April 15, 1969 P. F. KING 3,438,705

AUTOMATIC XEROGRAPHIC DEVELOPMENT CONTROL

Filed Jan. 3, 1967 Sheet 1 of 3

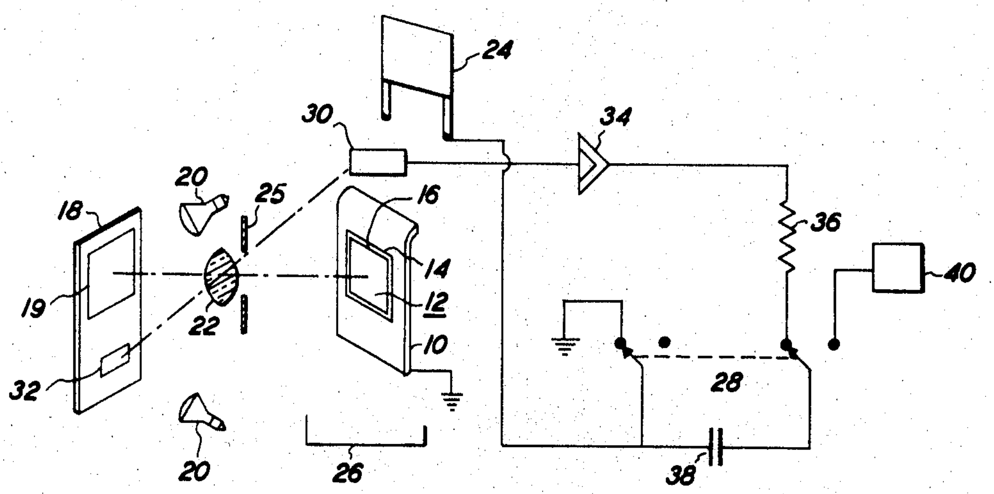

FIG. 1

