United States Patent [19]

Coriale

[11] **3,788,739**

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[54] **IMAGE COMPENSATION METHOD AND APPARATUS FOR ELECTROPHOTOGRAPHIC DEVICES**

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[73] Assignee: **Xerox Corporation,** Rochester, N.Y.

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[52] **U.S. Cl.** ..... **355/17,** 96/1 R, 355/3

[51] **Int. Cl.** **G03g 13/00**

[58] **Field of Search** ..... 355/3, 13, 16, 17; 96/1 R

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[57] **ABSTRACT**

A compensation method and apparatus wherein an electrometer probe is positioned in proximity to an exposed area of a charged photoreceptor surface. The probe is positioned only in that position of the area which is always light struck. Measurement of the surface potential and comparison of the surface potential to a fixed reference provides a control signal which can be employed to compensate charge, exposure, transfer and development.

7 Claims, 5 Drawing Figures

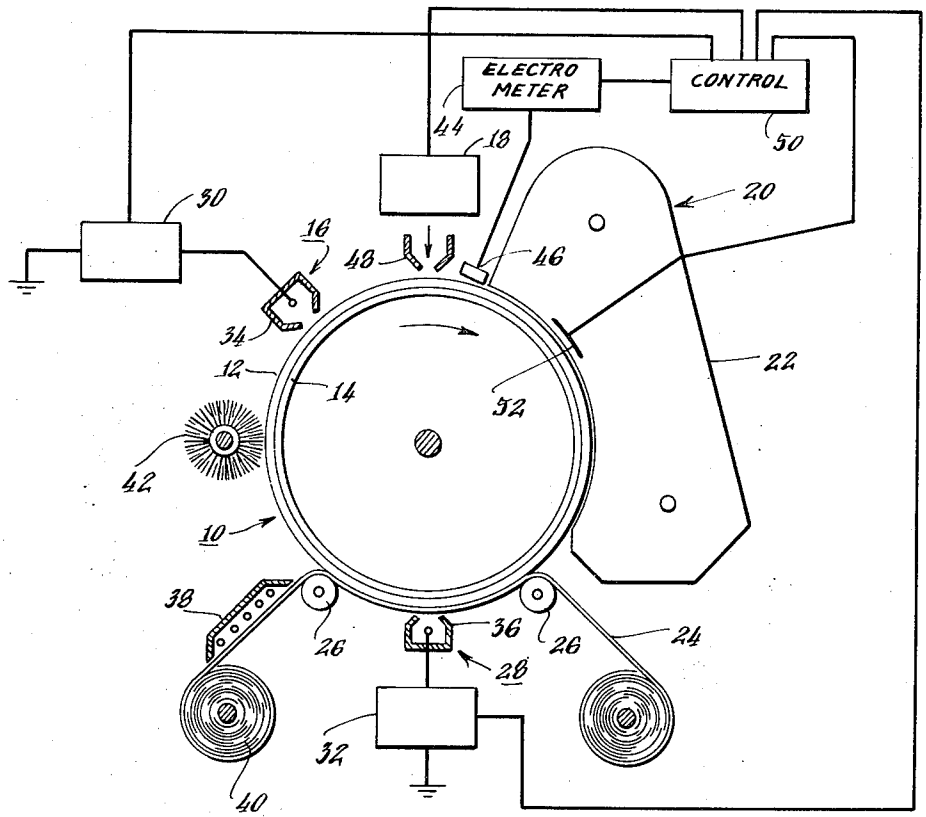


Fig. 1.

