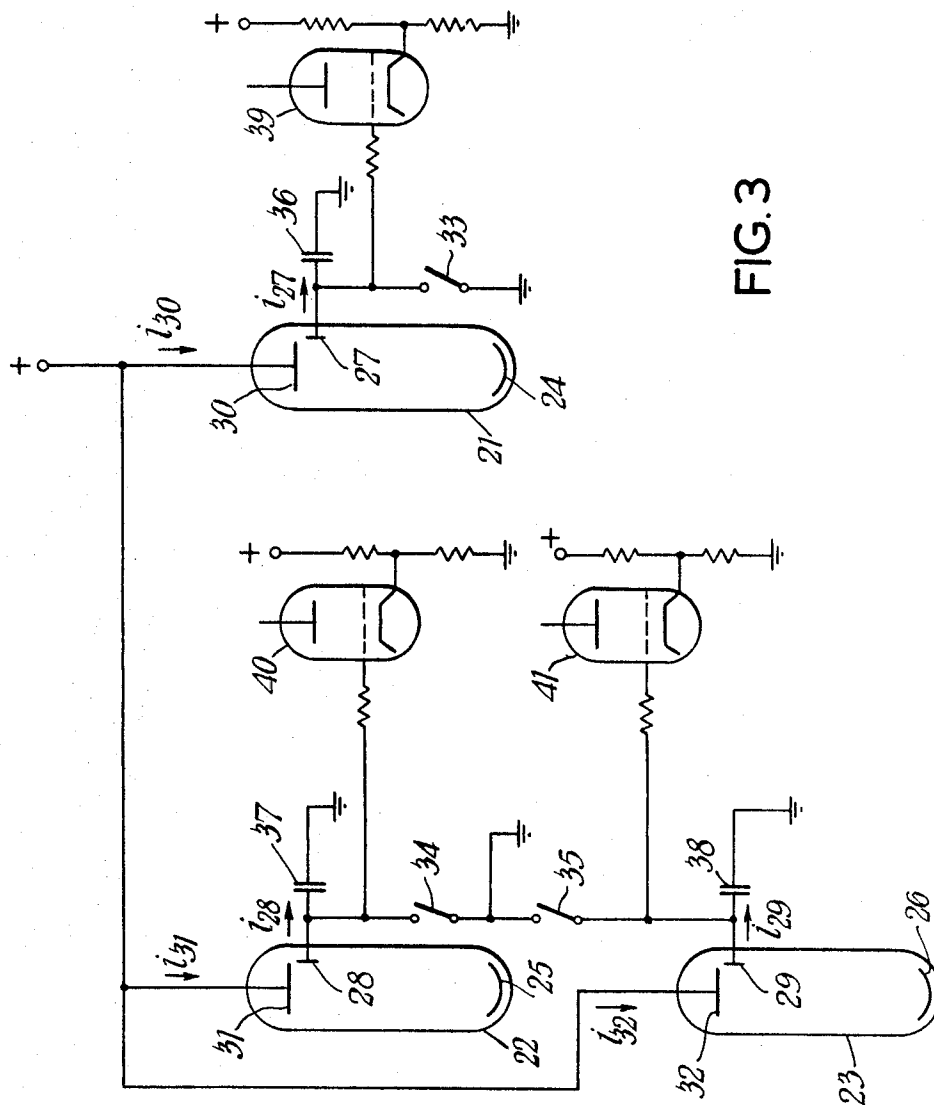


FIG. 3

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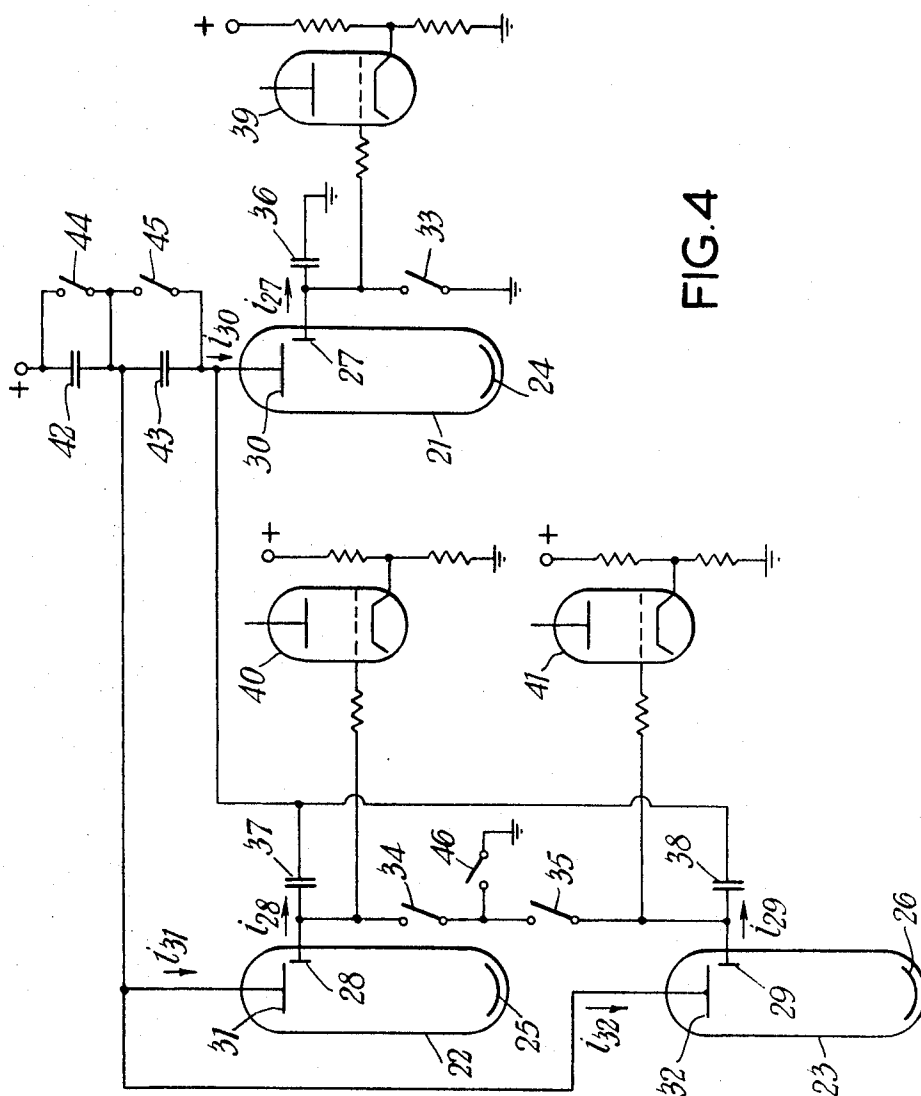


FIG. 4