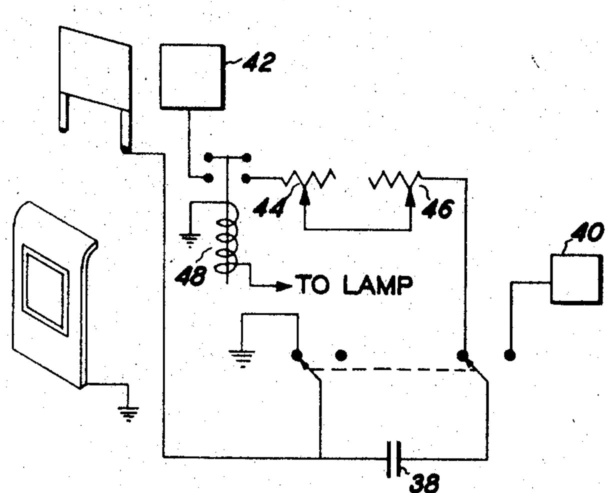

FIG. 2

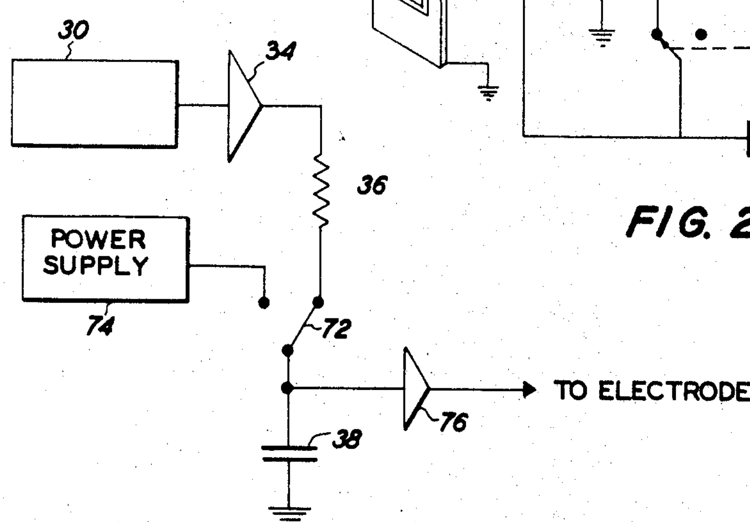

FIG. 4

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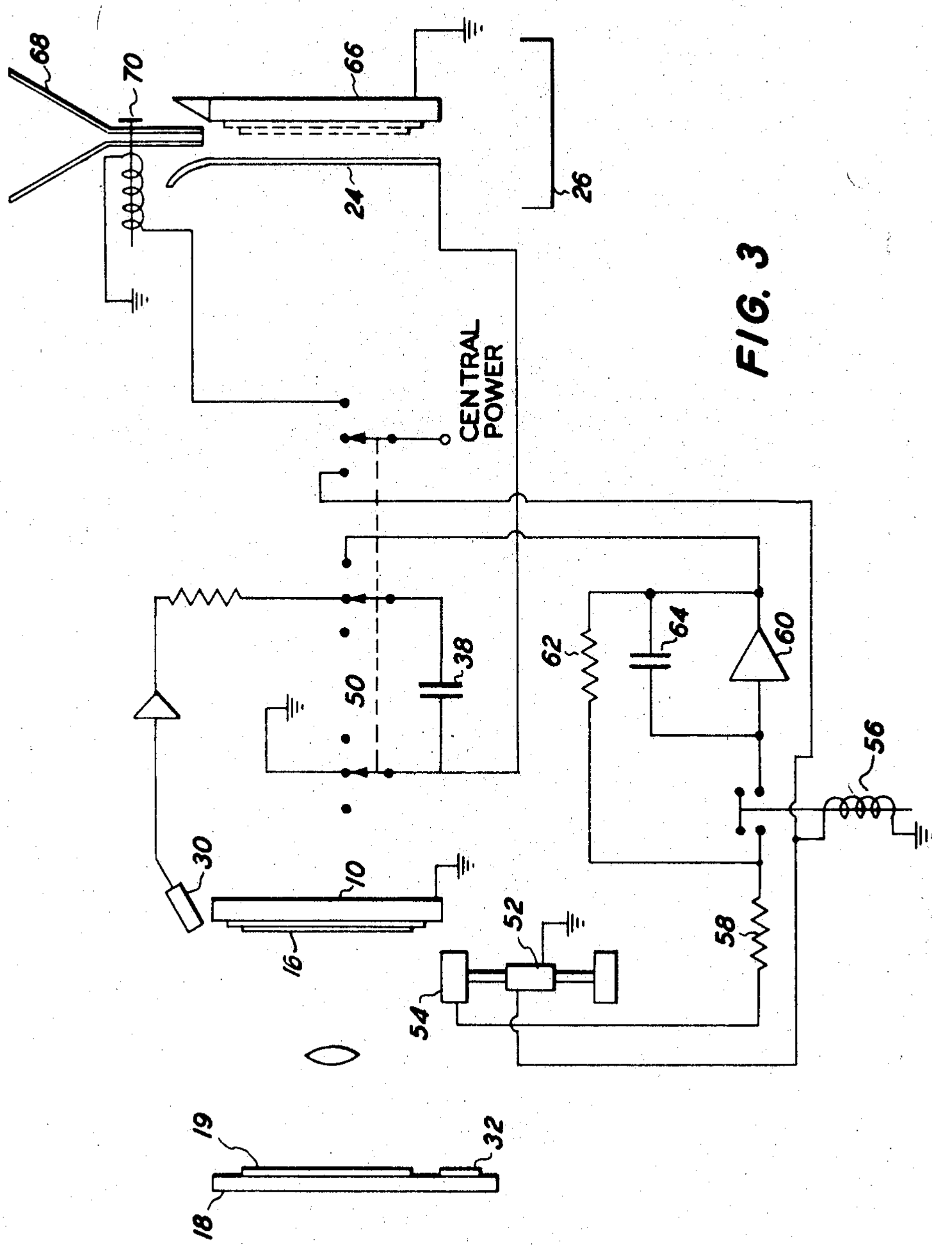