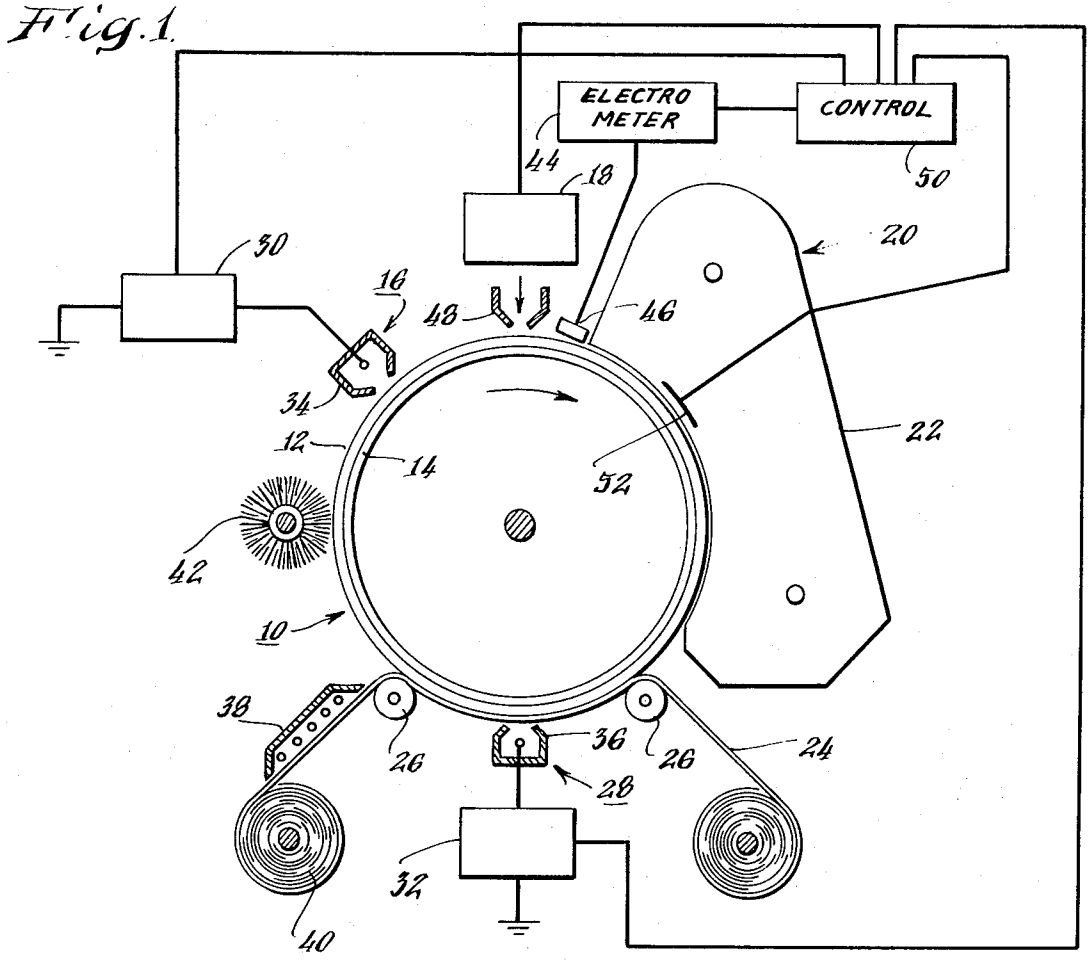


Fig. 2.

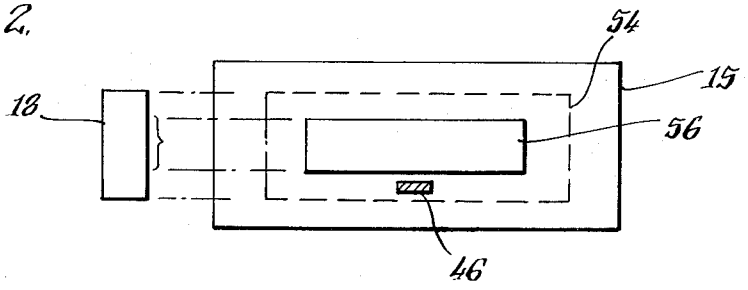


Fig. 3.

