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APPARATUS FOR CONTROLLING EXPOSURE DURING PHOTOGRAPHIC PRINTING OF VARIABLE CONTRAST MATERIAL

Filed March 19, 1968 5 Sheets-Sheet 1

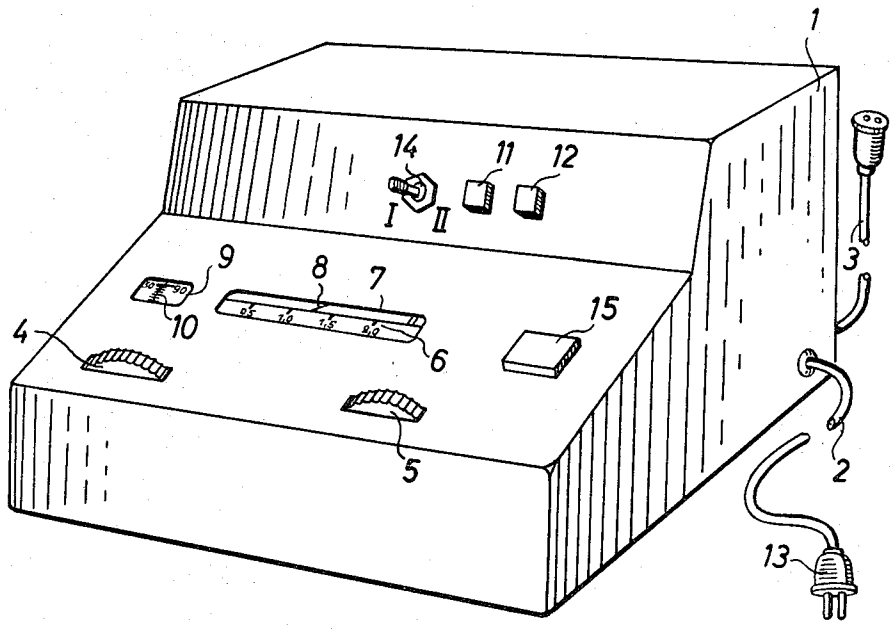

Fig.1

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Filed March 19, 1968 5 Sheets-Sheet 2

