Jan. 19, 1960 D. R. CRAIG 2,921,512

PHOTOGRAPHIC PRINTING

Filed June 17, 1957

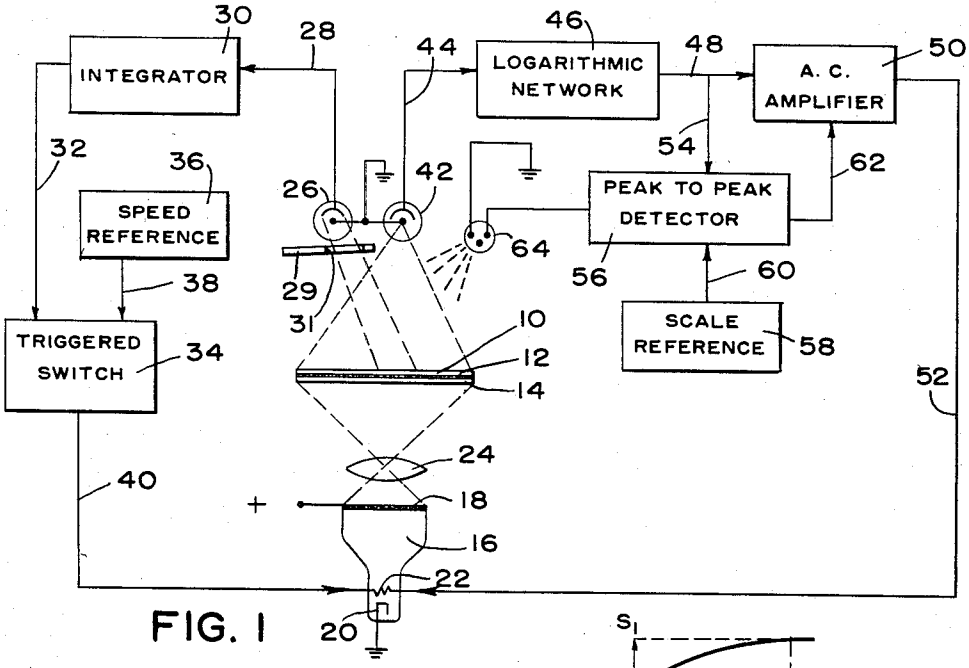


FIG. 1

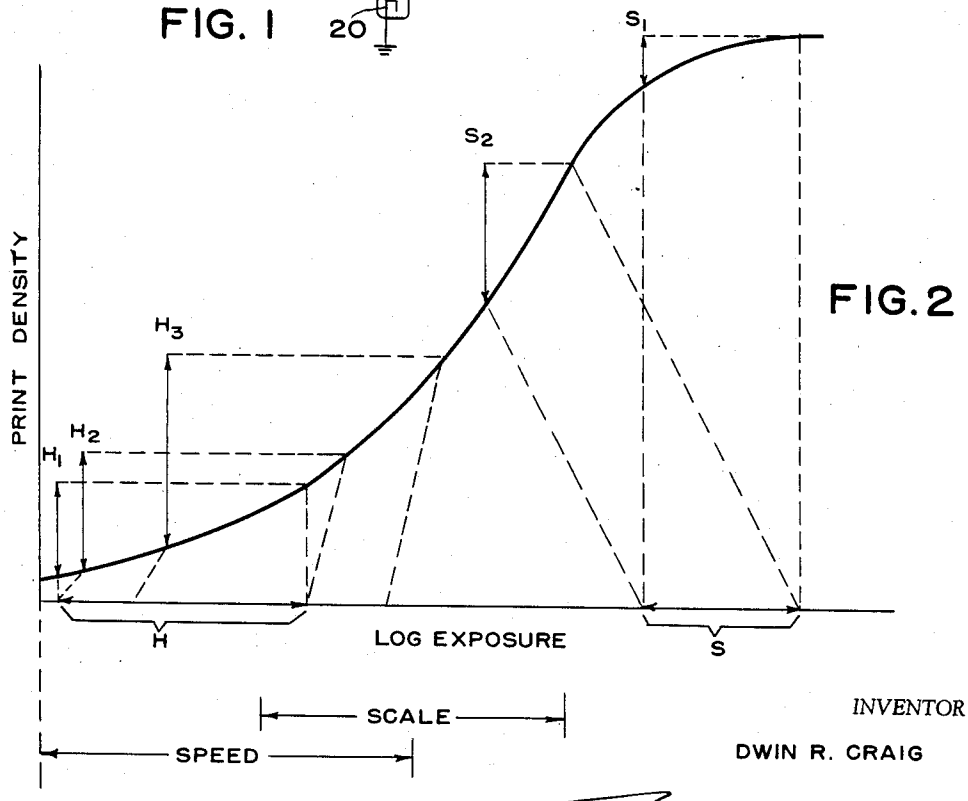


FIG. 2

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United States Patent Office 2,921,512
Patented Jan. 19, 1960