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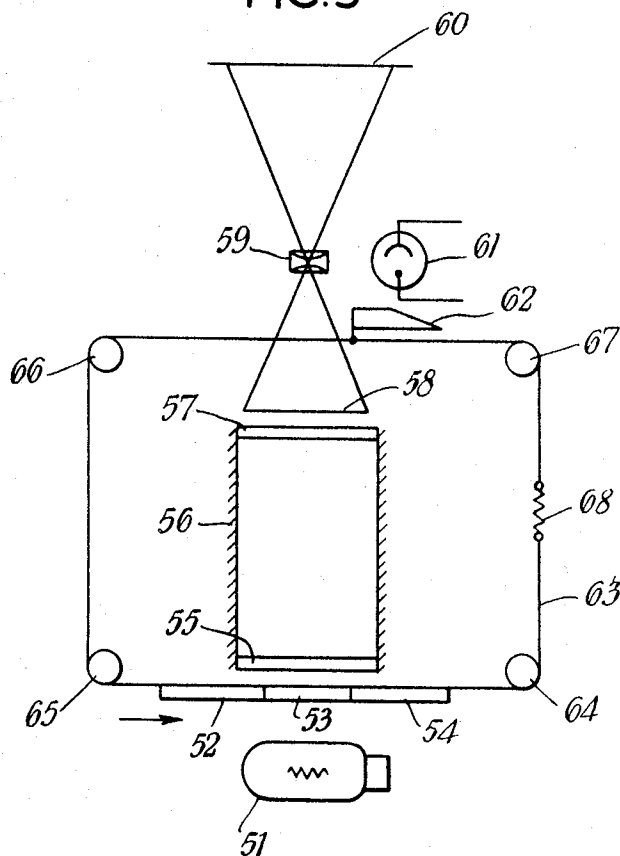
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FIG. 5