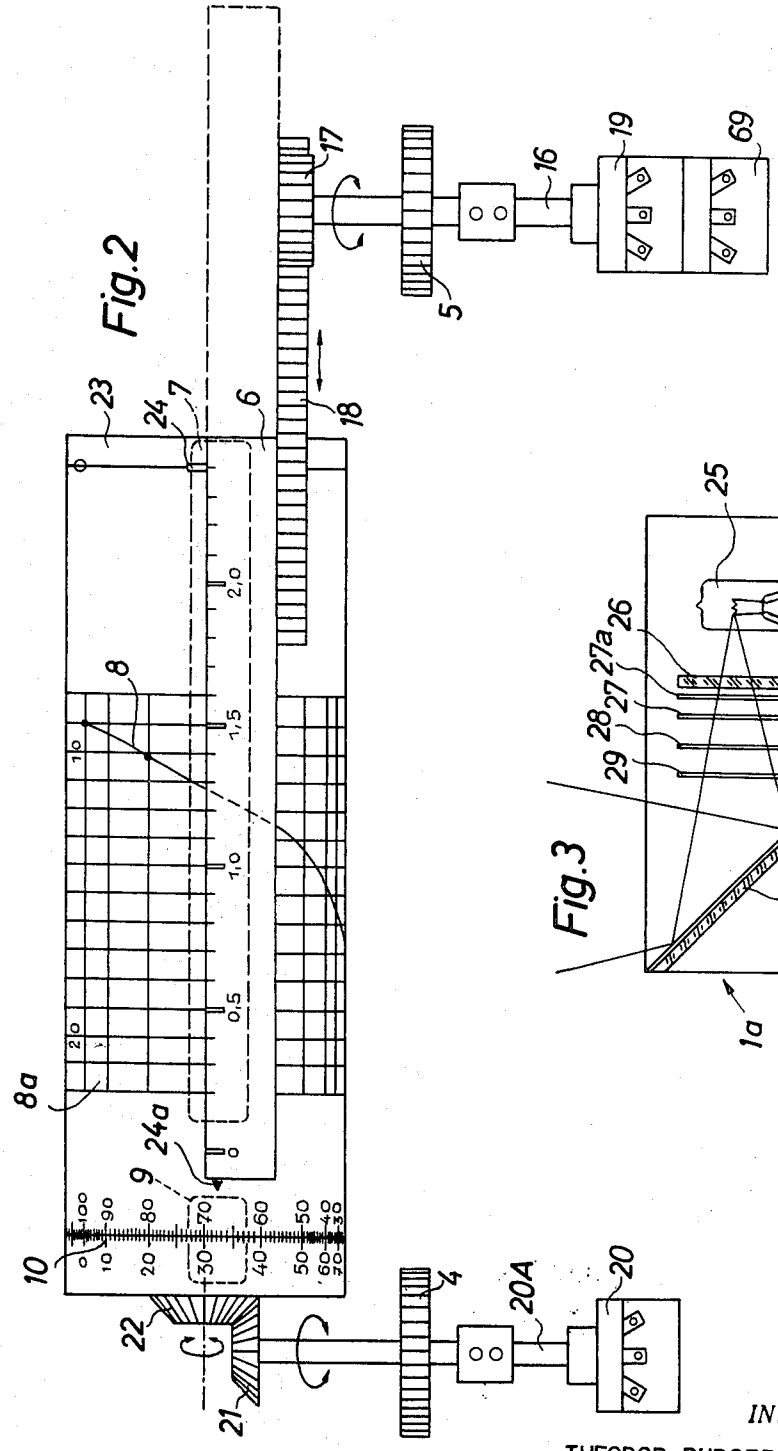

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Fig.4

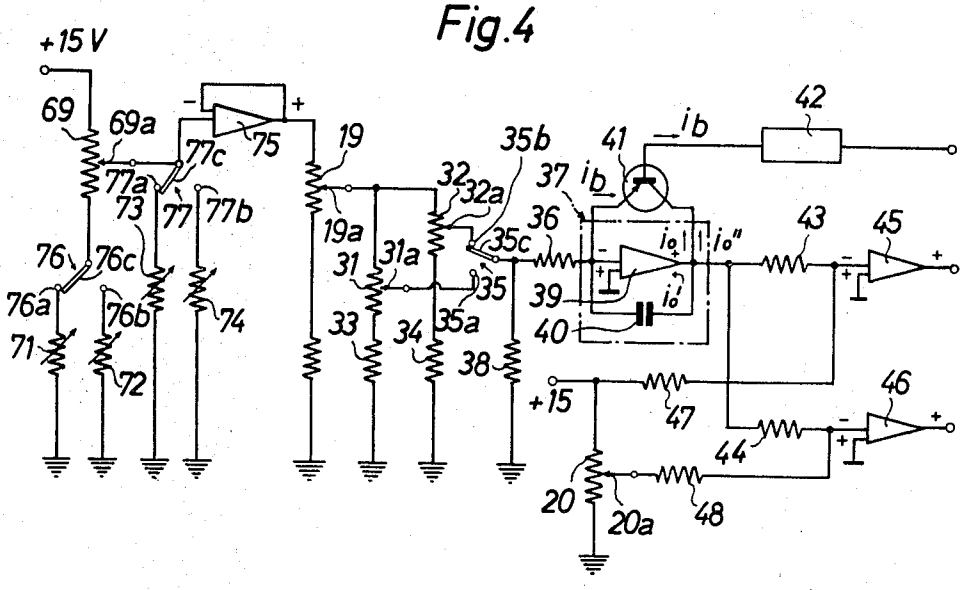

Fig.5

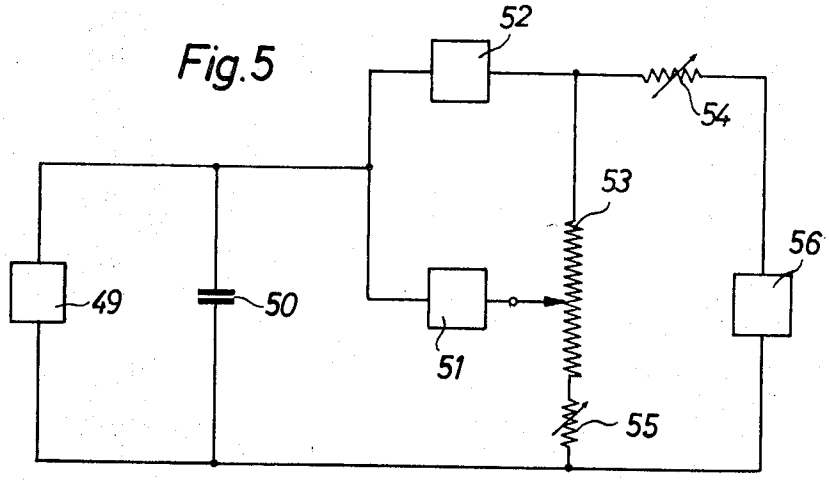

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Fig.6

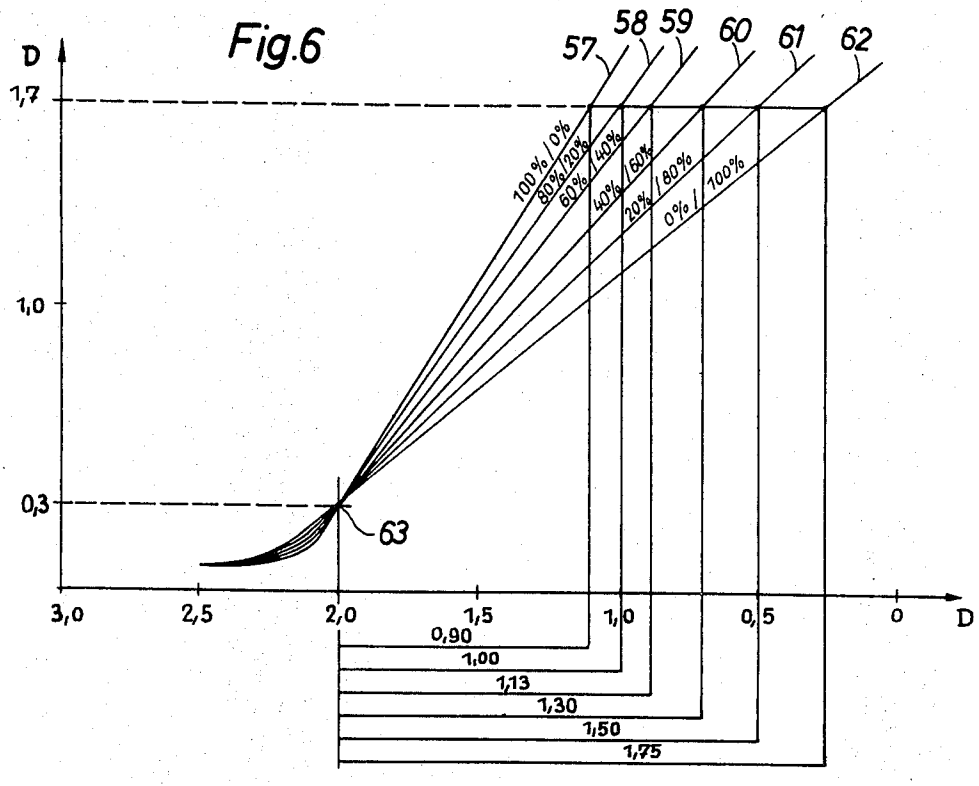

Fig.8

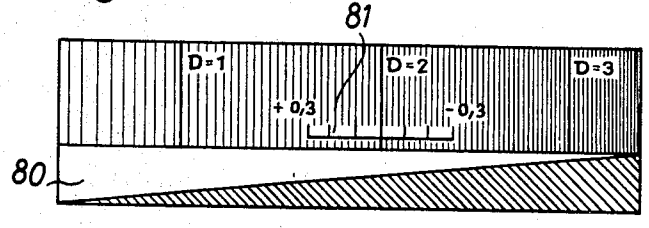

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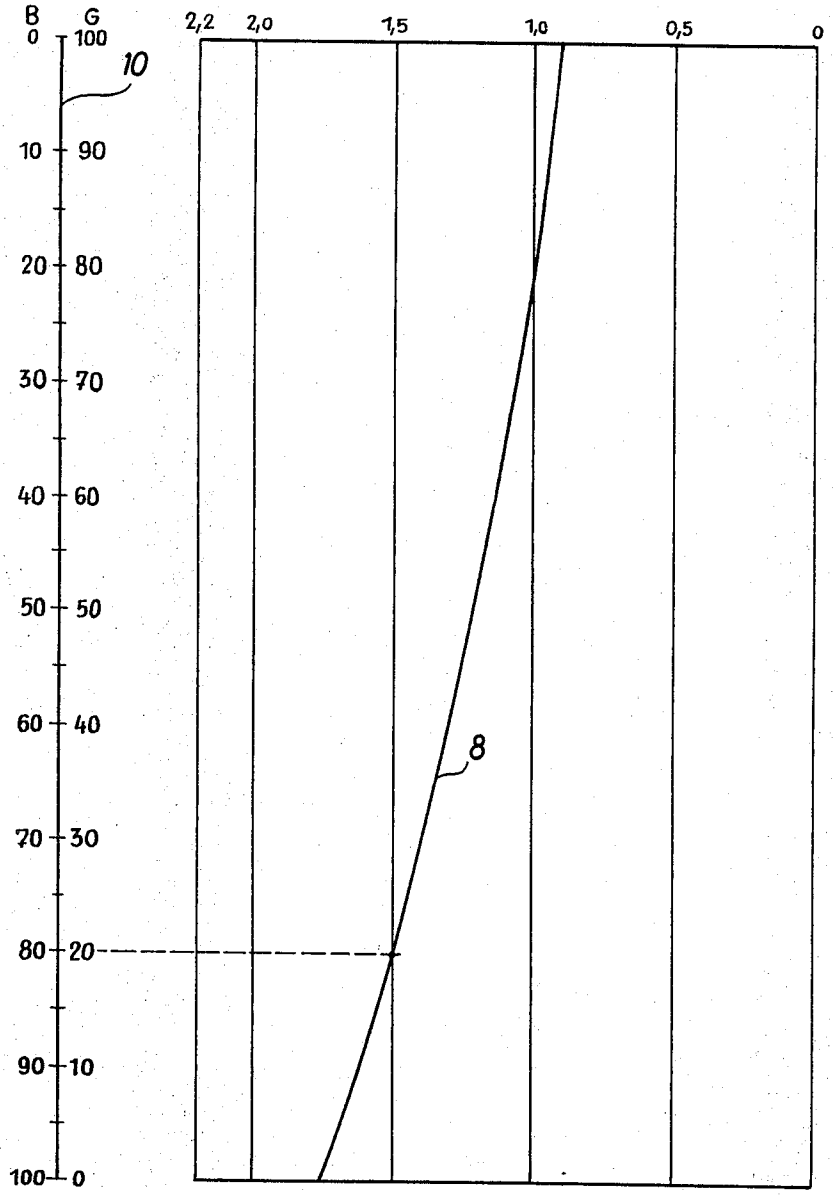
Fig.7



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United States Patent Office 3,531,199 Patented Sept. 29, 1970

3,531,199

APPARATUS FOR CONTROLLING EXPOSURE DURING PHOTOGRAPHIC PRINTING OF VARIABLE CONTRAST MATERIAL

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Int. Cl. G03b 27/76
U.S. Cl. 355—71 34 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for controlling exposure during photographic printing of variable contrast paper which is exposed to light passing through a negative in two extreme colors and whose gradation is different for each extreme color comprises an electronic timer wherein a first knob selects the total exposure time as a function of the density of a negative and by considering the sensitivity of paper. A second knob selects the ratio of exposures to light in two extreme colors within the total exposure time by way of a calibration curve which is determined in advance for the particular contrast grade of paper as a function of the density range of a negative.

BACKGROUND OF THE INVENTION

The present invention relates to an apparatus for controlling exposure during the photographic printing of variable contrast photofinishing material which is exposed to light passing through a negative in two different colors.

In the graphic arts, particularly in the production of intaglio printing forms by photographic means, the contrast of prints must vary within an accurately determined range. In accordance with presently prevailing practice, negatives are photographed and the exposure time is selected as a function of the maximum or minimum density of such negatives. The resulting prints are developed by regulating the duration of processing and the temperature and/or concentration of developing agent in such a way that the developed print exhibits the desired range of densities. Such processes are complicated; also, they consume too much time and must be carried out by highly skilled technicians. Furthermore, the number of exposures which turn out badly is very high. Still further, the just described processes cannot be carried out by resorting to continuous developing machines of the type known in X-ray technology wherein the conditions during processing remain unchanged.

