

Sept. 8, 1970

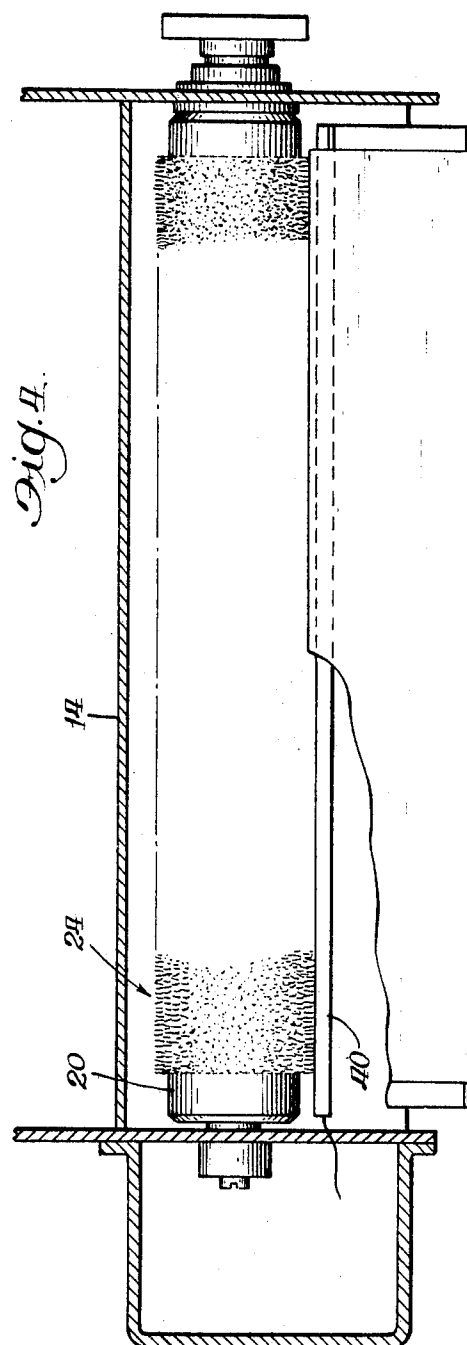
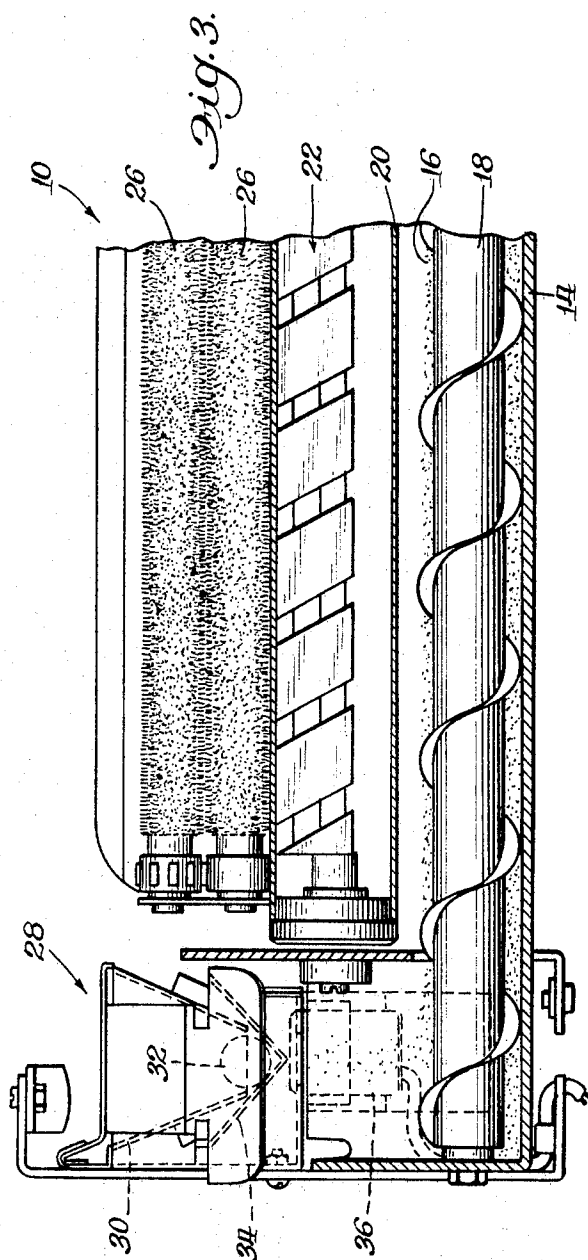
L. E. SHEFFO ET AL