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METHOD OF PRINTING POSITIVES FROM COLOR NEGATIVES WHOSE SUBJECTS INTEGRATE TO BLUE

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U.S. Cl. 96—23

6 Claims

ABSTRACT OF THE DISCLOSURE

This application describes a method of printing positives from multicolour negatives wherein for each colour component of printing light, red, green and blue, printing continues until a predetermined integral of light against time has been administered to the print material as measured by an exposure control means, said predetermined integral being substantially constant for negatives representing subjects integrating to grey, the improvement which comprises reducing the said predetermined integral in response to means for detecting an abnormally low ratio of integrated transmittance of the negative to blue light relative to light of longer wavelength.

This invention relates to the printing of photographic multicolour negatives and in particular to the printing of large numbers of colour negatives exposed by amateurs.

It is well known that the conditions of exposure, storage and processing of such negatives are so variable that compensation must be applied at the printing stage to correct for abnormalities of negative density to any or all of the colours of light, red, green and blue. Various proposals have been made providing compensation by automatic means. The best known of these proposals is set out in British Pat. 660,099. Other related methods are described in British Pats. 928,658, 956,462 and 1,016,561. All these methods suffer from the disadvantage that, whilst providing compensation for variations in exposure of negatives of typical subjects (e.g. street scenes, portraits, groups and landscapes including a relatively small proportion of sky) the said methods lead to prints of excessive optical density from negatives representing subjects which include a high proportion of blue sky and particularly those negatives representing subjects which comprise blue sky and water.

During the summer months, about 10 percent of colour negatives exposed by amateur fall into this category. Known methods of printing such negatives require manual selection of appropriate printer exposure modifications, e.g. by depressing push-buttons reducing exposure of print material to all three colours of printing light, red, green and blue. In most (but not all) known types of printer it is desirable to depress also a push button causing exposure to blue light to be reduced preferentially, so causing the print to appear less yellow (i.e. more blue) after processing.

Although negatives representing all types of subject matter require a proportion of push-button corrections during printing, and although these corrections include adjustment both of print density and of print colour, no useful correlation between required density and colour corrections has hitherto been observed. Such a correlation has now been found between negatives representing blue subjects (and hence requiring a "plus blue" correction on most conventional automatic printers) and the need for a density reduction in the print ("minus density" correction push-button depressed during printing).

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The present invention is a refinement of the known printing art and provides a method for making the densities of prints dependent on the colours of their corresponding negatives.

The invention provides also apparatus for recognition of negatives representing subjects which integrate to blue (rather than grey) and for reduction of the exposure of print material to printing light when such recognition is effected by said apparatus.

Therefore, according to the present invention there is provided a method of printing positives from multicolour negatives wherein for each colour component of printing light, red, green and blue, printing continues until a predetermined integral of light against time has been administered to the print material, said predetermined integral being substantially constant for negatives representing subjects integrating to grey, but being reduced in response to means for detecting an abnormally low ratio of integrated transmittance of the negative to blue light relative to light of longer wavelength.

In a preferred form of the invention, the reduction in said predetermined integral is proportional to the degree of abnormality in said ratio of integrated transmittance of the negative to blue light relative to light of longer wavelength.

In one embodiment of the invention, in the printer, light of fixed quality falls upon the negative to be printed, light passing the negatives falls on a first photocell responsive to blue light and on a second photocell responsive to light of longer wavelength (e.g. green, yellow or red light), the ratio of currents passed by said first and second photocells is measured and if said ratio is less than a predetermined value, a light attenuator is inserted in the path of light directed to the print material and/or removed from the path of light directed to photocells controlling exposure of print material to red, green and blue light.

Said light attenuator may be for example in the form of an optical density, a rotating sector wheel or a tapered shutter. Preferably the light attenuator is made to attenuate blue light to a greater degree than red or green light.