It is also known to make prints from amateur photographs by exposing photographic paper to light in two different color to obtain a desired gradation. The apparatus which are used for making such prints comprise a fully automatic scanning unit which determines the maximum and minimum opacities of a negative. A computer calculates the exposure time on the basis of the thus determined density values. The prints are made on variable contrast (gamma) paper which is exposed to yellow and blue light. A serious drawback of presently known exposure control apparatus for variable contrast paper is that it is extremely difficult to change the ratio of blue light to yellow light for different contrast grades of printing material and for different gamma values so as to insure satisfactory prints for all intermediate values. The relationship between the gamma values for both extreme colors is not linear and no mathematical formula has been

devised to date to reproduce such relationship with a desired degree of accuracy. Therefore, the above-outlined conventional exposure control apparatus failed to gain widespread acceptance in the industry.

It is also known to employ a photographic timing device which can be adjusted to set the exposure time and the desired gradation of printing material in the conventional contrast grades "extra hard," "hard," etc. Such timing device does not establish a fixed relationship between the two extreme colors and the resulting gamma of printing paper. Accurate determination of gamma in accordance with the density range of the negative is not possible; therefore, such devices cannot be used in reproduction of negatives for graphic arts.

SUMMARY OF THE INVENTION

It is an object of the invention to provide a relatively simple but versatile exposure control apparatus which can be used to select the gradation of variable contrast printing material in such a way that the prints exhibit a standardized range of contrasts irrespective of variations in density of the negatives and by resorting to an unchanged developing procedure.

Another object of the invention is to provide a novel electronic timer device which can be utilized in the exposure control apparatus to select the ratio of exposures of variable contrast printing paper to light in two different colors in automatic response to selection of total exposure time.

A further object of the invention is to provide an exposure control apparatus which can be used in combination with enlargers, contact printers, projection printers, and/or repro cameras.

An additional object of the invention is to provide an apparatus which can be used for automatic control of a printer to determine the total exposure and the ratio of exposures to light in different colors within the total exposure time or which can furnish indications to facilitate manual adjustment of a printer or enlarger to select appropriate exposure times and ratios of exposures to light in different colors.

An additional object of the invention is to provide an apparatus which can be used to control exposure of different grades of variable contrast printing material.