3,527,651

METHOD OF AND APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES

Filed Oct. 20, 1966

2 Sheets-Sheet 2



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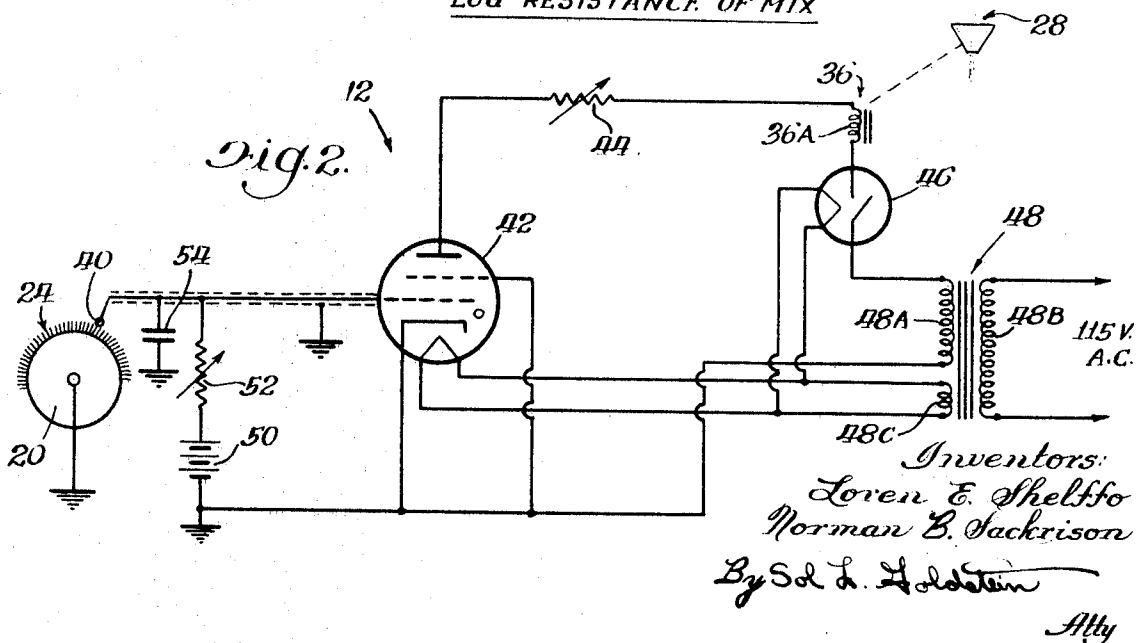
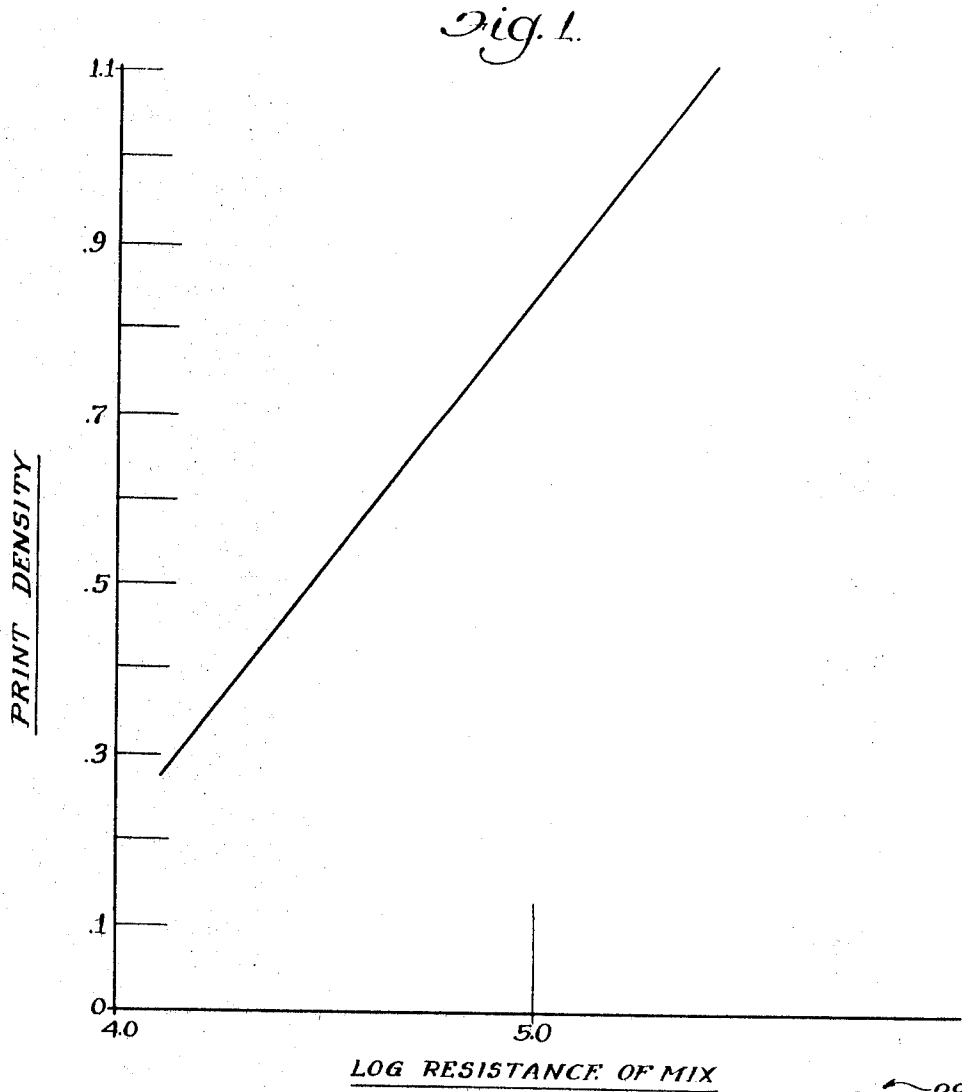
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Filed Oct. 20, 1966