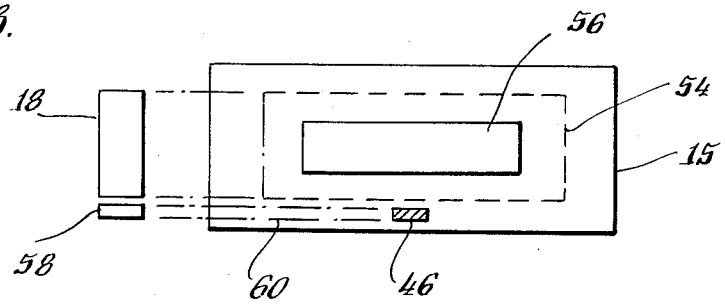


Fig. 4

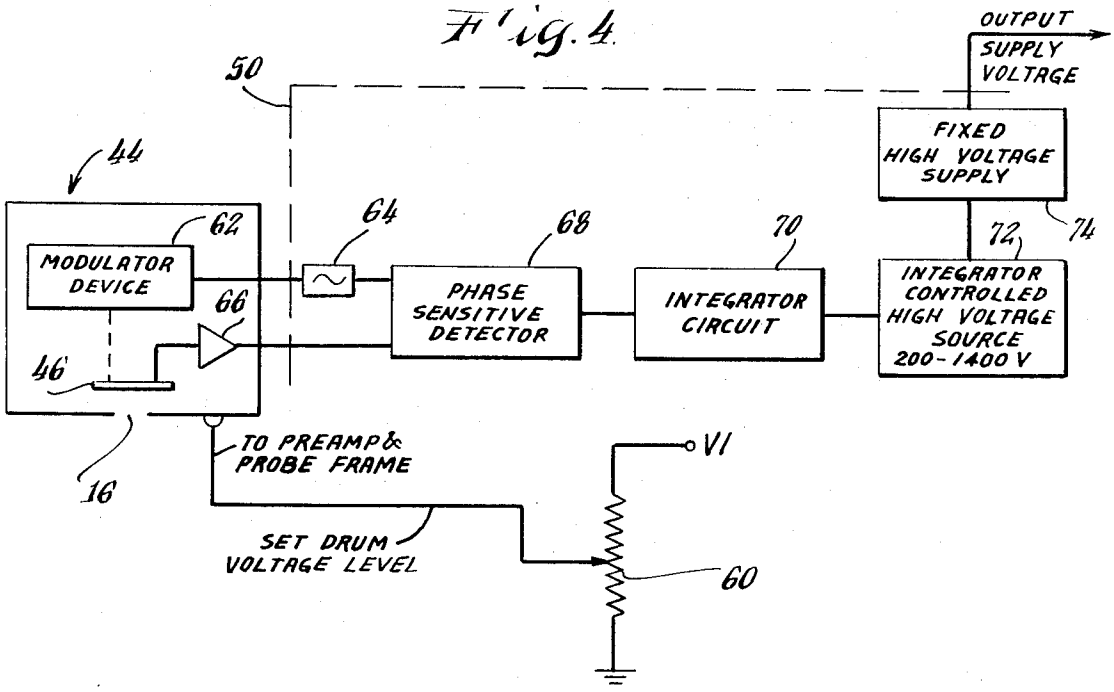

OUTPUT SUPPLY VOLTAGE
50
44
62
64
68
70
72
74
MODULATOR DEVICE
66
PHASE SENSITIVE DETECTOR
INTEGRATOR CIRCUIT
FIXED HIGH VOLTAGE SUPPLY
INTEGRATOR CONTROLLED HIGH VOLTAGE SOURCE 200-1400 V
46
16
TO PREAMP & PROBE FRAME
SET DRUM VOLTAGE LEVEL
VI
60