The improved apparatus comprises electronic timer means having first movable adjusting means for selecting the total exposure time to light in both colors (e.g., to blue and yellow light), second movable adjusting means for selecting the ratio of exposures to light in the two colors within the total exposure time, movable carrier means having a calibration curve which is determined in advance on the basis of the contrast grade of printing material and as a function of the density of the negative, and an operative connection between the carrier means and the second adjusting means to facilitate the selection of the ratio on the basis of the calibration curve.

The curve enables the person in charge to select the ratio of exposures to two colors on the basis of a density analysis of the negative in such a way that the contrast of prints is standardized within a predetermined range while the developing treatment to which the exposed variable contrast is subjected remains unchanged.

It was found that the operation of our timing means is particularly simple if the setting of the first adjusting means is a function of the previously determined maximum density of the negative by resorting to a density scale which is movable with reference to a stationary index, and if the setting of the second adjusting means is such that the calibration curve points out that graduation of the scale which indicates the previously determined minimum density of the negative. The densities of the negative can be determined by a suitable densitometer.

The novel feature which are considered as characteristic of the invention are set forth in particular in the appended claims. The improved exposure control apparatus itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of a portion of an exposure control apparatus which may be utilized in the practice of our method;

FIG. 2 is an enlarged view of certain parts in the apparatus of FIG. 1;

FIG. 3 is a schematic partly sectional view of a lamp housing which can be controlled by the apparatus of FIG. 1;

FIG. 4 is a diagram of the electric circuit for the apparatus shown in FIG. 1;

FIG. 5 illustrates a portion of a modified circuit;

FIG. 6 is a graph showing certain steps in determination of the calibration curve;

FIG. 7 illustrates a calibration curve which is determined on the basis of the graph shown in FIG. 6; and

FIG. 8 illustrates a wedge which is utilized in making of test strips.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 illustrates the housing **1** for the electronic timer of an exposure control apparatus which embodies one form of our invention. This housing does not contain a densitometer which is employed to determine the maximum and minimum densities of a negative, either by the light reflection or by the light penetration method. The densitometer may be of the type which is manipulated by a technician to measure the density of lightest and darkest portions of a negative which are spotted by visual observation of the negative, or a fully automatic densitometer which not only detects but also records the densities of negatives.

The printing, copying or enlarging machine is also not shown in FIG. 1. Such machine may be a conventional contact-type printer or a conventional projection type photographic printer. The parts in the housing **1** of FIG. **1** determines the time of exposures in two different colors, namely, the total exposure time and the ratio of exposure times in two extreme colors. The transition from exposure in one color to exposure in the other color can be controlled directly by the exposure control apparatus. However, and particularly when the exposure times are long, the apparatus of FIG. 1 may be used to furnish indications of the required exposure times, and the operator thereupon sets the exposure times in the printer or changes the filters in accordance with such indications. The timer of the exposure control apparatus shown in FIG. 1 can be used in connection with conventional densitometers and printers.

The housing **1** resembles a control stand and is provided with a cable **2** and plug **13** for connection to an outlet or another suitable source of electrical energy. A second cable **3** can be connected to a lamp housing or projector **1***a* which is shown in FIG. 3. This lamp housing **1***a* accommodates electromagnets (not shown) which control a shutter **27** or analogous light blocking means and the color filter changing mechanism. The lamp housing **1***a* can be built into a printer or it may constitute an attachment which must be connected to or installed in existing printers. In the latter instance, the light source **25** in the lamp housing **1***a* is preferably controlled by the exposure control apparatus.

The front portion of the housing **1** accommodates two adjusting knobs **4**, **5** one of which can be manipulated by hand to select the positions of certain parts in dependency on the minimum density of the negative or picture carrier

and the other of which can be manipulated to select the position of certain other parts in dependency on the maximum density of the negative. A density scale **6** is movable in the housing **1** behind a window **7**. This window **7** further exposes a portion of a calibration curve **8**. A second window **9** located to the left of the window **7** exposes a second scale **10**. The housing **1** further carries two pilot lamps **11**, **12** each of which lights up during exposure in one of the two colors, a switch **14** having a portion movable between the positions I and II, and a starter button **15**.

The details of mechanical parts of the timer in the interior of the housing **1** are shown in FIG. 2. The adjusting knob **5** is fixed to a shaft **16** which carries a gear **17** meshing with a toothed rack **18** secured to the density scale **6**. The rack **18** can move the scale **6** back and forth in the longitudinal direction of the window **7**. The shaft **16** further carries the contact arms of two potentiometers **19**, **69**. The adjusting knob **4** is secured to a shaft **20**A which carries a bevel gear **21** meshing with a bevel gear **22** secured to a rotary carrier drum **23**. The gears **21**, **22** constitute a gear train which establishes an operative connection between the knob **4** and the drum **23**. The carrier drum **23**. The carrier drum **23** is rotatable about an axis which is parallel to the window **7** and rack **18** and to the front wall of the housing **1**. This drum carries the scale **10** at its left-hand end and it also carries a sheet **8***a* with the calibration curve **8**. The manner in which the sheet **8***a* is releasably secured to the periphery of the drum **23** forms no part of our invention. The sheet **8***a* may be provided with an imprinted system of coordinates to facilitate reading of the curve **8**. The shaft **20**A also carries the contact arm **20***a* of a further potentiometer **20**. A fixed index or pointer **24** is provided on the housing **1** adjacent to the right-hand end of the drum **23**, and this index can register with selected graduations of the density scale **6** in response to rotation of the knob **5**. A second fixed index **24***a* of the housing **1** cooperates with the scale **10** to pinpoint a selected ratio of exposures to yellow and blue light within the total exposure time.

The lamp housing **1***a* of FIG. 3 accommodates a printing lamp or an analogous light source **25** of known construction. It is desirable to select a lamp whose output is high in the range of the two colors to which the variable contrast paper is exposed during printing. Light issuing from the lamp **25** passes through a heat filter **26** and impinges against the shutter **27**. A filter disk **27***a* is located between the heat filter **26** and shutter **27**; this filter disk **27***a* may comprise two layers in order to place the one or the other of two grey filters into the path of light. The purpose of such grey filters will be described later. A yellow filter **28** and a blue filter **29** are installed behind the shutter **27**. These filters can be replaced by filters of other colors as long as the gamma values of variable contrast paper in the particular colors are widely different. For example, the yellow filter **28** could be replaced by a red filter. Suitable electromagnets or analogous moving means can be employed to move the shutter **27**, filter disk **27***a* and filters **28**, **29** into and from the path of light issuing from the source **25**. A mirror **30** is located behind the blue filter **29** to deflect the light by 90 degrees onto the negative or into a copying frame in order to insure homogeneous illumination of the picture carrier.

