

June 18, 1963

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3,094,049

XEROGRAPHIC DEVELOPER MEASURING APPARATUS

Filed Feb. 3, 1961

2 Sheets-Sheet 1

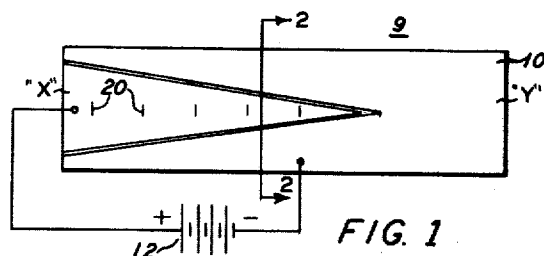


FIG. 1

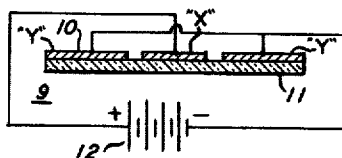


FIG. 2

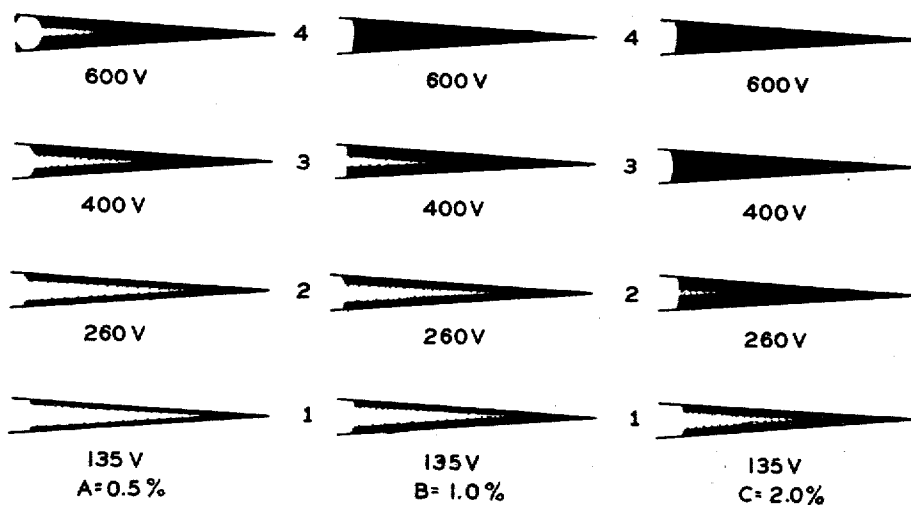


FIG. 4

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2 Sheets-Sheet 2

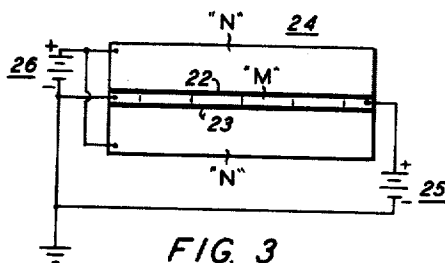


FIG. 3

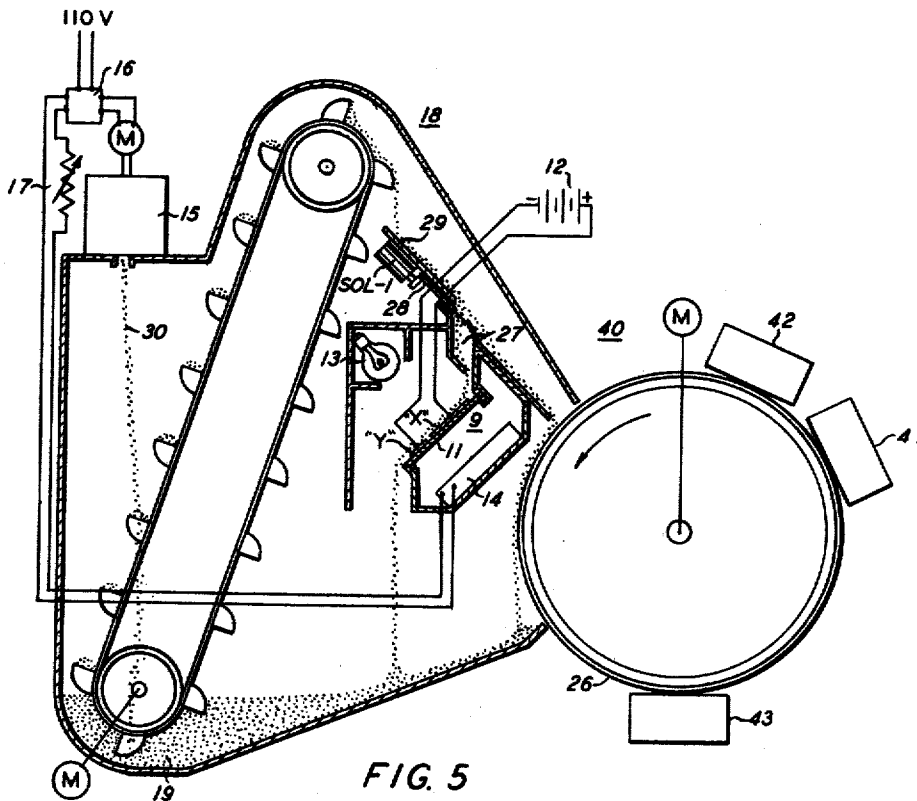


FIG. 5

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XEROGRAPHIC DEVELOPER MEASURING APPARATUS

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10 Claims. (Cl. 95-1.7)

This invention relates to xerography and in particular to method and apparatus for measuring effective concentration of electroscopic developer powder mixed with a carrier medium. More specifically, the invention relates to method and apparatus, whereby the ability of xerographic carrier developing material to develop a xerographically formed electrostatic latent image with an optimum image density can be determined.

In the process of xerography, for example, as disclosed in Carlson Patent 2,297,691, issued October 6, 1942, a xerographic plate comprising a layer of photoconductive insulating material on a conductive backing is given a uniform electric charge over its surface and is then exposed to the subject matter to be reproduced, usually by conventional projection techniques. This exposure discharges the plate areas in accordance with the radiation intensity that reaches them, and thereby creates an electrostatic latent image on or in the photoconductive layer. Electrostatic latent images can be formed in the manner of Carlson on xerographic plates of the types disclosed in Middleton patent U. S. 2,663,636 or in Bixby copending application Ser. No. 526,781 filed August 5, 1955, now Patent No. 2,970,906, and will be of the types primarily considered in this specification. It is to be understood however, that it is intended also to encompass within the scope of the invention electrostatic latent images formed by such other techniques known in the art as for example, disclosed in Walkup copending application Ser. No. 748,655 filed July 15, 1958, now Patent No. 3,001,848, and in Schwartz patent U. S. 2,919,967.