2,921,512

PHOTOGRAPHIC PRINTING

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Application June 17, 1957, Serial No. 666,124

6 Claims. (Cl. 95—73)

This invention relates to photographic printing and particularly to methods and apparatus for producing contact prints substantially automatically.

Obtaining a good print from a negative has traditionally been a matter of trial and error, based on the best judgment of highly experienced laboratory technicians. It is the purpose of this invention to eliminate completely the need for such judgment, by incorporating in an automatic contact printer not only a means for evaluating negatives but also additional means for properly executing the exposure. These evaluation and execution functions are performed simultaneously by means of feedback from a plurality of light sensing devices to a plurality of light sources, by virtue of which it becomes possible for the first time to print all black and white negatives on a single type of conventional high contrast printing material. Since all aspects of the final print are determined during exposure in the contact printer, it is also possible in accordance with the present invention to utilize a standardized developing technique regardless of the character of the negative being printed. The combination of standardized printing material, automatic contact printer, and standardized developing techniques, therefore reduces the production of high quality prints from a variety of negatives to a matter of routine. Exposure of the print is obviously the key to such an operation.

The contact printer contemplated by this invention performs automatically the several functions of dodging, choosing exposure level, and selecting the final print contrast. In quality printing, dodging has always been necessary to overcome the inherently short exposure scale and non-linear reproduction characteristics of printing papers; choice of exposure level has been achieved in the past by selecting an exposure time corresponding to the average density of the negative being printed; and the determination of final print contrast has been effected previously by the selection of a printing material whose exposure scale would equal that of the negative. Since all of these functions, or their equivalents, still appear to be necessary in quality printing, it is among the objects of this invention to provide methods and apparatus whereby they will be performed automatically, and by virtue of which their combined effect permits all negatives to be printed on a single emulsion, to be followed by a standardized development.

According to this invention, duration of the exposure is determined by a phototube and integrating circuit, by which light which has penetrated both the negative and photosensitized paper or other carrier will be integrated with respect to time. When the value of integrated light reaches a predetermined level corresponding to the speed of the emulsion, an electronic switch operates to terminate the exposure by extinguishing or otherwise rendering ineffective the exposing light. Consequently, variations between negatives and variations in average light level during exposure do not affect final print density. Automatic dodging is performed by using a cathode ray

tube as the printing light source, and employing a second phototube for continuously measuring the brightness of the scanning spot after it has penetrated both the negative and the photosensitized paper. Variations in signal level to control brightness of the cathode ray tube are fed back inversely from the phototube so that the scanning spot becomes brighter for denser areas in the negative and dimmer for thinner areas. The amount of inverse feedback applied is a function of density variations within the negative and is automatically controlled to permit residual excursions in brightness at the phototube which correspond to the exposure scale of the printing material. Extreme subject contrast can produce negatives of corresponding extreme contrast which may fall beyond the limits of the dodging circuitry and according to this invention the existence of such a negative is recognized by its peak to peak amplitude in the dodging channel, whereupon the automatic contrast control becomes effective. This automatic contrast control comprises a second light source arranged to superimpose a uniform layer of non-image forming light on the emulsion of the printing material, which is effected in a contact printer by transmitting light to the emulsion through the paper or other base of the printing material. This combined exposure to image forming light and non-image forming light causes a reduction in contrast similar to that produced by "flashing" as used in the graphic arts, or similar to the reduction in contrast encountered in aerial photography by the interposition of haze between the ground and the camera.

A more complete understanding of the invention will follow from a description of the accompanying drawings wherein:

Fig. 1 is a schematic circuit diagram depicting a contemplated form of apparatus; and

Fig. 2 is a curve which will assist an understanding of the principles of the invention.