FIG. 3

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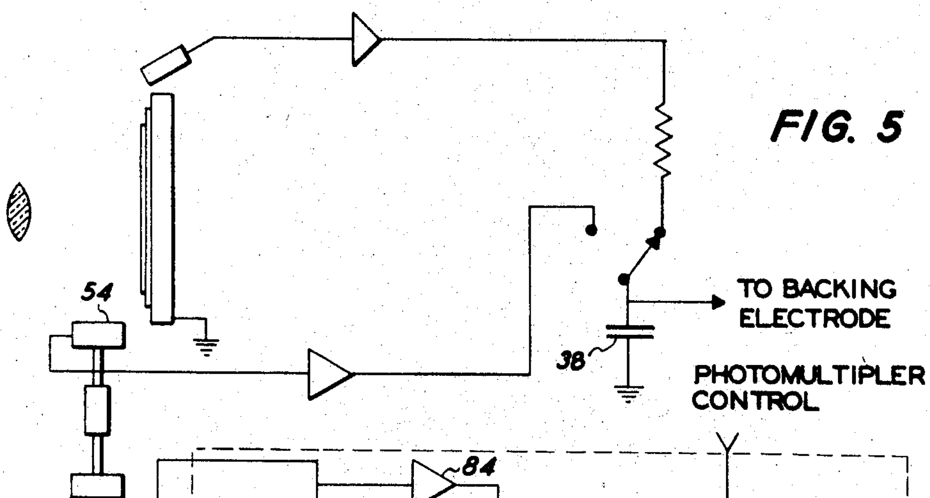

FIG. 5

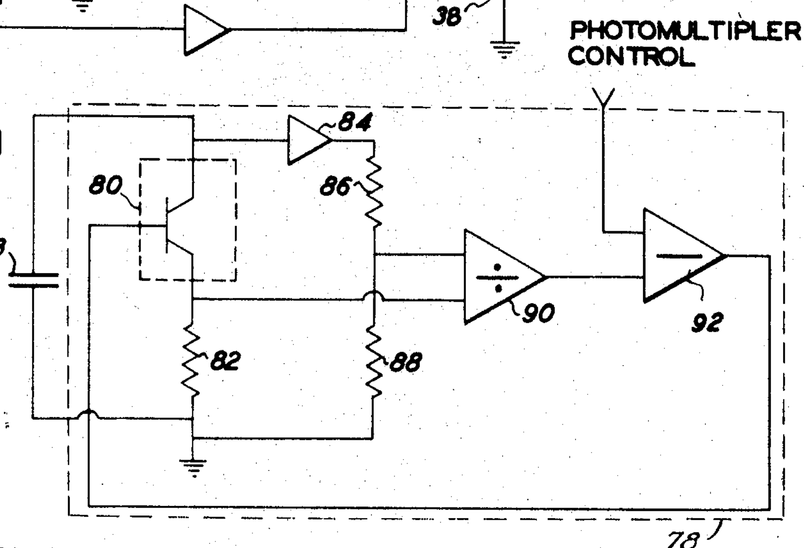

FIG. 7

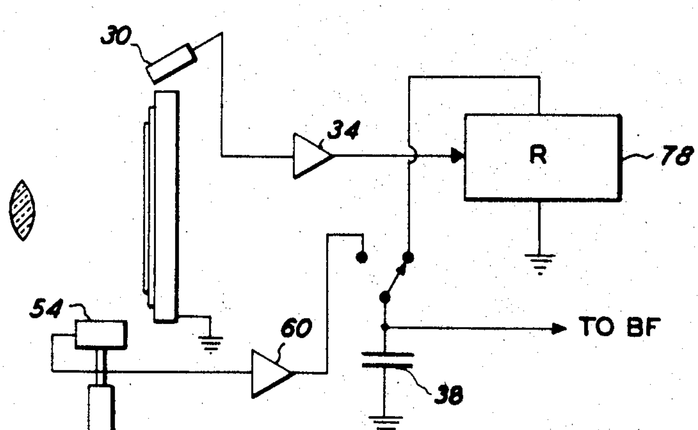

FIG. 6

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AUTOMATIC XEROGRAPHIC DEVELOPMENT CONTROL

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ABSTRACT OF THE DISCLOSURE

A xerographic exposure and development apparatus whereby background density is automatically controlled by a photosensitive device which scans the material to be reproduced. The potential derived from scanning the background material by the photosensitive device is then applied to the developing plate during exposure thereby reducing overcharging of the plate.