Fig. 5

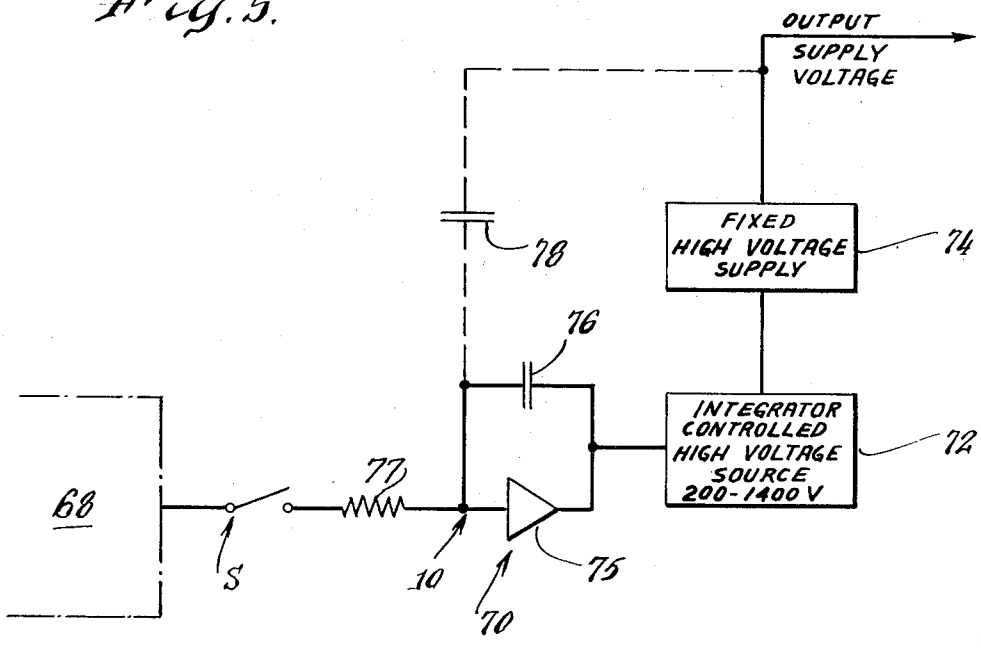

OUTPUT SUPPLY VOLTAGE
78
FIXED HIGH VOLTAGE SUPPLY
74
76
INTEGRATOR CONTROLLED HIGH VOLTAGE SOURCE 200-1400 V
72
68
77
S
10
75
70

IMAGE COMPENSATION METHOD AND APPARATUS FOR ELECTROPHOTOGRAPHIC DEVICES

This invention relates to automatic control of electrophotographic devices and more particularly to a method and apparatus for automatic compensation in an electrophotographic reproduction device.

In electrophotography in general, and more specifically in xerography, an electrostatic latent image is formed on an insulating photoreceptor surface, such as, for example, a photoconductive insulating layer or electrophotographic surface by the combined action of an electric field applied through a photoconductive material to cause selective conductivity in accordance with the pattern of actinic or like radiation to which the material is exposed. The result of this combined exposure and field is to form a pattern of electric charge on the photoconductive layer that is known in the art as an electrostatic latent image which is capable of utilization, for example, by deposition being known in the art as development.

The ultimate reproduction quality upon development depends on many factors, and prior art devices have proposed many forms of compensation for such factors. A control signal produced in response to a factor or factors affecting ultimate quality can be typically employed to control charging, exposure, transfer and development in any sequence or combination in order to provide such compensation.

Prior art compensation techniques do not, however, provide a convenient and expedient compensation technique or device which enables photoreceptor characteristics to be adequately determined as a factor in the generation of compensation signals.

In situations of varying temperature characteristics, for example, the intrinsic thermally caused drift in photoreceptor electrical parameters results in a wide variance in image potentials and varying output print quality. Also, variance in parameters between interchangeable photoreceptor materials in actual use, as in drum replacement in a xerographic copier, can also provide a similar unpredictability.

Prior art devices have attempted to measure photoreceptor surface potentials as a means of generating a control signal for monitoring and affecting various factors within the reproduction cycle. However, the use of these devices have not been manifested in a manner appropriate for the compensation of varying photoreceptor parametric characteristics. Further, prior art devices for measuring photoreceptor surface potentials for compensation purposes exhibit unreliability when employed to scan image levels since the image levels themselves are a resultant of photoreceptor parameters. Where photoreceptor surface potentials are measured outside the imaged area, compensatory signals cannot meaningfully be derived since the crucial factor of the photoreceptor response to the activating radiation is missing.

It is therefore the primary object of the present invention to provide a novel and unique method and apparatus for compensating for varying photoreceptor parameters.