2 Sheets-Sheet 1



1

3,527,651

METHOD OF AND APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGES

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Filed Oct. 20, 1966, Ser. No. 588,209

Int. Cl. G03g 13/08; G01r 27/02

U.S. Cl. 117—17.5

11 Claims

ABSTRACT OF THE DISCLOSURE

An arrangement for maintaining a predetermined ratio of carrier particles to toner powder in a toner mixture used in the developing assembly of an electrostatic copying machine. The arrangement comprises means for sensing the electrical resistance of the mixture and a control circuit connected to the sensing means for monitoring changes in the resistance of the mixture and, in response to such resistance changes, to provide the replenishment of toner powder.

This invention relates to a photoelectrostatic copying machine and, more particularly, to a new and improved developer unit for such a machine and a method of developing copies.

In the photoelectrostatic art the reproduction of a graphic subject onto a photoelectrostatic member involves the steps of imparting a sensitizing electrostatic charge to the member and exposing the charged member to a pattern of light and shadow corresponding to the original subject. The exposure results in a latent electrostatic image which is then developed by the application of an electroscopic powder or toner which adheres in the image areas and is fixed thereon by heat, pressure or solvent vapor technique.

The techniques for applying the toner in photoelectrostatic equipment in use today require the use of a carrier medium such as glass beads, iron particles, silaceous materials which triboelectrically hold the flocculent toner powder so that it may be brought into direct and intimate contact with the image. Contact by the carrier and toner mixture with the image may be accomplished by cascading over the image, or may be applied by the conventional magnetic brush technique using magnetically attractable carrier particles such as iron, magnetites or the like.

The production of quality prints of optimum density depends, among other things, on the proper ratio of toner to carrier. Since the toner is selectively attracted to the image the copy making process will steadily deplete toner from the mix. Obviously, it must be replenished and in amounts that restore the proper ratio. An overtuned or undertuned mix is a serious problem which frustrates the objective of turning out successive copies with uniform print or copy density.