Referring to Fig. 2, there is depicted a curve showing the H and D characteristics of a typical photographic printing emulsion, and illustrating the combined effect of the three automatic exposure functions contemplated by this invention. As commonly designated in this art, E represents exposure and log E symbolizes the logarithm thereof. The speed of the photosensitive emulsion is defined as the value of log E necessary to produce a middle density in the final print. The exposure scale of the photosensitive print material is defined as the difference in log E which can be reproduced on the substantially linear portion of the D, log E characteristic. As illustrated in Fig. 2, the difference in transmission of the negative between its highlight and shadow areas (S—H) exceeds the scale of the printing material. Consequently, in ordinary printing, both the shadows and highlights would be reproduced on the flat portion of the D, log E curve, highlight contrast H would be reduced to print contrast H_1 (underexposed), and shadow contrast S would be reduced to print contrast S_1 (overexposed). With automatic dodging however, more light is passed through the dense areas of the negative and less light is passed through its thin areas, producing an apparent compression of the negative which brings the values of S and H closer together on the log E scale, reproducing the highlights in the print as H_2 and the shadows as S_2. Highlight contrast H is here defined as density variation within an area smaller than the scanning spot but in a region of high density within the negative, and shadow contrast as density variation within an area smaller than the spot but in a thin region of the negative. These definitions provide the basis for a distinction between detail contrast and gross contrast, detail contrast referring to the length of either S or H, and gross contrast to their degree of separation. Accordingly, it can be seen that

automatic dodging tends to reduce gross contrast, *S—H*, while at the same time maximizing detail contrast, observing that S_2 is greater than S_1, and H_2 is greater than H_1. Whereas a scanning spot can exert no explicit influence on detail smaller than its own dimensions, it is nevertheless able to exert implicit control of detail contrast by altering its position on the *D*, log *E* curve. As clearly shown in Fig. 2, shadow contrast S_2 is nearly equal to negative contrast in the shadows S, whereas highlight contrast H_2 in the print is still less than highlight contrast in the negative H. This situation represents the case where gross contrast in the negative exceeds that which can be controlled by automatic dodging. To correct this situation, the printer must automatically inject some non-image forming light to further reduce contrast in the final print. If we assume that the relative intensity of light passing through S and H is expressed by the ratio 10:1, by the addition of one unit of non-image forming light, the new ratio becomes 11:2, representing a substantial reduction in contrast, as required. The shadow exposure on the other hand, was increased from 10 to 11, representing an increase in this value of only 10%, as compared with an increase of highlight exposure from 1 to 2, or 100%. Consequently, print contrast in the shadows S_2 is relatively unaffected, whereas print contrast in the highlights has been increased from H_2 to H_3, which in turn is now equal to highlight contrast in the negative H. From the foregoing it is apparent that a combination of the three functions described is capable of altering the apparent contrast of the negative, both gross and detail, to fit the exposure scale of the printing material. Exposure duration determines average print density, automatic dodging reduces gross contrast and maximum detail contrast, and superposition of non-image forming light further reduces both gross and detail contrast. It is therefore necessary to choose a printing material with sufficiently high gamma to accommodate the flattest negative which will be encountered in practice, whereupon all other negatives will be reduced to this same apparent contrast.

As depicted in Fig. 1, the paper or other support **10** is coated with an emulsion providing a photosensitive surface **12** and is placed in intimate contact with a negative or other transparency **14** to be reproduced and thus supported by conventional means. The primary light source is a conventional cathode ray tube **16** provided with a screen of fluorescent material **18** which emits actinic light when bombarded by a scanning beam of electrons from its cathode **20** under the control of one or more control electrodes **22**. The resulting spot of light at the face of the tube is projected by means of a lens **24** through the negative **14** exposing the photosensitive surface as it scans the area to be printed. The size of the projected spot depends on not only the electronic focus within the tube but also the optical focus and scale of magnification between the face of the tube and the negative. With perfect optics, the ratio of spot diameter to format dimensions will always be the same at the negative as at the face of the tube. In practice, this will produce a relatively unsharp dodging pattern as compared with the sharpness of images generally recorded on photographic materials. A spot having a diameter of approximately ⅛" covering a format whose dimensions are, say, 8" by 10", can be formed at a brightness level sufficient to represent practical printing speeds.