In an alternative embodiment of the invention, it is arranged that, if the ratio of current from said first and second photocells is less than the predetermined value, the sensitivity of a photoelectric integrator is increased so that a smaller integral of light against time is required to complete exposure of print material to light of at least one of the three colours, red, green or blue.

In a particular form of said alternative embodiment, the said integral is smaller in respect of at least one of the colours, red and green and the time of exposure to at least blue light is restricted to a predetermined maximum proportion of time of exposure to said one colour.

In yet a further form applicable to printers of known type in which a colour-selective light modulator is moved to cause light of adjustable quality to fall on a negative, said adjustable quality being selected to cause light of substantially constant quality to pass the negative, it is arranged that movement of said colour-selective light modulator in a sense increasing the proportion of blue light to red or green light incident on the negative causes a light attenuator to move into the path of light directed to the print material or out of the path of light directed to photocells controlling exposure of print material to red, green and blue light. Preferably said light attenuator is made to attenuate blue light to a greater degree than red or green light.

In another embodiment of the invention which is applicable to printers of the last-described type, movement of said colour-selective light modulator to increase the proportion of blue light incident on the negative produces

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an increase in the sensitivity of a photoelectric integrator so that a smaller integral of light against time is required to complete exposure of the print material.

The invention also includes apparatus for carrying out the invention.

A printer which employs the method of the invention will now be described with reference to FIGS. 1 and 2.

In FIG. 1 the lamp 1 illuminates the diffusing screen 2 at the input of the mirror tunnel 3. Light emerging from the mirror tunnel 3 strikes a second diffusing screen 4 below the multicolour negative 5 which is to be printed. Light from diffuser 4 passes negative 5 and is directed by lens 6 to form an image of negative 5 on print material 7.

Photocells 8, 9, 10 sensitive respectively to red, green and blue light, receive scattered light passing negative 5. Each of the photocells 8, 9, 10 is connected to a photoelectric integrator of known type (not shown) arranged to operate a shutter (not shown) to terminate exposure of print material 7 to the corresponding colour component of printing light.

As so far described the embodiment shown in FIG. 1 corresponds to well known practice.

Additional photocells 11, 12 are responsive respectively to blue light and light of longer wavelength, e.g. yellow. The double optical wedge 13 is disposed below lens 6 and photocell 11.

Referring to FIG. 2 the photocells 11, 12 are connected in series between electrical supply terminals 14, 15. The junction of photocells 11, 12 is connected to one input of a differential amplifier 16. The other amplifier input 16 is connected to the junction of two resistors 17, 18 which are connected in series between supply terminals 14, 15. The output of amplifier 16 is connected to motor 19. Motor 19 is mechanically coupled to move the double wedge 13. The connections of amplifier 16 are chosen so that an increase in intensity of green light on photocell 12 and/or a decrease in intensity of blue light on photocell 11 causes double wedge 13 to move in the direction of the arrow in FIG. 1.

When double wedge 13 so moves the optical density in the path of light reaching lens 6 is increased and the optical density in the path of light reaching photocell 11 is decreased. Thus for any particular negative 5 the double wedge 13 will move to a stable position in which the ratio of light intensities falling on photocells 11, 12 are in the proportion predetermined by the ratio of resistances 17 and 18.

Resistances 17 and 18 are proportioned so that if the negative represents a subject integrating to grey, double wedge 13 places little or no optical density in the path of light reaching lens 6.

If negative 5 is subsequently replaced by a negative representing a subject integrating to yellow, the higher proportion of blue light to green light transmitted by such negative will cause motor 19 to withdraw double wedge 13 completely from the path of light entering lens 6. Prints from such negatives will therefore be made according to known practice with little or no deviation from the "integrate-to-grey" principle.

If negative 5 is replaced by a negative representing a subject integrating to blue, motor 19 causes double wedge 13 to move in the direction of the arrow and to insert density in the path of light entering lens 6.

Since double wedge 13 does not intercept light reaching photocells 8, 9, 10 density introduced in the path of light entering lens 6 reduces the exposure to light of print material 7. Consequently negatives representing subjects integrating to blue will provide prints of density lower than would normally be provided by printing according to be known "integrate-to-grey" principle.