FIG. 4 illustrates the electric circuit of the exposure control apparatus. One end of the winding of potentiometer **69** is connected with a source of reference voltage (+15 volts) and the other end of this winding is connected to the movable central contact **76***c* of a two-way electric switch **76**. The fixed contacts **76***a*, **76***b* of the switch **76** are connected with the ground by way of variable resistors **71**, **72**. These resistors form with the potentiometer **69** a voltage divider for reference potential. The selected voltage is taken off by the contact arm **69***a* which is connected to the input of a buffer amplifier **75** and with the movable central contact **77***c* of a second two-way electric switch **77**. The fixed contacts **77***a*, **77***b* of the switch **77** are con-

nected with the ground by way of variable resistors **73, 74.** The parts **69, 71, 72, 73** and **74** constitute the elements of a corrective circuit for the Schwarzschild effects of variable contrast printing paper.

The output potentiometer **19** is mechanically coupled with the potentiometer **69** as shown in FIG. 2. The contact arm **19***a* of the potentiometer **19** is connected with the windings of two additional potentiometers **31, 32** which constitute a voltage divider and which are connected with the ground by way of two resistors **33, 34.** The contact arms **31***a*, **32***a* of potentiometers **31, 32** are connected with the fixed contacts **35***a*, **35***b* of a third two-way electric switch **35** whose movable central contact **35***c* is connected with the input of an operational amplifier or signal generator **37** by way of a fixed resistor **36.** A further resistor **38** is connected to the ground and to a junction between the movable contact **35***c* and resistor **36.**

The operational amplifier or signal generator **37** serves to produce a voltage as a function of time, namely, a negative potential which increases from zero potential at the start of exposure. This amplifier **37** comprises an amplifier **39** of the type known from the art of analog computers and connected with a feedback element **40.** The operational amplifier **37** produces a voltage which increases above or decreases below the starting voltage of the feedback element **40** as a function of time. The plates of the feedback element **40** are connected to the emitter-collector circuit of a switching transistor **41** which discharges the feedback element **40** sufficiently in response to a signal from a conventional control unit **42** prior to start of an exposure. The transistor **41** is preferably of the silicon junction alloy type. When the transistor switch is closed, only the saturation voltage across the emitter-collector circuit remains.

The operation of the circuit shown in FIG. 4 is as follows:

When the circuit for control current i_b is completed, the transistor **41** is conductive and the feedback element **40** discharges (current i_o). The transistor **41** is assisted by the action of the amplifier **39** because the control current i_b flows to the input (i_o). When the charge of the feedback element **40** is led away, the polarity of voltage is reversed. Thus, an inverse operation of the transistor **41** takes place because i_b is taken over by i_o. The base current ceases to flow to the input so that there exists only a saturation voltage of the inversely operating transistors between the inlet and outlet of the amplifier **39.** It can be readily proven that such saturation voltage is in the order of a few millivolts.

The output of the operational amplifier **37** is connected with two current comparing or evaluating devices **45, 46** by way of resistors **43, 44.** These devices compare the currents flowing from the operational amplifier **37** with reference currents flowing through resistors **47, 48.** The reference current for the device **45** is obtained from a source of reference voltage (in the present instance +15 volts) and resistor **47** as a function of the output signal of the generator **37.** The reference current for the device **46** is obtained from the potentiometer **20** (which constitutes a voltage divider and determines the operating range of the device **46**) and resistor **48** which is connected with the contact arm **20***a*.

The device **45** may be a trigger and can be connected with an electromagnet which serves to move the blue filter **29** of FIG. 3 into and from the path of light issuing from the lamp **25.** The device **46** can be connected with an electromagnet for moving the yellow filter **28.**

An OR-gate is connected with the current comparing devices **45, 46** to control an electromagnet which moves the shutter **27** from the closed or light blocking position shown in FIG. 3. The control unit **42** may comprise an arrangement which moves the shutter **27** to closed position during exchange of filters **28, 29** in order to prevent unfiltered light from reaching the negative and printing paper if the exchange of filters requires a relatively long interval of time.

The exposure control apparatus of FIGS. 1 to 4 operates as follows:

The housing **1** is connected with a source of electrical energy by way of cable **2** and plug **13** and with the lamp housing **1***a* of FIG. 3 by way of cable **3.** The contact arms of potentiometers **31, 32** must be moved to positions in which the voltage at the input of the operational amplifier **37** reaches such a value that the rise in voltage at the output of the amplifier **37** as a function of time corresponds to the darkening effect of printing light upon the variable contrast printing paper. It is advisable to employ two potentiometers (**31, 32**) because the sensitivity of printing paper (i.e., darkening of paper per unit of time as a function of intensity of illumination) is normally not the same for both extreme colors and different contrast grades of printing paper. For example, the potentiometer **31** can be used for calibration of exposure in blue light and the potentiometer **32** for calibration of exposure in yellow light. Since the just mentioned calibrations are carried out in the printer, it is preferred to carry out such calibrations by simultaneous consideration of the influence of light intensity in the respective color upon the paper. The resistor **38** serves to bring about some linearization of adjustment by potentiometers **31** and **32.**

In addition to just mentioned calibration for sensitivity, the operator must attach to the drum **23** a sheet **8***a* with a calibration curve **8** whose configuration depends on the gradation of printing paper. The manner of plotting the curve **8** will be described in connection with FIGS. 6 and 7.

The variable resistors **71, 73** resp. **72, 74** are adjusted to compensate for Schwarzschild effects of printing paper in the two colors. If the two groups of variable resistors **71, 73** and **72, 74** are replaced by fixed resistors, the two-way switches **76, 77** can be dispensed with. Such modification of the circuit shown in FIG. 4 can be carried out if the Schwarzschild exponents for the two colors are the same. In such instances, the Schwarzschild exponents can be accounted for by altering the density scale **6,** for example, by pasting a different scale over the scale **6** of FIGS. 1 and 2.