Xerography, as pertinent to the present invention, comprises an image reproduction method wherein an electrostatically charged photoconductive insulating member is exposed to a light image and the resulting electrostatic latent image is developed or made visible through the selective deposition of electrostatically attractable particles. Alternatively, the latent image may optionally be transferred and fixed in image configuration to a sheet of paper or other support material. The development methods in widespread use in xerography were selected for their suitability for producing high contrast black and white copies with a fixed exposure despite variability in the original document. However, development methods are also known which produce high quality images with solid area coverage tonal gradation. These methods resemble conventional silver halide photography in that exposure is preferably adjusted to correspond to a particular subject or class of subjects being reproduced. These methods are generally characterized, in that the photoconductive insulating member, referred to as a xerographic plate, is brought into contact with electrostatically attractable particles while spaced as closely as feasible to an equipotential member known as a development electrode. In one known embodiment, the development electrode is a metallic plate and the electrostatically attractable particles are poured through the channel between the electrode and the photoconductive insulator. In other known embodiments, the attractable particles are precoated on a metallic plate which is then pressed against the photoconductive insulator or else the equipotential member is comprised of electrically conductive filaments or the like mixed with electrostatically attractable particles and poured across the photo-conductive insulating member. These configurations cause an electrostatic field to be formed between the photoconductive member and the equipotential member in proportion to the charge on the photoconductive member and are also effective to increase the electric field above large areas of uniform charge density. It is these electric fields which cause the electrostatically attractable particles to move to and adhere to the photoconductive insulator for purposes of development. In this way, large solid areas as well as tonal gradations may be developed. However, the potential on the development electrode must be accurately matched to the minimum potential on the photoconductor if images are to be formed with clear backgrounds or highlights.

The exposure latitude is quite small when a development electrode is employed as described above. The small exposure latitude on the underexposed side of optimum is caused by the electrostatic potential which remains

2

on the plate in the background or highlight areas, i.e., those receiving maximum illumination. This background potential produces an electric field between the photoconductive insulator and the development electrode and the electrostatically attractable particles are deposited in those areas giving a high background density in areas which should be reproduced as white. The small exposure latitude on the overexposed side of optimum is caused by the reduced potential on the photoconductive insulator in the image areas. This reduced potential creates an electric field which is insufficient to give good solid area development.

Brief summary of the invention

Increasing the exposure latitude on the overexposed side of optimum exposure can be achieved by minimizing the space between the development electrode and the photoconductive insulator. For example, the previously described method may be used in which the electrode is coated with a thin layer of particles and pressed against the photoconductor. This invention, however, is primarily addressed to the problem of increasing the exposure latitude on the underexposed side of optimum and, at the same time, provide an automatic control to achieve minimum background density. While it is, in principle, possible to measure the potential on a xerographic plate after exposure and adjust the electrode potential to the minimum measured potential, such a method is not feasible in practice for two reasons. First, the plate would have to be completely scanned by a very small area electrometer. This would be both expensive and time consuming, the plate potential meanwhile decaying as the measurement is in progress. Second, a particular subject may not contain a white area, and the minimum plate potential may not correspond to an area which should remain undeveloped. The desired result is accomplished by measuring the exposure which would be received by the xerographic plate in a background or highlight area, deriving from this exposure and from the initial potential on the xerographic plate a new potential substantially equal to the potential which would result from the exposure of the xerographic plate to a background or highlight area, and applying this potential between the development electrode and xerographic plate during development.

Objects

It is accordingly the principal object of the invention to provide means and method for automatically optimizing the potential on a xerographic development electrode so as to minimize background deposition in a developed image. Further objects will become apparent in connection with the following description of various embodiments of the invention.

Brief description of the drawings

FIG. 1 shows a first embodiment of exposure and development apparatus according to the invention;

FIG. 2 shows a modification of FIG. 1;

FIG. 3 shows a further embodiment in which the initial potential is measured before each exposure;

FIG. 4 shows a further form of control and development apparatus;

FIG. 5 shows a modification of FIG. 4 in which the initial potential is measured before each exposure;

FIG. 6 shows a further embodiment including an electronically adjustable resistor; and,

FIG. 7 shows the resistor of FIG. 6.

Detailed description

FIG. 1 shows an illustrative embodiment of the invention. A support member **10** is adapted to support a xerographic plate **12** illustratively comprising a metallic backing sheet **14** and a layer of photoconductive insulating material **16**, such as vitroeous selenium or a dispersion of zinc oxide in a resin binder. A platen **18** is positioned facing the xerographic plate and is adapted to carry a document, photograph or other subject **19** which is to be reproduced. When the platen is illuminated by lamps **20**, lens **22** will focus an image of the subject onto the xerographic plate. There is also provided a development electrode **24** which pivots about hinges and is illustrated in its upward position which permits exposure of the xerographic plate. The development electrode can also be swung downwards (as positioned in FIGURE 3) where it defines a narrow channel with the xerographic plate. In this position, a xerographic developer, such as a mixture of micron-sized resin particles with larger glass beads or the like, can be poured through the gap between the xerographic plate and the development electrodes and caught in a receptacle **26**. Alternatively, a gaseous suspension of sub-micron sized particles can be blown through the space between the xerographic plate and the development electrode or the development electrode can be precoated with particles and pressed against the plate.