That part of double wedge 13 intercepting light reaching lens 6 may, with advantage, be made to attenuate blue light to a greater degree than red or green light. That is to say this part of the double wedge 13 would appear a

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yellow-brown. That part of the double wedge 13 intercepting light reaching photocell 11 may conveniently have similar properties.

By arranging double wedge 13 to attenuate blue light to a greater degree than red or green light, it is arranged that when a negative is printed which represents a subject integrating to blue, the exposure of print material 7 to blue light is reduced in greater proportion than the exposure to red light or green light. In this way not only is the optical density of the print reduced, but the colour of the print is changed from that which would result by printing according to the known "integrate to grey" principle. The preferential attenuation of blue light ensures that prints made from negatives representing blue subjects shall themselves integrate to blue.

A printer which employs an alternative embodiment of the invention will now be described with reference to FIGS. 3 and 4.

FIG. 3 represents part of the exposure control circuit of a known type of colour negative printer in which exposure of print material to red, green and blue light proceeds concurrently. The Agfa Colormator N76/90 is such a printer and FIG. 3 represents part of the control circuit of this machine. In FIG. 3 three photomultiplier tubes 21, 22, 23, respond to blue, green and red components of printing light passing the negative (not shown) to be printed and falling on photocathodes 24, 25, 26 respectively. In photomultiplier tubes 21, 22, 23 currents emitted by photocathodes 24, 25, 26 respectively, are amplified in electron multipliers of which only the last secondary emission electrodes 27, 28, 29 (hereafter called *dynodes*) and collector electrodes, 30, 31, 32 are shown. The current i_{30} drawn by collector electrode 30 is given by

$$i_{30} = n \cdot i_{27} \quad (1)$$

where i_{27} is the current passing out of dynode 27 and $n/(n-1)$ is the secondary emission factor of dynode 27 under the conditions of operation.

Similarly,

$$i_{31} = n \cdot i_{28} \quad (2)$$

and

$$i_{32} = n \cdot i_{29} \quad (3)$$

Prior to commencement of a printing cycle, switches 33, 34, 35, are closed so that capacitors 36, 37, 38 are discharged and the control grids of thermionic valves, 39, 40, 41 are at earth potential. In this condition, valves 39, 40, 41 are held non-conducting by positive bias voltages applied to their respective cathodes.

When a print is to be made, switches 33, 34, 35 open just prior to opening of a shutter (not shown) which allows light passing the negative to fall on printed material (not shown) and also on photocathodes 24, 25, 26. From photomultiplier tubes 21, 22, 23, dynode currents i_{27} , i_{28} , i_{29} , pass into capacitors 36, 37, 38, respectively. Each such current is proportional to the intensity of light falling on the respective photocathode. Currents i_{27} , i_{28} , i_{29} , charge capacitors 36, 37, 38 until valves 39, 40, 41 conduct. As each valve conducts it causes a shutter to close so terminating exposure of the print material to the corresponding colour component of printing light. Termination of exposure will occur when each capacitor 36, 37, 38 has acquired a predetermined charge, i.e. the integral of current over time has reached a predetermined value. Thus if the photocathodes 24, 25, 26 are exposed to blue, green and red light respectively for times t_{24} , t_{25} , t_{26} respectively,

$$i_{27} \cdot t_{24} = C_{36} \times \text{constant} \quad (4)$$

$$i_{28} \cdot t_{25} = C_{37} \times \text{constant} \quad (5)$$

$$i_{29} \cdot t_{26} = C_{38} \times \text{constant} \quad (6)$$

Thus in the known practice to which FIG. 3 relates, the print material is exposed to each component of printing light for a time inversely proportional to intensity of that component and substantially independent of the intensity of either other component.