The maximum and minimum opacities of a negative are determined with a densitometer in a manner as described above. The desired maximum and minimum opacities or densities of the print are known in advance. The operator then manipulates the adjusting knob **5** to shift the density scale **6** by way of the gear train **17, 18** and to simultaneously adjust the potentiometers **19** and **69** so that the index **24** on the housing **1** registers with that graduation of scale **6** which corresponds to previously determined maximum density or opacity of the negative. The potentiometer **19** has an antilog characteristic curve and selects for the calibrating potentiometers **31, 32** a voltage which is indicative of the required overall exposure time by considering the sensitivity and Schwarzschild exponents of printing paper for the individual colors. Thus, the knob **5** can select the total exposure time. The contact arm **19***a* of the potentiometer **19** can be said to form part of the adjusting means which includes the knob **5,** and movement of the contact arm **19***a* by way of the knob **5** brings about a change in the position of density scale **6** by way of the gear **17** and rack **18.**

In the next step, the operator turns the adjusting knob **4** to select the ratio of exposure times in yellow and blue light. The knob **4** is turned until the intersection between the calibration curve **8** and density scale **6** pinpoints that graduation of scale **6** which indicates the determined minimum density or opacity of the negative. The index **24***a* then pinpoints on the scale **10** that graduation which indicates the ratio between exposures to yellow and blue light within the total exposure time.

It is clear that the mechanism shown in FIG. 2 can be modified so that the index **24** pinpoints the graduation corresponding to minimum density and that the curve **8**

pinpoints the graduation corresponding to maximum density value of the negative.

The knob **4** also adjusts the potentiometer **20** by moving the contact arm **20***a* to a position corresponding to a value of between ground potential and +15 volts. The contact arm **20***a* can be said to form part of adjusting means for selecting the ratio of exposures to yellow and blue light. The gears **21, 22** constitute an operative connection between the contact arm **20***a* and knob **4** on the one hand and the drum **23** on the other hand. When the position of contact arm **20***a* corresponds to a potential of +15 volts, the current comparing device **46** responds almost simultaneously with but always slightly ahead of the current comparing device **45**. The latter terminates the exposure. The exopsure to blue light (filter **29**) precedes the exposure to yellow light (filter **28**) and such exposure to blue light then takes up almost the entire interval which is allotted for the exposure by appropriate setting of the knob **5**. If the contact arm **20***a* is closer to a position which is indicative of ground potential (zero point of current), the exposure to yellow light takes up the major part of total exposure time, i.e., the zero point of current at the input of the device **46** is reached much sooner. When the device **46** responds, i.e., when the blue filter **29** is replaced with the yellow filter **28** a suitable relay (not shown) actuates the switches **35, 76** and **77**. The resistors **71, 73** are disconnected from and the resistors **72, 74** are connected with the circuit. Also, the voltage divider **31, 33** is replaced by the voltage divider **32, 34**. In this way, the apparatus takes into consideration the sensitivity and the Schwarzschild exponents of printing paper for each of the extreme colors yellow and blue.

In the next-following step, the operator presses the starter button **15** to begin the exposure to blue light (filter **29**) so that the pilot lamp **11** lights up. When the output current of the operational amplifier **37** through the resistor **44** reaches a negative value which equals that of the reference current flowing through the resistor **48**, the device **46** causes the associated electromagnet to remove the blue filter **29** and to close the shutter **27**. At the same time, the aforementioned relay actuates the switches **35, 76** and **77**.

Depending on the type of light source, the exposure to the other (yellow) color can begin immediately following withdrawal of the blue filter **29** or with a short delay which is required to carry out the interchange of filters. The control unit **42** comprises or controls conventional means for interrupting or preventing any changes in voltage at the output of the operational amplifier **37** during the exchange of filters. When the exposure is to be resumed (to yellow light), the voltage at the output of the amplifier **37** changes again and the electromagnets which move the yellow filter **28** into the path of light and open the shutter **27** are energized. The exposure to yellow light is terminated when the current flow at the input of the current comparing device **45** decreases to zero. The electromagnets are then deenergized so that the shutter **27** closes and terminates the exposure.

In order to enable the printer to utilize different types of printing paper (e.g., for print toning or screen technique) without changing the adjustment of calibrating potentiometers **31, 32** and variable resistors **71–74**, the apparatus preferably comprises two or more sets of such potentiometers and variable resistors. The selector switch **14** of FIG. 1 can be actuated to connect the appropriate set into the circuit of FIG. 4 at the will of the operator, i.e., depending on the type of paper which is employed in the printer. The position of the filter disk **27***a* in the lamp housing **1***a* is changed simultaneously with actuation of the switch **14** to place the other grey filter into the path of light which issues from the lamp **25**. This is advisable in order to select the intensity of printing light in dependency on the type of printing paper. For example, when operating with a color screen, the intensity of light should be much higher than for copying of half-tone negatives.

The mechanical construction of the exposure control apparatus can be simplified by fixedly mounting the density scale **6** in the housing **1**. The knob **5** is then used to select the total exposure time in accordance with the previously determined maximum and minimum opacities of the negative and the knob **4** is used to determine the duration of exposures to blue and yellow light by simultaneously moving the contact arm **20***a* of the potentiometer **20** and by turning the drum **23** with the calibration curve **8** to a position in which the curve **8** pinpoints that graduation of the scale **6** which indicates the density range of the negative, namely, the difference between the maximum and minimum densities. The graduations of scale **6** then indicate successive values of the density range which may increase linearly in a direction from the left to the right, as viewed in FIG. 1 or 2. Such graduations can be applied to a standardized sheet in accordance with the previously described procedure. The manipulation of the just described apparatus is somewhat more complicated because it is necessary to determine not only the maximum and minimum densities of a negative but also the difference between such extreme densities prior to manipulation of the exposure time selecting knob **5**.

FIG. 5 illustrates a modified electric circuit which can replace the circuit of FIG. 4. The numeral **49** denotes a constant source of electrical energy which is employed to charge a capacitor **50** which replaces the signal generator **37**. The charge of this capacitor **50** is measured by two scanning or evaluating circuits **51, 52**. The range of output signals produced by circuits **51, 52** can be adjusted by three potentiometers **53, 54, 55**. The scanning circuit **52** is connected with a source **56** of reference potential by way of potentiometer **54** which latter is adjustable to account for the sensitivity of printing paper. The scanning circuit **51** receives only a portion of reference potential by way of the potentiometer **53** which constitutes a voltage divider. The potentiometer **55** is in series with potentiometer **53** and is employed to take into account different sensitivities of printing paper to light in the extreme colors blue and yellow as well as to take into consideration different densities of light which is transmitted to the negative by the light source. The potentiometer **55** replaces the potentiometers **31, 32** of FIG. 4. The potentiometers **31, 32** or **55** can be used in addition to or as a substitute for grey filters which may be used in conjunction with color filters **28, 29** in order to bring about coarse adjustment of light density at the negative or such adjustment of density that the darkening of printing paper per unit of time is the same during exposure in either one of the two extreme colors. The potentiometer **53** determines the ratio of exposure times in blue and yellow light. A further potentiometer in the energy source **49** is adjustable to determine the slope of the curve which indicates the rise of potential between the plates of capacitor **50** as a function of the maximum density of the negative. Otherwise, the circuit of FIG. 5 operates in the same way as the circuit of FIG. 4.