In order to develop an electrostatic latent image, it is required to dust the image with a developer powder, whereby the powder particles are selectively attracted to the charged areas to form a visible powder particle image of the electrostatic latent image.

Development of the image is effected with developers which comprise, in general, a mixture of a suitable pigmented or dyed electroscopic powder, hereinafter referred to as "toner" and a granulated carrier material termed "carrier" which by means of cascading over the image functions to carry and to generate triboelectric charges on the toner.

The general process of development to which this invention relates is termed "carrier development." In general, in carrier development the toner composition is loosely coated on the carrier surface to which it remains loosely affixed by reason of electrostatic attraction thereto. The type of carrier development most widely used commercially is called "granular" or "cascade" carrier development. This system is more fully described in U.S. 2,618,551 to L. E. Walkup and U.S. 2,638,416 to Walkup and Wise. In this process the electroscopic toner is desirably mixed with a granular carrier, either electrically conducting or insulating, magnetic or non-magnetic, provided that the particles of granular material when brought in close contact with the toner particles acquire a charge having an opposite polarity to that of the granular carrier particles and adhere to and surround the granular carrier particles.

If a positive reproduction of the electrostatic image is desired, the carrier is selected so that the toner particles acquire a charge having the opposite polarity to that of the electrostatic image. Alternatively, if a reversal reproduction of the electrostatic image is desired the carrier

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is selected so that the toner particles acquire a charge having the same polarity as that of the electrostatic image to be repulsed thereby.