FIG. 4 relates to an embodiment of the invention which may be used in conjunction with apparatus of the type described with reference to FIG. 3. The embodiment shown in FIG. 4 is distinguished from the known practice of FIG. 3 by the additional capacitors 42, 43, the additional switches 44, 45, 46 and by the connection of capacitors 37 and 38 to collector 30 rather than to earth. In FIGS. 3 and 4, like parts are denoted by like reference numbers. In FIG. 4, switches 44, 45, 46 are closed prior to the start of an exposure cycle. When an exposure cycle begins, switches 44, 45, 46 open. They close again only when exposures to all three colour components of printing light have terminated.

At the start of an exposure cycle the control grids of valves 39, 40, 41 are all at earth potential and capacitors 42, 43 are discharged. Current i_{27} from dynode 27 of the blue-sensitive photomultiplier 24 charges capacitor 36 exactly as described previously in relation to FIG. 3 and the known art.

Current i_{28} from dynode 28 of the green-sensitive photomultiplier 25 charges capacitor 37. Capacitor 37 is however connected to capacitors 43 and 42 in series.

If V_b , V_g and V_r denote the potentials of the control grids of valves 39, 40, 41 and t denotes time from start of printing then:

$$\frac{dV_b}{dt} = \frac{i_{27}}{C_{36}} \quad (7)$$

but:

$$\frac{\delta V_g}{i_{28}} = \left[\frac{1}{C_{37}} + \frac{1}{C_{43}} + \frac{1}{C_{42}} \right] \delta t \quad (8)$$

Now V_g is a function also of i_{28} , i_{30} , i_{31} and i_{32} . That is:

$$\frac{\delta V_g}{i_{29}} = \left[\frac{1}{C_{43}} - \frac{1}{C_{42}} \right] \delta t \quad (9)$$

$$\frac{\delta V_g}{i_{30}} = - \left[\frac{1}{C_{43}} + \frac{1}{C_{42}} \right] \delta t \quad (10)$$

$$\frac{\delta V_g}{i_{31}} = - \frac{1}{C_{42}} \delta t \quad (11)$$

$$\frac{\delta V_g}{i_{32}} = - \frac{1}{C_{42}} \delta t \quad (12)$$

Hence:

$$\frac{dV_g}{dt} = \frac{i_{28}}{C_{37}} + \frac{1}{C_{43}} (i_{28} + i_{29} - i_{30}) + \frac{1}{C_{42}} (i_{28} + i_{29} - i_{30} - i_{31} + i_{32}) \quad (13)$$

Substituting from Equations 2 and 3,

$$\frac{dV_g}{dt} = \frac{i_{28}}{C_{37}} + \frac{1}{C_{43}} (i_{28} + i_{29} - i_{30}) - \frac{1}{C_{42}} [i_{30} + (n-1)(i_{28} + i_{29})] \quad (14)$$

If, now one puts

$$\frac{C_{42}}{C_{43}} = (n-1) \quad (15)$$

Then

$$\begin{aligned} \frac{dV_g}{dt} &= \frac{i_{28}}{C_{36}} + \frac{(n-1)}{C_{42}} (i_{28} + i_{29} - i_{30}) \\ &\quad - \frac{1}{C_{42}} [i_{30} + (n-1)(i_{28} + i_{29})] = \frac{i_{28}}{C_{37}} - \frac{n \cdot i_{30}}{C_{42}} \end{aligned} \quad (16)$$

By a similar process it may be shown that

$$\frac{dV_r}{dt} = \frac{i_{29}}{C_{38}} - \frac{n \cdot i_{30}}{C_{42}} \quad (17)$$

Equations 16 and 17 show that the rise in voltages V_g and V_r towards the critical values terminating exposure to green and red light is retarded in proportion to the intensity of blue light transmitted by the negative and giving rise to current i_{30} .

For negatives representing subjects integrating to grey, i_{30}/i_{28} and i_{30}/i_{29} will be in substantially fixed proportions. Consequently the effect of the retardation can be offset by suitably reducing C_{37} and C_{38} . The printer will then produce satisfactory prints from such negatives.

By adjustment of the relative intensities of red, green and blue printing light components, it is preferably arranged that such negatives cause printing to occur with substantially equal times of exposure to the three colour components, red, green, blue.