The first step in making an image normally consists in electrostatically charging xerographic plate **12** to a uniform potential on the order of several hundred volts. This can be carried out by any suitable conventional charging apparatus, not shown. When the xerographic plate is suitably charged and is in the indicated position, lamps **20** may be energized for a suitable length of time required to selectively discharge the charge on the xerographic plate to form a developable electrostatic latent image pattern. Alternatively, the exposure can be adjusted by varying the light intensity or by varying the lens aperture through the use of a diaphragm **25**. Since the density and quality of the resulting developed image is strongly dependent upon exposure when a development electrode is employed, the exposure will be adjusted for the particular subject matter or class of subject matter being reproduced through the use of an exposure meter, or trial and error, or the judgment of the operator. Before starting the exposure, switch **28** will be placed in the left-hand position and a photomultiplier or other photosensitive device **30** will look through lens **22** at a small sample of background reference material **32**, positioned on platen **18** adjacent to the subject **19**. Material **32** will be of the same material or at least have the same optical density as the background areas of the subject. Thus, the light incident on photomultiplier **30** will be the same as that which would be received by an area of the xerographic plate upon which is imaged a white or highlight area of the original subject. Photomultiplier **30** is connected to a voltage amplifier **34** which is, in turn, connected through a resistor **36** to capacitor **38**. Capacitor **38** is thus charged up during an exposure in the same proportion as the xerographic plate is discharged. More specifically, the use of a high gain amplifier and a high value of resistance will cause the capacitor to charge up linearly at a rate proportional to the intensity of illumination on photomultiplier **30**. Since, however, the voltage on the xerographic plate decays in an approximately exponential fashion under illumination, it is preferable to employ a lower value of amplifier gain and a lower value of resistance, such that capacitor **38** is charged exponentially in a manner approximating the decay of voltage on the xerographic plate. After exposure is terminated, the development electrode is swung down into position and switch **28** is moved to the right-hand position so that the formerly grounded side of the capacitor **38** is now ungrounded and connected to the development electrode **24** and the side of the capacitor formerly connected to amplifier **34** is now connected to a power supply **40**. The power supply potential is made equal to the potential which is initially applied to the xerographic plate by the charging apparatus, not shown.

In the illustrated embodiment, the polarity of power supply **40** will be the same as the polarity of charge on the xerographic plate **12** and similarly, the output of amplifier **34** will be of that same polarity. Accordingly, when switch **28** is moved to the right-hand position, the potential on the development electrode **24** will be equal to the potential of power supply **40** minus the potential accross capacitor **38**, and will closely approximate the potential which appears on plate **12** in areas corresponding to image highlights or which would appear as such highlights. When development is thereupon carried out by the previously described methods, or any other methods, there will be no electric field between the xerographic plate and the development electrode in image highlight areas and no electrostatically attractable particles will be deposited on the xerographic plate, or even on the development electrode, in such areas. The result will be a developed image having clear, background free highlights or background areas, and this result will be achieved automatically over a wide range of exposures.

Where it is known that the original subject **19** will have white margins or other areas which will be predictably of lowest density, sample material **32** may be omitted and the photomultiplier adjusted so as to focus on such margin areas. In such cases, it will generally not be feasible to aim photomultiplier **30** through lens **22** since the photomultiplier would then have to occupy the same position as the xerographic plate. However, the photomultiplier can then be provided with a lens system of its own. FIG. 2 shows a simplified form of part of the apparatus of FIG. 1 in which the photomultiplier **30**, amplifier **34**, and resistor **36** have been replaced by a power supply **42** and a pair of variable resistors **44** and **46**. One of the resistors is calibrated in terms of lens aperture and the other resistor is calibrated in terms of background optical density of the subject being reproduced. A relay **48** connects the power supply only when the lamps are lit. In this way, the potential developed across capacitor **38** will be a function of the lens aperture, the background density, and the length of exposure and will accurately reflect the decrease in potential on the xerographic plate. However, the apparatus of this figure, unlike that of FIG. 1, will be affected by such factors as variations in the output of lamps **20** due to aging or variations in supply voltage as well as to the affects of dust and dirt on lens **22**. The illustrated arrangement, however, is adequate for many purposes and may be substituted for the photomultiplier shown in FIG. 1 or in any of the figures which follow.