Thus, in granular carrier development the materials for the granular material are selected in accordance with their triboelectric properties in respect to the electroscopic toner so that when mixed or brought into mutual contact one material is charged positively if the other is below it in a triboelectric series, and negatively if the other material is above it in a triboelectric series. By selecting materials in accordance with their triboelectric effects, the polarities of their charge when mixed are such that the electroscopic toner particles adhere to and are coated on the granular carrier particles. Thus, the development of the electrostatic image is accomplished by rolling or cascading across the image-bearing surface a developer composition of relatively large carrier particles having toner particles on their surface and electrostatically coated thereon. As the composition cascades or rolls across the image-bearing surface, these toner particles are electrostatically deposited on and secured to the charged portions of the image and are not deposited on the uncharged or background portions of the image. More than that, toner particles accidentally deposited on these background portions are physically removed therefrom by electrostatic action of the carrier particles passing there-across whereby these toner particles are electrostatically secured to the rolling carrier particles and are picked up from the surface in this manner. The result is an excellent visible copy of the electrostatic image formed by the toner particles electrostatically clinging to the image surface and removable therefrom by any of various means such as adhesive transfer, electrostatic transfer or the like.

The granular carrier particles are grossly larger than the toner particles by at least one order of magnitude of size, and are shaped to roll across the image-bearing surface. Generally speaking, the carrier particles should be of sufficient size so that their gravitation or momentum force is greater than the force of attraction of the toner in the charged areas where the toner is retained on the plate in order that the granular carrier particles will not be retained by the toner particles, while, at the same time, the toner particles are attracted and held, or repelled, as the case may be, by the charged or uncharged areas of the plate since they acquire a charge of opposite polarity to the charge of both the granular carrier particles and the plate. It has been found best to use granular carrier particles of a size larger than about 200 mesh, usually between about 20 and about 100 mesh, and toner particles of a size from about 1 to 20 microns. The granular carrier particles may, if desired, be somewhat larger or smaller as long as the proper size relationship to the electroscopic toner is maintained so that the granular carrier particles will flow easily over the image surface by gravity when the plate is inclined without requiring additional means or measures to remove them.

The degree of contrast or other photographic qualities in the finished image may be varied by changing the ratio of granular carrier to electroscopic material. Successful results have been had with from about 10 to about 200 parts by weight of granular carrier particles capable of being passed through a 30 mesh screen and being collected on a 60 mesh screen to 1 part of the electroscopic toner having a particle size of 1 to 20 microns. Generally speaking, carrier-to-toner ratios in the order of about 100 to 1 prove satisfactory and preferred compositions run from about 70 to 1 to about 150 to 1. In such preferred compositions the carrier acts effectively to remove any toner particles which might tend to adhere to a non-image area and the tone itself forms a dense readily transferable and fusible image.

Closely related to the cascade carrier development is magnetic brush development as disclosed in U.S. Patent 2,832,311. In this process a granular carrier is selected having ferromagnetic properties and selected relative to the toner in a triboelectric series so as to impart the desired electrostatic polarity to the toner and carrier as in cascade carrier development. On inserting a magnet into such a mixture of toner and magnetic granular material the carrier particles align themselves along the lines of force of the magnet to assume a brush-like array. The toner particles are electrostatically coated on the surface of the granular magnetic carrier particles. Development proceeds as in regular cascade carrier development on moving the magnet over the surface bearing the electrostatic image so that the "bristles" of the magnetic brush contact the electrostatic image-bearing surface.

Thus, toner in the tumbling developer adheres to the latent image charge and partially denudes the carrier particles which pass off the plate. As toner powder images are formed the toner consumed must be replenished to the developer mixture substantially in proportion to the amount consumed.

Excessive toner concentration in the developing material effects heavy deposits of toner in the image areas in combination with an undesirable deposit of toner in the non-image background areas producing prints of poor contrast with blotchy images of poor resolution. Conversely with a low concentration of toner particle, the resulting images are faint and produce prints of low contrast.

In automatic xerographic machines for the reproduction of copy it is usual to have a constantly moving xerographic plate which may be in the form of a cylindrical drum. By means of a continuously operative developing apparatus a continuous flow of developing material is delivered to the xerographic plate. Since original copies have varying amounts of image coverage, as for example, standard typewriter copy has approximately five percent coverage, while graph paper of 10 x 10 lines/inch has approximately thirty-five percent coverage, it is necessary in order to produce prints of consistently good quality to vary the toner dispensing rate in accordance with the rate of consumption which is correlated to the type and frequency of copy being reproduced. Thus, in automatic machines, the dispensing is achieved in metered quantities at regulated intervals by which it is hoped to attain the objective of achieving toner compensation in accordance with consumption.