Negatives representing subjects integrating to yellow (or photographed by relatively yellow light) may then be printed without further adjustment of the printer to produce prints integrating substantially to grey. Such negatives transmit a relatively high proportion of blue light to green or red light. Consequently the ratios of blue/green and blue/red light exposure times (i.e. t_{24}/t_{25} and t_{24}/t_{26}) will be reduced. Therefore exposure to blue light will have terminated before exposure to green or to red light.

From Equations 1 and 4 it follows that at t_{24} (the end of blue printing exposure),

$$V_g = \frac{i_{28}}{C_{37}} \cdot t_{24} - \frac{n^2}{C_{42}} \times \text{constant} \quad (18)$$

Thereafter, since i_{30} falls to zero, dV_g/dt is given by

$$\frac{dV_g}{dt} = \frac{i_{28}}{C_{37}} \quad (16A)$$

Hence, before V_g reaches the value required to terminate exposure to green light, the total retardation provided by i_{30} amounts to a constant voltage which is the same as for negatives representing subjects integrating to grey.

A different condition arises when negatives are printed representing subjects integrating to blue. Such negatives transmit a relatively small proportion of blue printing light. Consequently the ratios i_{30}/i_{28} and i_{30}/i_{29} are abnormally small and little retardation is applied to dV_g/dt and dV_r/dt . As a result, the green and red light printing exposures terminate at abnormally small exposure integrals ($i_{28} \cdot t_{25}$ and $(i_{29} \cdot t_{26})$, i.e. for this type of negative, Equations 5 and 6 are not true.

As thus far described, it will be clear that a negative of a blue seascape will print with exposure integrals to green and to red light reduced in proportion to the "blue-ness" of the subject. The exposure integral to blue light will tend to proceed to the normal value, however, and if permitted to do so, a print will be produced which is grossly overexposed to blue light, i.e. the print will appear too yellow. This fault may be eliminated by arranging that exposure to blue light is not permitted to continue once both green and red light printing exposures have terminated. This may readily be provided by mechanical or electrical interconnection of the shutters controlling exposure to the separate printing light components.

An alternative arrangement, described in co-pending British patent applications, Nos. 32,885/66 and 54,585/66 cognated allows the time of exposure to blue light to exceed by a prescribed factor the exposure time to one or both of the colours green and red.

A further embodiment of the invention will now be described with reference to FIG. 5. This indicates how the invention may be applied to a known type of printer exemplified by the Kodak S3 Printer. A description of the relevant parts of the Kodak S3 Printer has been published (Hunt: Journal of Photographic Science, 11, pp. 109-120, 1963).

In FIG. 5, only those parts of the printer are shown which are necessary to an understanding of the method of applying the invention.

In FIG. 5, light from lamp 51 passes through one or more of filter elements 52, 53, 54, to strike an opalescent diffusing screen 55 at the lower end of a mirror tunnel 56. Light emerging from the upper end of the tunnel 56 passes a second diffusing screen 57 and negative 58. Some

of the light passing negative 58 is directed by lens 59 to form an image of negative 58 on print material 60.

Filter elements 52, 53, 54 are yellow, very pale magenta and blue respectively in colour. According to the known method of operation of the printer, the elements 52, 53, 54 are moved in the direction indicated by the arrow in FIG. 5, or in the reverse direction, until a position is reached at which the proportions of elements 52, 53, 54 in the path of light entering tunnel 56 are such as to provide the required proportion of blue light to red and green light incident on negative 58. After this condition has been reached, a shutter (not shown) is opened to expose the print material to light passing lens 59. Light passing negative 58 falls on photocell 61 which is connected to discharge a capacitor (not shown) through a predetermined voltage interval and then to cause the shutter to close once more.

The invention may be applied to the above-described type of printer by adding components 62-68. A graded optical attenuator 62 is arranged in the path of light reaching photocell 61. The attenuator 62 may take the form of a tapered shutter or optical wedge. Attenuator 62 is attached to wire 63 which passes around rollers 64, 65, 66 and 67 and is tensioned by spring 68. Wire 63 is attached to filter elements 52, 53, 54 so that as they are adjusted in position, the position of attenuator 62 in front of photocell 62 is varied.