Heretofore, replenishment was accomplished by the operator manually adding toner from a dispenser at regular intervals. This is not an expedient solution for many reasons including the time required, the nature of the materials to be handled, the frequency at which the toner must be replaced to maintain uniform print density, and the fact that the actual usage of toner by the copying machine is a function of the type of copy and the number of copies and not related to a time interval. In an attempt to avoid these deficiencies, a number of copying machines include arrangements for counting the number of copies produced or measuring the length of copy material produced and using these conditions as a means for controlling the automatic metering or dispensing of toner

2

material into the developer mixture. Although these automatic arrangements represent a substantial improvement, they are still subject to a number of disadvantages.

As an example, the units that count the number of copies produced are not capable of taking into account the varying image areas developed from one copy to the next. Unless each original to be reproduced has approximately the same amount of toner consumption, replenishment based on the number of copy sheets going through will not be effective in maintaining the proper ratio of carrier to toner. Similarly, dispensing devices dependent on the length of copy material going through suffers from the same deficiency.

Attempts have been made to correlate the opacity of the developer mix deposited on a conductive image pattern, which is connected to a power source to electrically bias the pattern so that it attracts an amount of electroscopic powder, in direct relation to its concentration in the mix and the amount of bias. Such a technique is quite complex and requires strict control over other variables that may affect the final reading, such as cleaning of the optical system, particle size control and the like.

A genuinely automatic control that can sense and correct for variations in toner concentration based on an electrical condition of the mix that is independent of the number of copies, length of copy sheet or without having to simulate image reproduction as the determining step, has heretofore been unavailable. The method and apparatus of this invention makes possible such a monitoring system by sensing the average resistance of the developer mix which has been found to vary directly as a function of the ratio of the carrier to toner present in the mix. It has been found that as the amount of toner decreases the resistance of the mix decreases and the relationship will be true for most systems of carrier and toner recognizing that the slope of the relationship will change for different systems.

Accordingly, one object of the present invention is to provide a new and improved photoelectrostatic copying machine.

Another object is to provide a photoelectrostatic copying machine including new and improved developer means.

Another object is to provide a new and improved method of developing copies to obtain uniform print density.

A further object is to provide a new and improved developer unit including means for automatically maintaining a predetermined ratio of carrier material to toner material.

A further object is to provide a new and improved developer unit including means for sensing the actual ratio of carrier material to toner material and for automatically dispensing toner material in accordance with a produced signal until the ratio sensing control is satisfied.

A further object is to provide a new and improved developer unit of the type having a developer mixture of electrically conductive and insulating particles in which means are provided for sensing the ratio of the two types of particles in the mixture and for automatically adding a quantity of the insulating particulate material to maintain the desired ratio of materials in the mixture.

A further object is to provide a magnetic brush developer using a developer mix of powdered iron and toner powder in which the electrical resistance of the mixture is measured and used to control the addition of toner powder to the mixture.

Another object is to provide a magnetic brush developer assembly in which toner material is selectively added to the developer mix by measuring the electrical resistance of the portion of the mix that has been formed into a bristle-like mass.

A further object is to provide an assembly for accurately measuring the electrical resistivity of a mass of powdered iron and toner powder used to develop electrostatic images.

In accordance with these and many other objects, an embodiment of the invention comprises a photoelectrostatic copying machine of the type in which a latent electrostatic image developed on a surface is developed and placed in visible form by a developer unit using a mixture of carrier particles and powdered toner. The developer unit places the mixture of carrier particles and toner powder in contact with or in proximity to the electrostatic image, and the toner material is selectively deposited on the surface in accordance with the electrostatic image to provide a visible image that is subsequently placed in permanent form.

In one form, the developer unit can comprise a magnetic brush developer assembly comprising a rotating cylinder supplied with a developer mixture which is comprised of electrically conductive, powdered iron carrier particles and toner powder formed of a substantially insulating resinous material. During a portion of its path of rotation, the cylinder or drum is subjected to the influence of a magnetic field which forms the mixture into a bristle-like mass covering a portion of the outer surface of the cylinder. The imaged surface is moved in a direction substantially transverse to the axis of rotation of the cylinder so that the bristle-like mass is moved into contact with the image surface to transfer toner material to the surface in accordance with the electrostatic image thereon. This transfer of the toner powder from the developer mixture to the image surface depletes the supply of toner material available for developing and will tend to produce light or undertoned copies upon continued use of the developer unit.