FIG. 3 shows a further embodiment of the invention in which the initial potential on the xerographic plate is measured before each exposure. This will often prove desirable because existing electrostatic charging apparatus sometimes produces variable results from one charging to another and because different xerographic plates will often accept varying potentials from the same charging apparatus. In this embodiment, switch **50** is first placed in the left-hand position, which causes solenoid **52** to raise an electrometer **54** into a position where it is adjacent to the surface to the photoconductive insulating surface **16** of the xerographic plate and produces an output voltage proportional to such potential. At the same time, relay **56** is closed, connecting the electrometer through input resistor **58** to operational amplifier **60** which amplifies the electrometer output by a factor equal to the ratio of feedback resistor **62** to input resistor **58**. When switch **50** is placed in the intermediate position, at or prior to exposure, the electrometer is retracted from the exposure path and relay **56** is opened, thus causing the operational amplifier **60**, in conjunction with feedback capacitor **64**, to hold its previous output. The operational amplifier and its associated components will be recognized as constituting a conventional sample and hold circuit. During exposure, the circuit of this figure functions exactly the same as that of FIG. 1 and after exposure, switch **50** is turned to the right-hand position and the circuit again functions as in FIG. 1, except that the power supply **40** of FIG. 1 has been replaced by the actual measured initial plate potential as stored at the output of amplifier **60**.

In this figure, a different development arrangement is exemplified wherein capacitor **38** is connected to a development electrode remote from support member **10**. After exposure, the xerographic plate is removed from support member **10** and placed on a second support member **66** which is positioned adjacent to development electrode **24**. A developer hopper **68** is positioned above the channels formed between the development electrode and the xerographic plate and is provided with a solenoid valve **70** such that when switch **50** is turned to the right-hand or development position, the solenoid valve will open and discharge developer material across the xerographic plate.

FIG. 4 shows another form of the invention, the mechanical structure of the previous figures being omitted for simplicity. In this embodiment, one end of capacitor **38** is permanently grounded or connected to a source of fixed potential. The other end of the capacitor is initially connected through switch **72** to a source of fixed potential **74** and is thereafter discharged by a photomultiplier **30** acting through amplifier **34** and resistor **36** by an amount equal to the loss in potential suffered by the xerographic plate itself. A buffer-amplifier **76** may be used in this figure or in the embodiments of other figures to transfer the supply voltage to the development electrode, where the capacitance or leakage resistance of the electrode would otherwise discharge the capacitor **38**. If the buffer-amplifier has a gain other than unity, the voltage developed on capacitor **38** need not be equal to the desired development electrode potential but need only be proportional desired value. Since the voltage on the capacitor can be made opposite to the polarity of the residual plate potential, the same results as previously described may be had by applying the resulting voltage to the back of the xerographic plate, and grounding the development electrode, providing exactly the same fields between the plate and development electrodes as in the previous embodiments.

FIG. 5 shows an embodiment similar to that of FIG. 4 except that an electrometer **54** is employed to measure the actual initial potential on the xerographic plate. Since this potential is only required to be used to precharge capacitor **38** before exposure, only a simple amplifier **60** is required rather than the sample and hold circuit of FIG. 3.

FIG. 6 shows a final and preferred embodiment of the invention. Prior to exposure, capacitor **38** is charged to the initial plate potential by electrometer **54** and amplifier **60**. During exposure, capacitor **38** is connected to a variable resistance circuit **78** which is controlled by photomultiplier **30**. More specifically, resistance circuit **78** provides a controllable resistance in shunt with capacitor **38** and which is inversely proportional to the light incident on photomultiplier **30** during exposure. Thus, capacitor **38** will be discharged in an exponential fashion with a time constant which is a function of the incident illumination. This corresponds quite closely to the way the xerographic plate itself is affected by radiation and, accordingly, the potential on capacitor **38** at the end of exposure will accurately reflect the potential on the xerographic plate in background or highlight areas. This potential can be applied to the development electrode exactly as in previous figures.