It is another object of the present invention to provide for measurement of surface potential on a photoreceptor area in a manner which will provide a control signal which may be employed to compensate for varying photoreceptor parameters.

The foregoing objects are accomplished by the detection of photoreceptor surface potential within an area exposed to an image projection but only over that portion of the area which will be exposed to the maximum exposure radiation intensity. Employed in an electrometer probe mounted above the surface of the photoreceptor in juxtaposition with that portion of an exposed area which is external to the image portion of said area. Since the exposure is designed to be wider than the image itself, the image will be bordered on at least one side or edge thereof with sufficient margin to enable an electrometer probe to sense the surface potential of the fully exposed segment. Measurement of the actual response of the photoreceptor to full impinging radiation provides an accurate indication of the photoreceptor parameters. The developed signal can then be employed in conjunction with a suitable control mechanism to vary accordingly a desired machine operation, such as charging, exposure, transfer or development control.

The foregoing objects and brief description of the present invention, as well as further objects, advantages and features will become more apparent from the following more detailed description and appended drawings wherein

FIG. **1** illustrates the present invention in conjunction with a xerographic processor,

FIG. **2** is a detail of the photoreceptor surface,

FIG. **3** is an alternative embodiment of a detail of the photoreceptor surface,

FIG. **4** is a block diagram of an electrometer circuit, and

FIG. **5** is a diagram illustrating a modification of FIG. **4.**

An exemplary electrostatic copying apparatus adapted to employ the process of the present invention in the form of a cylindrical drum is illustrated. The drum, generally designated **10** comprising a dielectric material **12** coated on support substrate **14,** when in operation, is generally rotated at a uniform velocity in the direction indicated by the arrow so after portions of the drum periphery pass the charging unit **16** and have been uniformly charged they come beneath the energy source **18** for exposing the charged surface to the image to be reproduced. Subsequent to charging and exposure, sections of the drum surface move past the developing unit, generally designated **20.** This unit is of the cascade type which includes an outer container or cover **22** with a trough at the bottom containing a supply of developing material. The developing material is picked up from the bottom of the container and cascaded over the drum surface by a number of buckets on an endless driven conveyor belt. This development technique which is more fully described in U.S. Pat. Nos. 2,618,551 and 2,618,552 utilizes a two element developing mixture including finely divided pigmented marking particles or toner and larger carrier beads. The carrier beads serve both to deagglomerate the fine toner particles for easier feeding and charge them by virtue of the relative positions of the toner and carrier material in the triboelectric series. The carrier beads with toner particles clinging to them are cascaded over the drum surface. Electrostatic field from the charge pattern on the drum attracts toner particles from the carrier beads serving to develop the image.

The carrier beads, along with any residual toner particles not utilized during the development step fall back into the bottom of the container **22.** The developed image continues around until it comes into contact with the copy web **24** which is passed up against the drum surface by two idler rollers **26** so that the web moves at the same speed as the periphery of the drum. The toner in the developing mixture is periodically replenished from a toner dispenser not shown. A transfer unit **28** is placed behind the web and spaced slightly from it between the rollers **26.** This unit is similar in nature to the surface charging mechanism **16** in that both operate on the corona discharge principle. Both the charging device **16** and the transfer unit **28** are connected to a source of high DC potential of the same polarity identified as **30** and **32,** respectively, and including corotron discharge wires represented at **34** and **36,** respectively, surrounded by a conductive metal shield.

In the case of the corona discharge transfer unit, a charge is deposited on the back of web **24** and this charge is of the same polarity as the charge initially deposited on the drum and also opposite in polarity to the toner particles utilized in developing the latent image. A discharge deposit on the back web **24** pulls the toner particles away from the drum by overcoming the force of attraction between the particles and the charge on the drum. After transfer of the toner image to web **24,** the web moves beneath a fixing unit **38** which serves to fuse or permanently fix the toner image to web **24.** In this case, a resistance heating-type fixer is illustrated. However, here again, other techniques known in the art may also be utilized including the subjection of the toner image to a solvent vapor or spraying of the toner image with an adhesive film-forming overcoating. After fixing, the web is rewound on a coil **40** for later use.