FIG. 6 illustrates the mode of graphically determining the calibration curve **8**. The density D of the negative is measured along the abscissa, such density corresponding to the logarithm of $I.t$ wherein I is the intensity of illumination and t is the exposure time. The density D of the print is measured along the ordinate. The exposure time is selected in such a way that the density of the print is in a medium density range. The numerals **57** to **62** indicate a bundle of darkening curves measured on prints taken with grey filters with different ratios of blue and yellow light. The two outer curves **57, 62** respectively indicate illumination exclusively with yellow and blue light. During calibration with potentiometers **31, 32** on the basis of shots taken with grey wedges in pure yellow and blue light, the curves **57** and **62** are displaced in such a way that they intersect each other at

or close to the point **63**. This point corresponds to a print density of 0.3 and is determined by the original illumination and by calibration for a number 2 density of negative. It can be readily proven by calculation that the calibration can bring about parallel displacement of curves **57–62** in twice the logarithmic ratio and that it also applies for other *I.t* values which deviate from the negative density value of 2.0. The curves **58–61** indicate a series of changes in the ratio of blue and yellow light, always by 20 percent. Each of these curves intersects a different portion of a horizontal line which intersects the paper density value 1.7 on the ordinate.

The curve **8** of FIG. 2 can be obtained in accordance with FIG. 7 by plotting the values indicating the ratio of individual exposures (curves **57–62**) on a chart indicating the density range of the negative, for example in the density range of 0.3 to 1.7. FIG. 7 shows a curve **8** which indicates that, at a ratio of 40 percent blue light to 60 percent yellow light, the density range of the negative must be 1.13 in order to obtain a desired density range of 1.4 in the print. If the ratio of blue light to yellow light is 80 to 20 percent, the density range of the negative should be 1.5. On the basis of the curve **8**, appropriate adjustment of the knob **4** can select any one of a number of intermediate values without further calculations.

In actual practice, the apparatus is preferably calibrated by resorting to a calibrating wedge. The constant of the wedge equals the constant of the scale **6**, i.e., $D=0.2$ cm. In order to simplify the calibrating operation, the wedge is preferably provided with a small auxiliary scale which is printed onto the material which is exposed to light during calibration. FIG. 8 shows a calibrating wedge **80** which is provided with an auxiliary density scale **81**. The range of graduations on the scale **81** is from +0.3 to −0.3 and the zero value coincides with the density value 2 of the wedge. The knob **5** is manipulated to place the graduation 2 on the density scale **6** into registry with the index **24**. In order to expose a first test strip, the knob **4** is adjusted first for exposure to yellow light along and thereupon for exposure of a second test strip to blue light. A densitometer is then employed to determine the position of the point corresponding to desired minimum density (for example, 0.3) on each of the thus exposed test strips. If the position of such point coincides with zero graduation of the auxiliary scale **81**, the calibration of the apparatus for sensitivity is accurate. However, if the thus determined points coincide with a positive or negative graduation of the auxiliary scale, the corresponding calibrating potentiometer **31** or **32** must be adjusted in accordance with the thus determined value. To this end, the potentiometers **31, 32** are provided with scales having graduations from +0.3 to −0.3 whereby the zero graduation corresponds to the central position of the respective contact arm.

The calibration can also be carried out in such a way that the curves **57–62** of both grey filters intersect each other on the line passing through the graduation 1.7 on the ordinate. It is further clear that the range +0.3 to −0.3 of graduations on the auxiliary scale **81** and the value 2 for the maximum density are given solely by way of example.

Our exposure control apparatus can also be used in combination with an enlarger. The lamp housing **1***a* of FIG. 3 is then replaced by a box which is placed in the path of light in an enlarger and contains only the color filters **28, 29** and shutter **27**. The mirror **30** is omitted and the lamp **25** is replaced by the light source of the enlarger. The function of the grey filter **27***a* is performed by the diaphragm in the enlarger. When the rate of magnification is changed, the diaphragm is adjusted to maintain the intensity of light at a substantially unchanged value.

If the apparatus is used in combination with a repro camera having a motor-driven rotary filter disk and which can contain a number of filters, an adapter must be connected between the camera and the exposure control apparatus in order to convert the signals produced by apparatus for direct control of electromagnets which move the shutter **27** and filters **28, 29** into appropriate electrical impulses serving to regulate rotation of the filter disk and to insert selected filters into the path of light in the camera.

It is further clear that the apparatus is not limited to a control of the exposure of printing material whose graduation is different for blue and yellow light. For example, the apparatus can control exposure of printing material in blue and red light. The thus exposed materials can be processed under identical circumstances regarding the duration of developing step and the temperature, type and concentration of developing solution. Very satisfactory results are achieved if the test strips and the exposed printing material are developed in accordance with "gamma-infinity," namely, if they are developed for such periods of time that the developing solution ceases to cause further darkening. Such method of developing can be carried out by semiskilled persons without resorting to expensive automatic processing machines.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge, readily adapt it for various applications without omitting features which fairly constitute essential characteristics of the generic and specific aspects of our contribution to the art, and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. In an apparatus for controlling exposure during the photographic printing of variable contrast printing material which is exposed to light passing through a negative in two colors and whose gradation is different for each of said colors, a combination comprising electronic timer means having first movable adjusting means for selecting the total exposure time to light in said colors; second movable adjusting means for selecting the ratio of exposures to light in said colors within said total exposure time; movable carrier means having a calibration curve determined on the basis of the contract grade of said printing material and as a function of the density of the negative; and an operative connection between said carrier means and said second adjusting means to facilitate the selection of said ratio on the basis of said curve.