Whereas, various apparatus for the uniform dispensing of toner are known to those in the art, each is operative in response to a setting determined by an operator from visual inspection of finished copy. That is, the dispensing rate is adjusted inversely with the image density of finished copy and it should be apparent that dispensing by these means results in image densities largely dependent on the alertness and ability of the operator. Not only must he detect the need for a setting change, but he must be able to accurately effect the proper degree of change to the dispenser setting. When the operator has overset the dispensing rate, excess toner must be consumed before the system reverts to optimum operating conditions. When the rate is underset, the concentration must be rebuilt. In either instance, considerable waste of material and time usually occurs, since setting changes are usually made only after copy deterioration has become apparent. Other attempts to achieve better control include apparatus such as disclosed in Giaimo Patent U.S. 2,956,487 in which automatic sensing of images is utilized instead of manual sensing of the images by an operator.

A truly automatic dispenser apparatus operative in response to a predetermined optimum toner concentration in the developer has heretofore been unavailable, since a means to measure the concentration has heretofore been unknown. By the method and apparatus of the invention it is possible to measure the toner concentration on the carrier. It is further possible to regulate, in response to

the measurement, operation of a toner dispenser whereby toner is compensated as a direct function of consumption. The advantages of the invention should be obvious. With the human element removed the quality of finished copy is increasingly consistent and waste of materials and loss of time considerably reduced.

It is therefore the principal object of the invention to provide method and apparatus for the measurement of toner concentration in a xerographic developing mixture.

It is a further object of the invention to provide method and apparatus for the determination of the ability of a xerographic developing mixture to develop electrostatic latent images on a xerographic plate with optimum image density.

It is a still further object of the invention to provide method and apparatus adapted to regulate a toner dispenser unit in a manner that is more responsive to production of constant print quality than method and apparatus available heretofore.

These and other objects of the invention are attained by means of connecting a bias potential between isolated conductive layers formed in a predetermined pattern on an insulating support. By passing a quantity of developing mixture over the pattern, toner from the mixture deposits onto the pattern as a function of toner concentration and pattern field strength and by selection of pattern having graduated variations it is possible to directly reflect the relative toner concentration. That is, by comparing the pattern of toner deposition to a known standard correlated to the pattern of the conductive layers, the measure-responsive thereto is operatively connected to a toner dispenser to regulate operation thereof.

An embodiment of the invention is illustrated in the following drawings in which:

FIG. 1 illustrates a plan view of an embodiment in accordance with the invention;

FIG. 2 is a sectional view taken substantially along line 2—2 of FIG. 1;

FIG. 3 illustrates a plan view of a second embodiment in accordance with the invention;

FIG. 4 compositely illustrates toner deposition patterns achieved with the apparatus of FIG. 1 and illustrates deposition as a function of toner concentration and bias voltage; and,

FIG. 5 schematically illustrates a xerographic developing apparatus in which the apparatus of the invention is responsive to patterns of the type in FIG. 4 in a manner to regulate operation of a toner dispenser.

Referring to FIGS. 1 and 2 there is illustrated apparatus constructed in accordance with the invention that includes a plate on which a conductive film 10, which may, for example, be aluminum has been evaporated onto a suitable insulating base 11 which, for example, may be a 1" by 3" microscope slide. By means of a sharp instrument a line is scribed through the metallic film to form a pattern that divides the film into two isolated conductive layers designated "X" and "Y." From opposite poles of a suitable D.C. potential source 12, which may include means to vary the output voltage, conductive layers X and Y are energized to opposite polarities.

The pattern thus formed is preferably one which when biased electrically is capable of calibrated variation in electrical field strength. As illustrated, a desirable pattern in accordance with the invention includes a pattern formed in a wedge or V shape, such that maximum field strength within the wedge occurs at the tip and along its edges increasingly diminishing in the central portions rearwardly from the tip. The polarity applied to X is selected to be of opposite polarity to that acquired triboelectrically by the toner particles whereby they are electrostatically attracted to the layer X as the mixture passes thereover. In the center of the V is a series of graduated reference indicia 20 which are calibrated to correspond with

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toner deposition patterns of known concentrations when biased with a predetermined voltage.