After passing the transfer station, the drum continues around and moves beneath the cleaning brush **42** which prepares the surface for a new cycle of operation. It should be noted that this apparatus may also be operated at varying speeds by setting the corona discharge unit at a high enough voltage so that the surface of the dielectric will be charged fully at the highest speed.

The foregoing explanation is intended to be exemplary only. The web **24** can be replaced by individual sheets, fed serially into contact with the drum **10.** A typical mechanism embodying single sheet feed and illustrative of the mechanical details of the process described above is shown by U.S. Pat. No. 3,301,126 to Osborne et al.

As shown in FIG. **1,** the electrometer **44** is positioned with a probe **46** electrostatically coupled to the surface **15** and mounted near the energy source **18,** and more particularly adjacent the exposure slit frame **48.** The electrical output from the electrometer **44** is a signal representative of the surface potential in the photoreceptor region beneath the electrometer probe. A typical electrometer construction is shown in U.S. Pat. No. 3,013,203 to Allen et al. The signal is applied through a control unit **50** to control any of the desired machine functions, including charging, exposure, transfer and developing. With respect to developing, the control unit **50** is shown as coupling an output to a development electrode **52** located within the developing unit **20.** Typical examples of control of development electrodes for variation of developed images are shown in U.S. Pat. No. 3,424,131 to Aser et al.

Referring to FIG. **2,** the development of the electrometer probe **46** is illustrated with reference to the photoreceptor surface in the image area. In FIG. **2,** the photoreceptor surface **15** is shown as if seen from the top in the area of the exposure provided by energy source **18.** The radiation of the exposure encompasses an area **54** on the surface **15,** indicated by the outer dashed line. The actual image is provided over a smaller area **56,** illustrated as framed by a solid line. The marginal area between the inner and outer areas thus defines a portion of the exposed area which will always receive a maximum level of radiation. The electrometer probe **46** is fixed in this marginal area. In this manner, the electrometer probe will always indicate an image potential corresponding to the photoreceptor characteristic or parameters with respect to maximum background levels provided by the radiation source in the image areas. By controlling machine operations in accordance with this level, a more precise control over the quality of the ultimately developed image can be generated without regard to variation in photoreceptor parameters caused by environmental factors or by photoreceptor substitutions. In addition, variations in the output level of the energy source **18** are also compensated in that the quality determination is always based upon the photoreceptor's response to exposure. Varying response due either to photoreceptor parameters or to energy source variation will result in the same effect: an image potential level on the photoreceptor surface. By employing the area of maximum exposure as a sampling area, the electrometer output will always provide a corresponding level of reference from which an adjustment or control can be derived.

Referring to FIG. **3,** an alternate embodiment is illustrated wherein a separate source of radiation **58** is positioned alongside the primary image source **18.** The source **58** provides a separate area **60** in which the electrometer probe **46** is positioned. The intensity of the second source **58** is fixed to correspond to the maximum intensity of the first source **18.** Since the photoreceptor surface **15** shares both exposed areas **54** and **60,** the response of the photoreceptor **15** to the radiation of the source **58** will be of the same characteristic as the response of the photoreceptor to the maximum intensity radiation of the source **18.** Thus, the electrometer probe will be well outside the area of image **56,** and that tighter tolerances (or greater image area) between areas **54** and **56** can be provided.

In conjunction with FIGS. **4** and **5,** an example of the manner of deriving a control voltage by use of an electrometer and control circuit is set forth.