FIG. 7 illustrates one way in which the variable resistance circuit **78** of FIG. 6 can be realized. The capacitor is connected through a controllable resistive device **80**, such as a transistor or vacuum tube, to a current sampling resistor **82** and to a high impedance buffer-amplifier **84**, such as a field-effect transistor in a source-follower configuration. A sample of the buffer amplifier output is taken by a voltage divider comprising resistors

86 and **88** and compared in a dividing circuit **90** with the voltage across current sampling resistor **82**. The output of dividing circuit **90** will represent the ratio of the capacitor voltage to the current drawn from it and hence will be proportional to the apparent resistance in parallel with the capacitor. Preferably, the inputs to the divider circuit are connected so that the output is instead proportional to one over the effective resistance. The output of the divider circuit is compared with the photomultiplier output in a differential amplifier **92** which generates an output signal proportional to the difference between the resistance seen by capacitor **38** and the desired resistance. This signal is applied to the control terminal (e.g., base or grid) of the resistive element **80**. There is thus formed a feedback regulating circuit which constrains the resistive element to simulate a variable resistor having a value inversely proportional to the light intensity at the photomultiplier.

The foregoing figures and the description thereof are intended to be illustrative of the invention rather than definitive thereof. Accordingly, the scope of the invention is to be determined solely from the claims, as many variations of the foregoing figures and descriptions will be obvious to anyone skilled in the art.

What is claimed is:

1. In a xerographic exposure and development apparatus wherein a xerographic plate electrostatically charged to an initial potential is exposed to an image pattern of radiation and thereafter developed by contact with electroscopic particles while in close proximity to a development electrode and as a function of the electric field between said plate and electrode;

the developed image background minimizing improvement comprising:

first circuit means activated solely during exposure to generate a potential increment which is a direct function of exposure time and exposure intensity and approximates the plate voltage decrement in maximally exposed areas thereof, and

second circuit means to substract said increment from said initial potential and apply the resulting potential between said plate and electrode to eliminate the field therebetween adjacent maximally exposed areas of the plate.

2. The apparatus of claim **1** wherein said initial potential is measured before each exposure.

3. The apparatus of claim **1** wherein said initial potential is represented by a fixed potential.

4. The apparatus of claim **1** in which said first circuit comprises a photodetector exposed to said image pattern of radiation and connected to one terminal of a storage capacitor, the other terminal of said storage capacitor being connected to one of said plate and electrode, and said second circuit comprises a switch to disconnect said capacitor from said photodetector and connect it to said initial potential.

5. The apparatus of claim **1** in which said first circuit comprises a fixed potential, a variable resistance means connected to said fixed potential, said resistance means being calibrated so that the potential developed thereacross is a function of the exposure intensity and duration and background density, said resistance means being connected to one terminal of a storage capacitor, the other terminal of said storage capacitor being connected to one of said plate and electrode, and said second circuit means comprising a switch to disconnect said capacitor from said resistance means and connect it to said initial potential.

6. The apparatus is defined in claim **2** wherein said first circuit comprises a photodetector exposed to said image pattern of radiation and conected alternately to one terminal of a storage capacitor and to the output of a sample and hold circuit, the other terminal of said storage capacitor being connected to provide a charging path for said capacitor, and said second circuit comprises a switch to disconnect said capacitor from said photodetector and connect it to the sample and hold circuit and to disconnect the other terminal of said capacitor from said charging path and connect it to one of said plate and electrode.

7. The apparatus of claim **2** wherein said first circuit comprises a photodetector exposed to said image pattern of radiation and connected to one input of a variable resistance circuit, the output of said variable resistance circuit being connected to one terminal of a storage capacitor, said terminal also being connected to one of said plate and electrode, and said second circuit comprising a switch to disconnect said capacitor from said variable resistance and connect said initial potential thereto.

8. The apparatus as defined in claim **7** where it said variable resistance circuit comprises a controllable resistive device, means connected to said device and to said

storage capacitor for producing an output which is proportional to the apparent resistance in parallel with said capacitor, means connected to the output of said proportional output producing means for comparing the output thereof and the output of said photodetector, and

means for connecting the output of said comparator means to the input of said controllable resistive device.

9. The apparatus as defined in claim **8** wherein said controllable resistive device comprises a transistor.

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LEO H. McCORMICK, *Assistant Examiner*