In the above arrangement it has been found that substantially complete development occurs in the central portion of the wedge rearwardly from the tip only up to the width at which the field strength is just sufficient to cause toner deposition. Beyond the maximum width, only edge development occurs and it is regarded therefore that development occurs to a threshold indicated by means of broad area coverage ability. By direct reading of the calibrated indicia 20 nearest the threshold of development the concentration of toner in the mixture is determined.

In FIG. 3 a second embodiment of the invention is illustrated in which two parallel thin lines designated 22 and 23 are scribed or etched approximately $\frac{1}{16}$ " apart on a transparent member 24 consisting of a resistive coating on glass. The resulting resistive area between the lines designated "M" is biased from a D.C. source 25 to produce a linear voltage drop, as for example, from 600 to 0 volts. By maintaining the adjacent resistive areas designated "N" at some reference potential, as for example, 150 volts from a D.C. source 26, a variable potential contrast is produced. Density of toner development is measured by optical techniques to relate toner density to potential contrast as compared to standards achieved with known concentrations. By applying a photoconductor over the resistive coating a xerographic plate surface can be simulated. An insensitive light such as red would then be preferably used for optical measurement of toner density.

Referring to FIG. 4 there are three vertical columns of deposition patterns designated A, B and C corresponding respectively to different known toner concentrations of selected mixtures, column A having the lowest toner concentration and column C the highest. Horizontally the deposition patterns are aligned in rows designated 1, 2, 3 and 4 corresponding respectively to different bias potentials of which line 1 includes the patterns of lowest bias potential while each succeeding row is of successively higher potential. It may be seen therefrom that the development deposition pattern has a dependency on both toner concentration and bias potential. In the conducted tests from which the illustrated patterns were derived, columns A, B and C corresponded to toner concentrations of 0.5, 1.0 and 2.0 percent respectively, whereas rows 1, 2, 3 and 4 corresponded to bias voltages of 135, 260, 400 and 600 volts respectively.

Not only was it found that the deposition patterns accurately reflected toner concentration but it was further found that subsequent cascading over a previous deposition pattern without previously cleaning the plate, reduced deposition on the pattern, substantially removing toner excess. However, cleaning of the plate between measurements may be desirable and for which a method consistent with the invention has been devised. This method consists of reversing the bias between electrodes. A brief cascade while the reversed bias is applied has been found to satisfactorily clean the calibrated deposition area.

In FIG. 5 there is illustrated a xerographic apparatus designated 40 which may for example, be of a type disclosed in Crumrine, et al. patent U.S. 2,852,651 in which a xerographic plate in the form of a rotating drum 26 is charged by a charging apparatus 41 and then exposed by an exposure means 42 to an image of activating radiation to form an electrostatic latent image on the drum surface to be developed. Development is effected by developing apparatus 18 after which the developed image may be utilized by utilization apparatus 43.

As illustrated, there is shown a developing apparatus 18 in which a developing mixture 19 is conveyed from a sump for release onto a slide 29. Therefrom the mixture is mostly cascaded over a rotating xerographic drum 26 and some is diverted into a cavity 27 to cascade over a measuring plate 9 having electrodes X and Y as illustrated in FIG. 1. The conductive electrode X is formed

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of NESA glass, being a trademark of Pittsburgh Plate Glass Company for a transparent conductive coating of tin oxide on a glass base. Electrode Y is of an opaque conductive material, and both electrodes are supported on a transparent insulator 11 which in this instance is the insulating glass layer of the NESA glass. The operating principle of the apparatus to be described is dependent upon measurable light transmission through the transparent plate areas, although obviously, as will become apparent, the principle of reflection could be substituted for that of transmission. Comparing the deposition pattern to a known standard could take any of several forms, as for example, a charge is transmitted or reflected light translated into an electrical signal as compared to the magnitude of signal received with deposition patterns of known toner concentration. Alternatively concentration could be measured by the change of bias potential required to effect a comparable pattern with that of a known concentration produced with a predetermined bias.