A phototube **26** is exposed to light penetrating the support **10** through a shield **29** containing an aperture **31** which restricts the field of view to a portion only of the format. This phototube **26** is D.C. coupled by a lead **28** to an integrator **30** which is connected by a lead **32** to a triggered switch **34** to which a source of adjustable speed reference voltage **36** is also connected by a lead **38**. The triggered switch is in turn connected by a lead **40** to the control electrode means **22** for terminating the exposure when the integrated light achieves a predetermined value. During the exposure, the pulsed light and D.C. component of light sensed by the phototube **26** are combined to discharge a capacitor constituting a part of the integrator **30**. Charge removed from this capacitor corresponds to the number of photons received by the phototube **26** which in turn corresponds to the amount of light incident on the portion of the area of the printing material to which the phototube is exposed. When the voltage on the integrating capacitor has dropped from a fixed preset value to a reference value manually selected by adjustment of the speed reference **36**, the electronic switch **34** is triggered. The manually inserted voltage reference corresponds to the speed of the printing material constituting the photosensitive surface **12**. This in turn corresponds to the amount of light which is necessary within the field of view of the phototube **26** to expose the printing material to a mid-tone of grey, and preferably the field of view of the phototube **26** can be manually directed by the operator to aim at any selected center of interest of the picture. This selected region will always receive the optimum exposure and will usually be bracketed by other areas of extreme highlight or shadow. When the electronic switch **34** is triggered by the integrator **30**, a signal is transmitted through the lead **40** to the control grid **22** of the cathode ray tube **16** to terminate the exposure.

During the exposure period, a separate phototube **42** is provided in the path of light penetrating the support **10** to perform the functions of automatic dodging control and automatic contrast control. The signal from the phototube **42** which views the entire format, is passed through a lead **44** to a logarithmic network **46**. This network converts relative transmission of light into the logarithm of relative transmission providing a more convenient notation for relating subsequent control functions to the *D*, log *E* characteristics of the photographic emulsion; it permits the system to cope with large variations in light level, without producing voltage limiting in the electronic circuitry; and it tends to provide a constant loop gain for signals representing variations within the negative, even though the absolute light level may be altered drastically due to changes in lens aperture, average negative density, or transmission of the printing material.

The signal from the logarithmic network **46** is fed through a lead **48** to an A.C. amplifier **50** where it is inverted, amplified, and fed through a lead **52** back to the grid **22** of the cathode ray tube **16**. Response of this feedback loop is rapid compared to the velocity of the spot in order to establish instantaneous and continuous control of spot brightness. If this loop were allowed to operate at 100% inverse feedback at which a change in spot brightness exactly matches and cancels a change in negative transmission, the gross contrast in the final print would be reduced to zero. Such prints are highly informative in that they provide a maximum of detail contrast throughout, a real asset to documentary photography such as aerial and scientific, but they are not pleasing from a pictorial standpoint. To avoid this severe reduction in gross contrast, it is necessary to reduce the value of loop gain and allow some variation in brightness at the phototube **42**.

The signal from the logarithmic network **46** is also fed through a lead **54** to a peak to peak detector **56**, such peak to peak signal, without feedback, representing the scale of the negative which is represented in Fig. 2 as *S—H*. A manually inserted scale or voltage reference **58**, connected to the peak to peak detector **56** by a lead **60** corresponds to the exposure scale of the photographic emulsion **12**. When the peak to peak signal exceeds this reference voltage, a signal is passed along a lead **62** to the A.C. amplifier, increasing its gain from zero to a positive value, which in turn provides inverse feedback via the lead **22** to the control electrode **22** of the cathode tube **16**. When, after a few sweeps, this inverse feedback has reduced the peak to peak signal back to the value

of the scale reference **58**, the gain of the A.C. amplifier is then allowed to drift back towards zero. Following this, the peak to peak signal recovers, once again introducing inverse feedback to the grid **22**. This type of hunting action thus maintains the peak to peak signal at a level corresponding to the scale of the emulsion.

When a negative is encountered whose density scale exceeds that which can be brought within acceptable range by the dodging control, it becomes necessary to introduce suitable contrast control in addition. A secondary light source **64** is arranged to illuminate the format uniformly with actinic light, passing through the back of the paper **10** to the emulsion **12**. The brightness of this light is controlled by the value of the peak to peak voltage from the phototube **42** and the logarithmic network **46**. An argon glow lamp is suitable for this application since it provides highly actinic emission and is readily controlled by low power electronic circuitry.