To provide means for automatically maintaining a desired ratio between carrier material and toner material, the improved developer unit of the present invention includes means for measuring the electrical resistivity of the developer mix correlated to the ratio of carrier material to toner material. This resistivity measuring means is connected to and controls the toner material dispensing assembly so that the dispensing assembly adds toner material to the mixture to maintain the ratio of toner material to powdered iron which provides the desired copy or print density. The sensing circuit is designed to measure the resistivity of that portion of the mix that has been formed into the bristle-like formation on the drum or cylinder of the developer unit. However, the resistivity of the mix can be measured anywhere in the developer unit.

Many other objects and advantages of the present invention will become apparent from considering the following detailed description in conjunction with the drawings in which:

FIG. 1 is a graph illustrating a typical relationship between print density and resistance of the powdered iron-toner mix in a magnetic brush developer unit;

FIG. 2 is a schematic circuit diagram of an arrangement for measuring the resistivity of the developer mix and for automatically controlling the addition of toner material to the mix;

FIG. 3 is a fragmentary sectional view of a magnetic brush developer unit with which the present invention can be used; and

FIG. 4 is a fragmentary sectional view illustrating the relationship between the portion of the magnetic brush developer and an electrode forming a part of the resistivity measuring circuit.

Referring now more specifically to the drawings, therein is illustrated a developer unit 10 (FIG. 3) of the magnetic brush type which is designed and adapted for use in a photoelectrostatic copying machine and which is adapted to place in visible form a latent electrostatic image developed on a surface by the copying machine. The developer unit 10 uses a developer mix of carrier

particles, such as finely divided iron, magnetite or ferrite, and a particulate toner powder consisting of, for instance, dyed or pigmented resin powder. The developer mix is magnetically formed into a bristle-like formation and brushed against the imaged surface to develop the latent electrostatic image by the selective attraction of the toner powder to the surface. A representative magnetic developer mix is described in detail in U.S. Pat. No. 3,320,169, assigned to the same assignee as the present invention.

To avoid any change in the intensity or density of the printed copy resulting from depletion of the consumable toner powder in the developer mix, the present invention includes a detecting or measuring circuit indicated generally as 12 (FIG. 2) for measuring the resistivity of the mixture and for automatically controlling the addition of toner powder to the developer mix in accordance with the changes in the resistivity of the developer mixture. Since the magnetic carrier particles are electrically conductive and since the toner powder has a substantially insulating characteristic, the ratio of carrier material to toner powder can be accurately calibrated in a particular system to the resistivity of the mix. Thus, it has been determined that it is possible to automatically control the addition of toner material to the developer mixture in dependence on variations in the resistivity of the mixture and thereby insure uniform density of the prints produced by the copying machine.

Referring now more specifically to FIG. 3 of the drawings, therein is illustrated the magnetic brush developer unit 10 which can be of any suitable construction. The illustrated magnetic brush assembly is of the general type shown and described in detail in U.S. Pats. Nos. 3,003,462 and 3,145,122. As illustrated therein, the unit 10 comprises a housing forming a receptacle 14 containing a quantity 16 of magnetic developer mix of the composition referred to above. A pair of driven conveyor screws, only one of which 18 is illustrated, distributes and mixes the developer mixture so that an adequate supply of the developer mix of uniform consistency is available along the entire length of an elongated drum or cylinder 20 which is mounted for rotation about an axis spaced above the lower wall of the trough or receptacle 14. A magnetic field producing means 22, such as one or a plurality of permanent magnets, is disposed within the drum 20 adjacent a portion of the periphery thereof so that during rotation of the cylinder 20, a portion of the developer mix 16 is formed into a bristle-like formation indicated as 24 (FIG. 4) and brushed into contact with the surface containing the electrostatic image to be developed. Although this image bearing surface can be of any suitable construction, the illustrated developer unit 10 is adapted for use with sheet or web copy material having a photoconductive surface on which the electrostatic image is directly produced. A pair of nap-covered rollers 26 (FIG. 3) of the type shown and described in detail in U.S. Pat. No. 2,894,744 provide part of a means for feeding the image bearing sheet or web past the magnetic brush.