In operation, either a constant bias with variations in pattern development or variations in required bias for a fixed development pattern is compared with a predetermined standard as aforesaid and the difference used to provide a feedback signal to control the toner dispensing rate. As illustrated, measuring plate 9 is suitably supported within the developing apparatus whereat a sample quantity of xerographic developing mixture cascades thereover through cavity 27. A gate 28 operated by a solenoid SOL-1 may optionally be included to close off cavity 27, where it is desired to effect intermittent determination of toner concentration or control thereof. Spaced to one side of the plate is a uniformly brilliant light source 13 having one or more lamps arranged stationary or moving to direct a beam of light through the wedge of X. Toner deposition being opaque partially blocks or obstructs the light transmission to photocell 14 which is affected in a manner to vary its electrical output in accordance with the incident illumination sensed. The output signal of photocell 14 is connected to a suitable adjustment setting of a toner dispenser 15 and which adjustment typically may be the speed regulator 16 of a variable speed electric motor, variable linkage or the like. A rheostat 17 or other suitable means may be provided for correlating the output of photocell 14 to the dispensing rate of dispenser 15. Toner 30 shown being dispensed drops into mixture 19 whereat it is agitated by the conveyor buckets and subsequently charged electroscopically as it cascades on slide 29.

With a given bias setting as toner is depleted from the mixture less development deposition occurs thus increasing the incident light transmitted to photocell 14 which in turn increases its output signal. This then activates the toner dispenser until an increased pattern decreases transmitted light to decrease current to reduce the rate of dispensing. Alternatively, operation of the dispenser can be intermittent where critically of control is permissible within a range of pattern variation such that dispensing occurs at the lower limits of the range and continues until concentration approaches the upper limit. Responsiveness of the measuring plate 9 to changes of concentration is dependent on the time lag required for circulation of the mixture through the cycle such that the effects, for example, of added toner are not realized until mixture containing the added toner is conveyed from the sump and cascades over the plate. However, the time lag can be controlled and in effect virtually eliminated by control of physical spacing of the elements.

By the disclosure above there is described a novel method and apparatus for measuring toner concentration in a xerographic developing mixture. The invention has many diversified laboratory and field applications and whereas it is particularly described in connection with xerographic developing mixtures it obviously has application in other fields of endeavor in which electroscopic powders are employed.

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Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the drawings and in the specification shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A method of measuring concentration of electroscopic powder in a mixture with a carrier medium including connecting a bias potential between isolated conductive layers formed in a predetermined pattern on an insulating support, moving a quantity of mixture on said pattern to electrostatically deposit powder thereon from the mixture, and comparing the pattern of powder deposition to a deposition pattern of known powder concentration.

2. A method of measuring concentration of electroscopic powder in a mixture with a carrier medium, including connecting a bias potential between isolated conductive layers formed in a predetermined pattern on an insulating support, moving a quantity of mixture on said pattern to electrostatically deposit powder thereon from the mixture, and varying the bias potential to effect a pattern of powder deposition comparable with a deposition pattern of known powder concentration.

3. A method of measuring concentration of electroscopic powder in a mixture with a carrier medium including connecting a bias potential between isolated conductive layers formed in a predetermined pattern on an insulating support, moving a quantity of mixture on said pattern to electrostatically deposit powder thereon from the mixture, and responding to the pattern of powder deposition with an electrical signal correlated to the difference in magnitude of the deposition pattern relative to a pattern of known powder concentration.

4. A method of measuring concentration of electroscopic powder in a mixture with a carrier medium including connecting a bias potential between isolated resistance layers on an insulating support to effect uniform variation of an electrical field, moving a quantity of mixture across said layers which mixture deposits powder on said layers because of said field in relation to its concentration in the mixture, and comparing the deposition pattern of powder to a reference pattern.

5. Apparatus for measuring concentration of electroscopic powder in a mixture with a carrier medium including an insulating support means, at least two conductive layers on the support means isolated from each other, said layers being arranged complementary in a predetermined pattern, means to connect potential of opposite polarity to adjacent of said layers, means to cascade over said pattern a quantity of mixture of which the concentration of electroscopic powder is to be measured, whereby powder from the mixture deposits onto at least one of said conductive layers, and means to compare the pattern of powder deposition to a reference pattern.