2. A combination as defined in claim **1**, wherein said timer means further comprises movable graduated density scale means coupled with said first adjusting means for movement relative to fixed index means, said total exposure time being selected when said index means pinpoints on said scale means a graduation which is indicative of one extreme density value of the negative, said second adjusting means being arranged to move said carrier means with reference to said scale means and said ratio being selected when said calibration curve pinpoints on said scale means that graduation which is indicative of the other extreme density value of the negative.

3. A combination as defined in claim **2**, further comprising a grey filter which is utilized in determination of said calibration curve, said filter having second density scale means whose constant is the same as that of said first mentioned scale means.

4. A combination as defined in claim **3**, wherein the constant of said first mentioned scale means is alterable as a function of the Schwarzschild exponents of variable contrast printing material.

5. A combination as defined in claim **2**, wherein said first adjusting means comprises a potentiometer having an antilog characteristic curve said potentiometer including a movable portion and further comprising a gear

train for changing the position of said scale means in response to movement of said movable portion.

6. A combination as defined in claim 2, wherein said second adjusting means comprises a potentiometer having a movable contact arm and wherein said carrier means comprises a drum rotatable about a predetermined axis, said operative connection being provided between said drum and said contact arm.

7. A combination as defined in claim 6, wherein said operative connection comprises a gear train.

8. A combination as defined in claim 6, further comprising a housing for said timer means, said housing having a front wall and said axis being parallel to said wall.

9. A combination as defined in claim 6, wherein said drum is provided with a scale which indicates the ratio of exposures to light in said colors in each angular position of the drum.

10. A combination as defined in claim 2, wherein said first adjusting means comprises a potentiometer including a movable portion and said second adjusting means comprises a voltage divider having a movable portion, said operative connection being provided between the movable portion of said voltage divider and said carrier means, said timer means further comprising means for changing the position of said scale means in response to movement of the movable portion of said potentiometer, generator means for producing a signal as a function of time which is variable by said potentiometer, first evaluating means for said signal, said first evaluating means having an operating range which is variable by said voltage divider and being arranged to effect a change from exposure of printing material to light in one of said colors to exposure to light in the other color, and second evaluating means arranged to terminate the exposure of printing material to light in the other color in dependency on the signal produced by said generator means.

11. A combination as defined in claim 10, wherein said generator means comprises a capacitor and a source of electrical energy connected in circuit with said capacitor.

12. A combination as defined in claim 11, further comprising a plurality of variable resistors connected in series with said voltage divider to adjust said evaluating means as a function of sensitivity of printing material to light in said colors.

13. A combination as defined in claim 10, wherein said generator means comprises an analog computer amplifier circuit, a feedback element for said amplifier circuit, and short-circuiting means in parallel with said feedback element and arranged to open at the start of an exposure.

14. A combination as defined in claim 13, wherein said feedback element is a capacitor.

15. A combination as defined in claim 13, wherein said short-circuiting means comprises a transistor having an emitter-collector circuit in parallel with said feedback element and a base, said timer means further comprising a control circuit connected with said base and arranged to produce a signal to change the condition of said transistor on the completion of an exposure.

16. A combination as defined in claim 13, wherein said potentiometer has an antilog characteristic curve and is connected in circuit with said amplifier.

17. A combination as defined in claim 10, wherein said timer means further comprises a corrective circuit for the Schwarzschild effects of printing material, said corrective circuit including a second potentiometer having a linear characteristic and including a movable portion mechanically coupled with the movable portion of said first mentioned potentiometer.

18. A combination as defined in claim 17, wherein said corrective circuit further comprises at least one variable resistor in series with said second potentiometer.

19. A combination as defined in claim 18, wherein the movable portion of said second potentiometer supplies voltage to said first mentioned potentiometer.

20. A combination as defined in claim 19, wherein said timer means further comprises a buffer amplifier connected between the movable portion of said second potentiometer and one terminal of the winding of said first mentioned potentiometer.

21. A combination as defined in claim 20, wherein said buffer amplifier has a high input impedance and a low output impedance.

22. A combination as defined in claim 17, wherein said corrective circuit further comprises at least one resistor connected between the movable portion of said second potentiometer and the ground to enhance the corrective effect of said second potentiometer.

23. A combination as defined in claim 10, wherein said timer means further comprises a source of D-C potential and wherein said potentiometer constitutes a voltage divider and is connected between said source and the ground.

24. A combination as defined in claim 23, wherein said timer means further comprises a pair of additional adjustable voltage dividers receiving current from the movable portion of said potentiometer, said additional voltage dividers being connected in parallel with the ground, said additional voltage dividers having movable portions connectable with the input of said signal generator means.

25. A combination as defined in claim 24, wherein said timer means further comprises two-way switch means for connecting said input with the movable portion of one of said additional voltage dividers at a time.

26. A combination as defined in claim 25, wherein said switch means comprises a pair of fixed contacts each connected with the movable portion of one of said additional voltage dividers and a third contact movable into engagement with one of said fixed contacts at a time and connected to said input, said timer means further comprising a resistor connected between said movable contact and the ground to linearize the adjustment by said additional voltage dividers.

27. A combination as defined in claim 10, wherein said signal generating means comprises an amplifier having an output connected with said evaluating means and wherein said second evaluating means is arranged to receive a reference signal and to terminate the exposure in response to a predetermined relationship between said first mentioned signal and said reference signal.

28. A combination as defined in claim 10, wherein said generator means has an output connected with said first evaluating means and wherein said voltage divider is arranged to supply to said first evaluating means a portion of a reference current producing a second signal, said first evaluating means being arranged to effect said change when the magnitude of said first mentioned signal is in a predetermined relationship to the magnitude of said second signal.

29. A combination as defined in claim 10, further comprising a pair of resistor means connected between the output of said generator means and said evaluating means.

30. A combination as defined in claim 29, wherein the resistance of said resistor means is identical.

31. A combination as defined in claim 29, wherein the resistance of one of said resistor means is a predetermined fraction of the resistance of the other resistor means.

32. A combination as defined in claim 10, further comprising resistor means connected between each of said evaluating means and a source of reference current.

33. A combination as defined in claim 1, wherein said timer means comprises a plurality of adjustable electrical components and wherein such components are connected in several groups each of which is utilized for a given type of printing material, and further comprising changeover switch means for connecting a selected group into the circuit of said timer means.

34. A combination as defined in claim 33, further comprising a light source and a filter element having a plurality of grey filters movable into the path of light which issues from said source, and further comprising means

for moving a selected grey filter into said path in response to actuation of said switch means.

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