Since the development of imaged surface by the developer unit 10 results in the removal of toner powder from the unit 10 and from the developer mixture 16 therein, the density or contrast of the copies produced by the copying unit 10 is reduced as the ratio of carrier particles to toner powder in the developer mixture 16 increases with usage of the machine 10. To avoid this reduction in print density, the unit 10 includes a toner dispensing assembly indicated generally as 28 for automatically adding toner material to the mixture 16. The construction and operation of the dispensing assembly 28 is shown and described in detail in U.S. Pat. No. 3,224,649. In general, the dispensing assembly 28 includes a hopper or receptacle 30 which contains a quantity of toner powder and which has a lower opening in which is disposed a plurality of spheres 32 resting on a somewhat inclined and generally V-shaped trough 34. An electric solenoid 36 is coupled to the trough 34 so that upon ener-

gization of the solenoid 36, the trough 34 is oscillated or vibrated to dispense toner material from the receptacle 30 to the receptacle 14 containing the supply of developer mix for the developer unit 10.

Although the dispensing assembly 28 can be controlled by a number of conditions which indicate the rate at which the toner material in the developer mix is being depleted, such as the number of copies run or the running length of copy material developed, these factors are, at best, only approximations of toner usage, and optimum uniformity of print density would be obtained by controlling the dispensing assembly 28 in direct response to the actual ratio of carrier material to toner powder existing in the developer mixture 16. In accordance with the present invention, it has been determined that the resistivity of the developer mixture 16 varies as a function of the ratio of the carrier material to toner material and that the operation of the dispensing assembly 28 can be controlled in accordance with the measured resistivity of the developer mixture 16 to effect a stabilization of the carrier-toner ratio and consequent uniform print density of the copies. As an example, with a magnetic developer mix of the type described in detail in the above-identified copending East et al. application, it has been determined that under a static condition the resistance of the mix varies from 1×10^4 ohms to 4×10^{11} ohms corresponding to the percentage of toner material in the finely divided iron carrier ranging from 5.5 to 11.1 percent by weight. Using the magnetic developer mix described in the copending East et al. application, under conditions of making copies, it has been determined that resistance values of from 2×10^5 ohms to 2×10^6 ohms will provide properly toned copies for that particular mix.

As an example, FIG. 1 plots the relationship between the log of the resistance of a representative developer mixture 16 and print density. Print density represents reflected light intensity measured on a photovoltometer in which the optimum value for copies is 1.0. From the characteristic curve shown in FIG. 1, it can be seen that the log of the resistance of the mixture 16 required to obtain the optimum print density is slightly in excess of 5.0 or a true resistance value somewhat in excess of 150K ohms. Different mixes, that is, mixes which employ different carriers or resinous materials, will have a different resistance range that gives a density of 1.0.

In order to use the measured resistivity of the developer mix as a means for controlling the automatic dispensing of toner material from the assembly 28 to the mixture 16 in the receptacle or trough 14, it is essential that accurate and reliable resistivity measurements be obtained. One means for obtaining such resistivity measurements is to insert two spaced electrodes in the body of the developer mix 16 within the receptacle 14, preferably in a location in which the mixture is being swept between the electrodes. When using such an arrangement care must be taken to avoid shunting the resistance path between the electrodes or one electrode and the frame.

In accordance with the present invention, it has been determined that accurate resistance measurements can be made by measuring the resistivity of the portion of the mixture 16 that is in the bristle-like formation 24 on the drum 20. Accordingly, the developer unit 10 is provided with an elongated and electrically conductive electrode 40 (FIG. 4) which is mounted on the frame for the developer unit 10 in an insulated relation thereto and in a position extending generally parallel to but spaced from the axis of rotation of the cylinder or drum 20. The electrode 40 is so spaced from the drum 20 that it engages the ends of the bristle-like formation 24 and serves the dual function of establishing a uniform pressure contact with the mixture 16 and serving as a "doctor blade" to maintain the bristle formation 24 at a uniform size prior to movement of the bristle-like formation into engagement with the imaged surface. The U.S. Patent No. 3,387,586, assigned to the same assignee as the present invention, discloses an