6. Apparatus for measuring concentration of electroscopic powder in a mixture with a carrier medium including an insulating support means, at least two resistance layers on the support means isolated from each other, said layers being arranged complementary to each other in a predetermined pattern, means to connect a bias potential between adjacent of said layers, said bias being effective when applied to produce in at least one of said layers a uniform variation of electrical field strength of polarity opposite to the triboelectric polarity of the power, means to cascade over said pattern a quantity of mixture of which the concentration of electroscopic powder is to be measured, whereby powder from the mixture deposits onto said pattern and means to compare the pattern of powder deposition to a reference pattern.

7. Apparatus for measuring developer concentration of a cascade developer mixture comprised of a finely-divided

developer powder and an electroscopic granular carrier, said apparatus comprising an insulating support means, at least two conductive layers on the support means isolated from each other, said layers being arranged complementary in a predetermined pattern, means to connect potential of opposite polarity to adjacent of said layers, means to cascade a sample quantity of developer mixture over said layer pattern to electroscopically attract the finely-divided developer powder from the mixture to said layer pattern to deposit thereon in a pattern correlated to the powder concentration in the mixture, and means to compare the deposition pattern of powder to a reference pattern whereby the concentration of powder in the mixture is determinable.

8. Apparatus for measuring developer concentration of a developer mixture comprised of a finely-divided developer powder and a magnetic carrier, said apparatus comprising an insulating support means, at least two conductive layers on the support means isolated from each other, said layers being arranged complementary in a predetermined pattern, means to connect potential of opposite polarity to adjacent of said layers, magnetic means to move a sample quantity of developer mixture across said layer pattern whereby finely-divided powder of said mixture deposits onto at least one of said conductive layers in a pattern correlated to its concentration in the mixture, and means to compare the pattern of powder deposition to a reference pattern whereby the concentration of developer powder in the mixture is determinable.

9. In an electrostatic apparatus for producing visible images including means for moving along a predetermined path a xerographic plate having a photoconductive insulating surface sensitive to electromagnetic radiation of a given type, and means disposed along said path in the following order: means for providing a substantially uniform electrostatic charge upon the surface of a plate, means for exposing the charged surface to an electromagnetic radiation image of the given type for producing an electrostatic latent image upon the plate surface substantially corresponding to the electromagnetic radiation image, and means for developing a visible image from the electrostatic latent image with a finely-divided developer substance contained in a developer mixture with a carrier medium; the improvement for controlling the density of the visible image comprising sensing means for sensing the concentration of the developer substance contained in a sample of the developer mixture, said sensing means including an insulating support means, at least two conductive layers arranged on said support means in a predetermined pattern isolated from and complementary to each other, and means to connect a bias potential to adjacent of said layers whereby developer mixture passing thereover will deposit developer substance in a pattern determinable of its concentration in the mixture, means to pass a sample of developer mixture from said developing means over said layers, means to produce a discrete electrical control signal correlated to the mixture concentration sensed by the sensing means and means operative in response to said signal to control the concentration of said finely-divided developer substance in the developer mixture as a function of the magnitude of said control signal whereby electrostatic latent images are developed with developer substance in a developer mixture of substantially consistent uniformity of concentration.

10. In an electrostatic apparatus for producing visible images including means for moving along a predetermined path a xerographic plate having a photographic insulating surface sensitive to electromagnetic radiation of a given type, means disposed along said path in the following order: means for providing a substantially uniform electrostatic charge upon the surface of a plate, means for exposing the charged surface to an electromagnetic radiation image of the given type for producing an electrostatic latent image upon the plate surface substantially corresponding to the electromagnetic radiation image, and

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means for developing a visible image from the electrostatic latent image with a finely-divided developer substance contained in a developer mixture with a carrier medium; and means to dispense finely-divided developer powder to the developer mixture of the developer means; the improvement for controlling the density of the visible image comprising sensing means for sensing the concentration of the developer substance contained in a sample of the developer mixture, said sensing means including an insulating support means, at least two conductive layers arranged on said support means in a pre-determined pattern isolated from and complementary to each other, and means to connect a bias potential to adjacent of said layers whereby developer mixture passing thereover will deposit developer substance in a pattern determinable of

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its concentration in the mixture, means to pass a sample of developer mixture from said developing means over said layers, means to produce a discrete control signal correlated to the mixture concentration sensed by the sensing means, and means operative in response to said signal to monitor the amount of finely-divided developer powder dispensed by said dispensing means whereby electrostatic latent images are developed with developer substance in a developer mixture of substantially consistent uniformity of concentration.

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