With reference to FIG. **4,** the frame of the electrometer detector probe **46** and its associated electronic circuitry **44** are connected to an adjustable reference potential designated set drum voltage level. The reference potential level is determined by the setting of potentiometer **60** in conjunction with reference voltage source **V1.**

The detector probe **46** is basically a sensitive electrode. The configuration of the detector probe **46** shown in FIG. **4** is meant to be a generic representation of detector probes of electrostatic modulators that may be exemplarily used according to the invention. These have a modulator device **62** operative in conjunction with sensitive electrode **46** to cause an AC voltage having a magnitude determined by the DC difference potential between the unknown photoreceptor potential

and the reference potential to be produced on sensitive electrode **46.** The phase of the described AC voltage relative to that of signals supplied by reference oscillator **64** is determined by the DC polarity of this potential difference. The AC voltage produced at sensitive electrode **46** is fed to preamplifier **66.**

The operation of the electrostatic modulator generically shown in FIG. **4** is as follows. The detector probe and particularly sensitive electrode **46** is positioned in electrostatic coupling relationship with the photoreceptor surface **15** to produce a detector signal at the sensitive electrode indicative of the magnitude and polarity of the actual surface potential of the drum. Sensitive electrode **46** is exposed to the surface of the drum through a window **16** of the probe housing frame. Reference oscillator **64** produces reference signals at a predetermined frequency which causes modulator device **62** to vary the coupling relationship and thereby produce modulated detector signals having a carrier frequency equal to the predetermined frequency. The modulated detector signals are applied to preamplifier **66.**

Reference oscillator **64** is also connected to one input of phase sensitive detector **68** and the output of preamplifier **66** is connected to the other input of phase sensitive detector **68.** The latter therefore receives reference signals from oscillator **64** and modulated detector signals, at fixed phase relationship with respect to the reference signals, from preamplifier **66.** After demodulation, an output signal indicative of the magnitude and polarity of the actual surface potential difference of the surface **15** relative to the present fixed potential is provided at the output of phase sensitive detector **68.**

As will be apparent, individual isolation transformers may be interposed between reference oscillator **64** and phase sensitive detector **68** and also between the preamplifier **66** and the phase sensitive detector **68.** There would normally be a common power supply for reference oscillator **64** and preamplifier **66** but reference oscillator **64** may operate relative to ground potential with its associated isolation transformer feeding modulator device **62.** The set drum voltage level is connected to the frame of the preamplifier and probe, thus establishing the preset fixed potential.

The output of the phase sensitive detector is a DC signal having a magnitude which is linearly related to the AC input thereto. It has a polarity that reverses with phase reversal of the input signal thereto. The output of the phase sensitive detector is connected to integrating circuit **70** which drives integrator controlled high voltage source **72.** The latter drives a floating, fixed high voltage supply **74,** which may be supplied by the xerography machine being utilized.

The operation of the described system may be illustrated by assuming exemplary values. However, the invention is not limited to such values and a wide range of other values would also be suitable. Where control is of a high voltage corotron, either in development or charging areas, a typical range of corotron supply voltage required to drive a given corotron under an exemplary range of (a) corotron-to-drum spacings, (b) ambient temperature, (c) pressure and (d) relative humidity, while maintaining a constant drum voltage might be 540 to 660 volts. If a minimum integrator controlled high voltage source output of 200 volts is assumed, a fixed high voltage supply source **74** of 5,200 volts should be connected in series with the controlled source **72.**

Further, assume a set drum voltage level of 600 volts and an actual drum surface voltage of 590 volts. With the drum voltage being 10 volts less than the set level, a corresponding AC voltage would be produced at sensitive electrode **46** and this would be amplified by preamplifier **66.** The output of the preamplifier would be demodulated by phase sensitive detector **68,** and the demodulated output thereof would be fed through to integrating circuit **70.** The output of the latter would thereby increase and cause a corresponding increase in the output of integrator controlled high voltage source **72** and consequently total corotron supply voltage. The corotron supply voltage applied to the input of the corotron, and thereby the corotron current, would thereby increase.

The increase in corotron current causes a corresponding increase in the drum surface charge density and thus an increase in the drum surface potential.

FIG. **5** shows one type of integrating circuit that may be used. It consists of amplifier **75** connected to function as an operational amplifier having feedback capacitor **76** and input resistor **77.** The capacitance of capacitor **76** must be chosen in consideration of the geometry and speed of rotation of the drum in order to optimize speed-of-response of the system. The system would be unstable and oscillatory if capacitor **76** is too small, and the speed-of-response would be excessively slow if capacitor **76** is too large.