arrangement for supporting the elongated electrode 40 immediately adjacent the path through which the bristle-like formation 24 on the drum 20 moves. A further advantage of the use of an elongated electrode 40 contacting the bristle-like formation 24 as a part of the circuit for measuring the resistivity of the mix is in the fact that the resistivity of the mix 16 and thus the ratio of the iron to the toner powder is being measured in the most important area, i.e., immediately preceding the contact between the mixture and the imaged surface. Thus, any variation in the ratio which might occur in the mixture disposed within the receptacle 14 is avoided. In addition, the electrode 40 provides an elongated area of contact with the mixture 16 extending along the entire length of the bristle-like formation 24. While the elongated electrode has been employed to advantage other electrode configurations may be employed. The use of a rake-type electrode as well as needle-like probes disposed at other vantage points in the developer unit have been eminently successful.

The control circuit 12 (FIG. 2) is coupled to the electrode 40 to sense the resistance of the mixture 16 in the bristle-like formation 24 and to control the operation of the dispensing assembly 28 in accordance therewith. The control circuit 12 includes a grid controlled gaseous conduction device of thyatron 42, the anode of which is connected through a variable resistance 44 to one terminal of a winding 36A for the operating solenoid 36 in the dispensing assembly 28. The other terminal of the winding 36A is connected through a time delay device 46 to one terminal of a secondary winding 48A on a power transformer indicated generally as 48. A primary winding 48B of the transformer 48 is connected to a conventional alternating current potential source. The other side of the secondary winding 48A is returned to the cathode of the thyatron 42. A second secondary winding 48C in the transformer 48 is connected to the filament of the thyatron 42, and this winding is also connected to the heating device of the thermal time delay device 46 so that after a time delay interval of, for instance, ninety seconds, sufficient to heat the filament of the thyatron 42, the time delay device 46 operates to a closed circuit condition to connect the lower terminal of the winding 36A to the secondary winding 48A.

To provide means for sensing the resistance of the mix in the portion of the developer mix 16 that is in the bristle-like formation 24, a biasing network is connected to the control grid of the thyatron 42. This biasing network includes a direct current potential source or battery 50, one terminal of which is connected to a reference potential source and the other terminal of which is connected through a variable resistance element 52 to both the electrode 40 and the control grid of the thyatron 42. The electrically conductive drum 20 is connected to the reference potential so that a circuit including the battery 50, the variable resistance 52, and the resistance disposed between the electrode 40 and the conductive drum or cylinder 20 provide a voltage dividing network, the center point of which is connected to the control grid of the thyatron 42. The electrode 40 is also connected to a bypass condenser 54, which serves to eliminate short term pulses at the thyatron.

As indicated above, it has been determined that the resistance between the electrode 40 and the electrically conductive drum or cylinder 20 provided by the intervening portion of the mix 16 in the bristle-like formation 24 is normally on the order of 2×10^5 to 2×10^6 ohms when the copies are properly toned. Thus, the variable resistance element 52 is adjusted so that with this resistance provided by the mixture 16, the potential applied to the control grid 42 is sufficiently negative to prevent conduction through the thyatron 42 during positive-going cycles of the input alternating current potential following the closure of the contacts in the time delay device 46. The variable resistance 52 can be adjusted to condition the circuit 12 for use with different developer mixes.

When the toner and developer mixture 16 becomes depleted, the resistivity of that portion of the mixture in the bristle-like formation 24 decreases so that a less negative or more positive potential is applied to the control grid of the thyatron 42. This more positive potential permits the thyatron to conduct during positively poled half-cycles and periodically energize the winding 36A of the solenoid 36. This intermittent energization of the solenoid 36 vibrates the feed trough 34 (FIG. 3) so that toner material from the receptacle 30 is discharged to the receptacle 14 in the developer unit 10. The amplitude of the excursions of the trough 34 and thus the rate at which the toner material is dispensed can be controlled by varying the resistance element 44 to control the current passing through the winding 36A. This operation continues until such time as the toner material added to the supply of the mixture 16 in the receptacle 14 increases to the desired level. At this time, the resistance between the electrode 40 and the cylinder 20 increases to the point at which a more negative potential is applied to the control grid of the thyatron 42 and conduction through this thyatron is terminated until the supply of toner is again depleted.