When a negative representing a normal subject (i.e. a subject integrating to grey) is printed, the filter elements 52, 53, 54 are placed substantially in the position shown in FIG. 5. In this condition optical attenuator 62 obstructs about 70 percent of light which would otherwise reach photocell 61. By reducing to one-third of its normal value the capacitance of the capacitor associated with photocell 61, it is nevertheless arranged that prints of the required density are produced.

When a negative of a yellow subject is printed, the filter elements will be moved in the direction of the arrow to withdraw part or all of the blue filter 54 from the path of light entering tunnel 56 and to introduce a higher proportion of yellow filter 52. Coupling through wire 63 causes attenuator 62 to move when filter elements 52, 53, 54 are so moved, but the attenuator is so shaped or graded that the proportion of light it obstructs remains substantially 70 percent for displacements of the filters in the direction of the arrow.

When a negative of a blue subject is printed, filter elements 52, 53, 54 will be moved in the opposite direction to that indicated by the arrow. Attenuator 62 will then be moved by wire 63 in a direction allowing a greater proportion of light to reach photocell 61. In consequence, the exposure of print material will be terminated after an exposure time which will be shorter than would have been produced without application of the invention.

If attenuator 62 is graded as indicated, the reduction in print density so obtained can be made proportional to the "blue-ness" of the original subject. The maximum density correction thus obtainable is dependent on the proportion of light normally obstructed by attenuator 62. If this is 70 percent, the maximum reduction in print exposure will be 70 percent on a very blue subject.

In another embodiment of the invention, the optical attenuator 62 is not required. Instead wire 63 is caused to rotate a potentiometer controlling the voltage through which the capacitor (not shown) must be discharged to terminate exposure of the print material.

I claim as my invention:

1. In a method of printing positives from multicolour negatives wherein for each colour components of printing light, red, green and blue, printing is carried out on the basis of the integrated-to-grey principle using a substantially constant predetermined integral of light against time

of exposure for the print material based on negatives representing subjects integrating to grey and measured by exposure control means, the improvement whereby print density and print colour can be corrected for negatives which represent subjects that integrate to blue, said improvement comprising measuring the ratio of integrated transmittance of the negative to blue light relative to light of longer wave length and reducing said integral in the event said ratio measures abnormally low with respect to the ratio for negatives that represent subjects integrating to grey.

2. A method according to claim 1 wherein the reduction in said predetermined integral is proportional to the degree of abnormality in said ratio of integrated transmittance of the negative to blue light relative to light of longer wavelength.

3. A method of printing positives from multicolour negatives according to claim 1 whereby light of fixed quality is caused to fall on the negatives, the light passing the negative is assessed to determine the ratio of intensities of radiation in the blue band of the spectrum relative to that in a band of longer wave length and if said ratio is below the value for correct print colour and density, light directed to the print material is attenuated relative to the intensity of light directed to the exposure control means.

4. A method of printing positives from multicolour negatives according to claim 1 whereby light of fixed quality is caused to fall on the negatives, the light passing the negatives is assessed to determine the ratio of intensities of radiation in the blue band of the spectrum relative to that in a band of longer wave length and if said ratio is below the value for correct print colour and density, a smaller integral of light against time is used to complete exposure of the print material to light of at least two of the three colours, red, green and blue.

5. A method of printing positives from multicolour negatives according to claim 1 whereby light of adjustable quality is caused to fall on the negatives, said adjustable quality being selected to cause light of substantially constant quality to pass the negatives, the method being characterized in that when the proportion of blue light in the adjusted light relative to red or green light is greater than a predetermined ratio such as to normally require correction of the print resulting therefrom, the light directed to the print material is appropriately attenuated.

6. A method of printing positives from multicolour negatives according to claim 1 whereby light of adjustable quality is caused to fall on the negatives, said adjustable quality being selected to cause light of substantially constant quality to pass the negatives, the method being characterized in that when the proportion of blue light in the adjusted light relative to red or green light is greater than a predetermined ratio such as to normally require correction of the print resulting therefrom, the sensitivity of the exposure control is increased so that a smaller integral of light against time is required to complete exposure of print material to light of at least one of the three colours, red, green and blue.

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U.S. Cl. X.R.

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