A contact printer embodying these features can be combined with mechanical means for positioning negatives and paper automatically so as to be capable of operation without supervision or need for operator decisions. After an initial calibration to establish the references for speed and scale of the printing emulsion, no further attention would be required, even though the negatives to be printed varied as widely as those encountered in ordinary amateur photography.

To illustrate the three exposure functions and their interdependence, it will be appropriate to consider the cause and effect of three general types of negatives which might be encountered. For convenience, the three classes will be designated respectively, "thin," "normal," and "contrasty." The "thin" negative is usually the result of either underexposure or underdevelopment. If underexposure, it will have low contrast, being reproduced on the toe of the characteristic curve of the negative material. If thin because of underdevelopment, it will likewise exhibit low contrast because of the developing characteristics of films. In either case, both the gross contrast and the detail contrast will be low. Therefore, the phototube **42** will sense very little peak to peak signal and there would be little, if any, inverse feedback for dodging. Furthermore, the peak to peak signal would fail to exceed the scale reference **58** and would produce no light from the secondary source **64** for contrast control, as result of which, the print produced would be characterized by maximum contrast.

The "normal" negative usually exhibits gross contrast which exceeds that capable of reproduction by high contrast printing materials. Consequently, during exposure the peak to peak signal would exceed the scale reference and would produce inverse feedback for dodging, in which case the amount of dodging would be just sufficient to prevent either the shadows or highlights from being reproduced on non-linear portions of the curve.

"Contrasty" negatives are usually the result of subject matter possessing a high degree of contrast, such as those illuminated by bright sunlight or photo flash sources, but they may be the result of overdevelopment of the film. In either case, both the detail contrast and the gross contrast would be extremely high. During the printing operation according to this invention, the peak to peak signal would exceed by far the scale reference tending to produce inverse feedback approaching 100%, a condition which is seldom if ever achieved due to practical limitations. Under these conditions however, the contrast control would be operating to energize the secondary light source **64** and thereby reduce not only the gross contrast but also the detail contrast to a point where the image could be reproduced by a standardized type of photosensitive coated paper made possible by this invention.

Whereas only one form of the invention has been shown and described, it should be construed as illustrative and should not be restrictive beyond the scope of the appended claims.

I claim:

1. Photographic printing apparatus comprising a primary light source for exposing a photosensitive emulsion through a transparency, photoelectric control means in circuit with said source controlling said source as an inverse function of the intensity of light penetrating said emulsion, photoelectric control means in circuit with said source controlling said source as a function of the total light penetrating said emulsion to terminate an exposure cycle, a secondary light source in an optical path including said emulsion but remote from said transparency, and circuit means including said secondary source and the first said photoelectric control means for energizing said secondary source to expose said emulsion substantially uniformly as a function of the contrast of said transparency.

2. Photographic printing apparatus as set forth in claim 1 wherein said primary light source is a cathode ray tube.

3. Photographic printing apparatus as set forth in claim 1 wherein the first said photoelectric control means includes a phototube in the path of light passing through said transparency, an output circuit for said phototube, a logarithmic network and an A.C. amplifier, said network and amplifier interconnecting said output circuit and source controlling circuit.

4. Photographic printing apparatus as set forth in claim 1 wherein the circuit means including said secondary source and the first said photoelectric control means comprises a phototube in the path of light passing through said transparency, an output circuit for said phototube, a peak to peak detector in said output circuit, an adjustable source of reference voltage connected to said detector, and an output circuit for said detector including said secondary source.

5. Photographic printing apparatus as set forth in claim 1 wherein the second said photoelectric control means includes a circuit containing a phototube, exposed to the light penetrating the emulsion, switching means connected to the light source, and integrating means responding to total light impinging on said phototube to actuate said switching means.

6. Photographic printing apparatus comprising a cathode ray light source having a cathode and control electrode means, support means for a transparency and a photosensitive surface to be exposed in the optical path of light produced by said source, a photoelectric sensing device in the optical path of light to which said surface is exposed, an inverse feedback amplifier and a peak to peak detector in circuit with said sensing device and control electrode means, a second source of light for exposing said surface in circuit with said detector; and a circuit including said control electrode means, switching means, and integrating means responsive to light impinging on said surface to control the duration of an exposing cycle.

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