The circuit may be modified by connecting capacitor **78** between the input of amplifier **75** and the output corotron supply voltage and reducing the value of capacitor **76** relative to the value thereof in the absence of capacitor **78.** The system would then be rendered capable of responding to faster changes in "fixed" voltage supply **74,** assuming integrator controlled high voltage source **72** has a corresponding speed-of-response capability.

By interposing switches S between the output of phase sensitive detector **68** and the input of integrator circuit **70,** the integrator input can be restricted to those times when a valid sample is being measured by the electrometer. This provides discontinuous sampling that might be required when plates or sheets, as opposed to drums, are being used in conjunction with the invention.

Thus the invention is not limited to use with a drum, but may also be used in conjunction with plates and sheets. The integrator circuit **70** memorizes the result of the immediate preceding sample, and may thereby serve as an initial condition for correcting subsequent samples.

Fixed high voltage supply **74** can vary slowly without adversely influencing the performance of the system provided (a) the rate-of-change of the "fixed" voltage is less than the maximum rate-of-change capability of the controller, and (b) the maximum change of the "fixed" voltage of the drum is within the capability of integrator controlled high voltage source **72** to supply in addition to that previously specified.

The high voltage portion of the circuit of FIGS. **4** and **5** consists of a fixed high voltage supply **74** series connected to integrator controlled high voltage source **72.** A single controllable supply, controlled by the low voltage integrator output may be substituted for elements

72 and 74 if desired for purposes of economy or simplicity of design.

With respect to use of the foregoing techniques in providing specific control of a development electrode, reference is made to the disclosure of U.S. Pat. No. 3,611,982 to S. Coriale et al., which disclosure is incorporated by reference herein.

While there has been shown and described the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various changes in form and details of the device may be made by those skilled in the art, without departing from the spirit of the invention.

I claim:

1. A method of producing a control signal for compensating for parametric variation in a photoreceptor surface, the steps of which consist of, charging said surface, exposing an oversized area of said charged surface larger in size that the area normally required for the image to a pattern of radiation, electrostatically detecting the potential level of said oversized area at a point outside the area normally required for the image, comparing said potential level to a fixed potential to derive a control signal, and utilizing said control signal to compensate said photoreceptor surface for parametric variation.

2. In a parametrically compensated electrophotographic reproducing device, the combination comprising a charged photoreceptor surface, means for exposing said charged photoreceptor surface to radiation over an area of said surface, said exposed area including a first portion reserved for the latent image to be reproduced, and a second portion exposed to the same radiation but lying outside said first image portion, means electrostatically coupled to said second portion of said area for measuring the potential level of said second portion of said area, said potential level providing an indication of the parameters of said photoreceptor, and control means coupled to said electrostatically coupled measuring means for supplying a control signal in response to the potential level measured for compensating said reproducing device in accordance with variations in said photoreceptor parameters.

3. The combination of claim 2 wherein said measuring means comprises an electrometer including a probe, said probe electrostatically coupled to said second portion of said area.

4. The combination of claim 2 further including a fixed potential level, said control means being responsive to said fixed level and the potential level measured to provide said control signal.

5. In a parametrically compensated electrophotographic reproducing device, the combination comprising a charged photoreceptor surface, first means for exposing said charged photoreceptor surface to a first radiation source defining an image over a first area of said surface, second means for exposing a second area of said charged photoreceptor surface to a second source of radiation of a fixed intensity corresponding to the maximum intensity of said first source, means electrostatically coupled to said second area for measuring the potential level of said second area, said potential level providing an indication of the parameters of said photoreceptor and control means coupled to said electrostatically coupled measuring means for supplying a control signal in response to the potential level measured for compensating said reproducing device in accordance with said photoreceptor parameters.

6. The combination of claim 5 wherein said measuring means comprises an electrometer including a probe, said probe electrostatically coupled to said second portion of said area.

7. The combination of claim 5 further including a fixed potential level, said control means being responsive to said fixed level and the potential level measured to provide said control signal.

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