It will be appreciated that the principle of operation of the instant invention relies on the electrical resistivity of the components that comprise the developer mix. The details of the invention have been described in terms of a particular developer mix and the data and ranges presented are intended to be exemplary and not limiting. The principle may be effectively applied to a wide range of resins combined with carriers following the teaching of the detailed description herein without departing from the spirit and scope of the invention.

What is claimed and desired to be secured by Letters Patent of the United States is:

1. In a copying machine of the type in which a recording member is imparted with an electrostatic charge and is developed by contact with a charge attractable toner powder, including a mixture of carrier particles and toner powder combined in a predetermined mix ratio of particles to powder, said carrier particles being more electrically conductive than said toner powder, and a developer assembly for receiving a quantity of the mixture and for applying the mixture to the electrostatic image which is developed by the selective adherence of the powder, the improvement comprising:

sensing means in said developer assembly for sensing the electrical resistance of the mix,

a control circuit connected to said sensing means for monitoring changes in resistance of the mix, and

a toner powder dispensing assembly responsive to said control circuit for dispensing powder to the developer assembly in response to changes in the mix resistance to maintain the ratio of carrier particles and toner powder at said predetermined level to provide optimum print density.

2. A copying machine as set forth in claim 1 wherein the developer assembly includes a magnetic brush applicator capable of forming said mix into an elongated brush-like configuration extending generally transverse to the direction of movement of the member and wherein said carrier comprises magnetically attractable particles.

3. A copying machine as set forth in claim 2 wherein the sensing means includes an elongated electrically conductive member positioned in the sweep path of the brush-like configuration.

4. A copying machine as set forth in claim 1 wherein the control circuit includes a controlled conduction device with a control electrode, said device being operable to a first and second state of conduction, and a bias network connected to the control electrode to maintain said conduction device in said first state of conduction so long as the resistance of said mix remains above a predetermined level, said conduction device being operable to change from said first to said second state of conduction in re-

sponse to the resistance of said mix falling below said predetermined level.

5. A copying machine as set forth in claim 4 wherein the dispensing assembly includes an operating solenoid with a winding, and in which the controlled conduction device is connected to the winding to control the energization of said solenoid in response to a change of state of conduction of said conduction device.

6. A copying machine as set forth in claim 5 further including a variable impedance element connected to the winding of said solenoid to control the amplitude of the current flowing through the winding, thereby to control the rate at which said toner powder is dispensed from said dispensing assembly.

7. In a copying machine of the type in which a recording member is imparted with an electrostatic charge and is developed by contact with a charge attractable toner powder, comprising:

a mixture of carrier particles and toner powder combined in a predetermined mix ratio of particles to powder, and

a magnetic brush assembly for forming bristles of the mixture and moving the bristles into engagement with the member to develop the electrostatic image, the improvement comprising:

a control circuit coupled to said magnetic brush assembly for monitoring changes in resistance of the mix, and

toner powder dispensing means responsive to said control circuit for dispensing powder to the magnetic brush assembly in response to changes in the mix resistance to maintain the ratio of carrier particles and toner powder at said predetermined level to provide optimum print density.

8. In a magnetic developer assembly for developing a latent electrostatic image on sheet or web material with a mixture of magnetic particles and toner powder comprising:

a receptacle for containing a supply of the mixture,

a magnetic brush assembly including an elongated cylinder rotatable about an axis and mounted adjacent the receptacle, said brush assembly including magnetic means which form a bristle-like and elongated covering on at least a portion of the periphery of the cylinder for applying mix to the member to be developed during rotation of the cylinder, and

a dispensing assembly for adding toner powder to the receptacle, the improvement comprising:

an elongated and electrically conductive member mounted adjacent the cylinder and extending generally parallel to the axis of the cylinder, said electrically conductive member being spaced from the outer periphery of the cylinder in the portion thereof covered by the bristle-like covering and engaging the bristle-like covering, and

a detecting circuit connected to the elongated member and the dispensing assembly for measuring the electrical resistance of the mixture and for selectively operating the dispensing assembly to dispense toner powder to the receptacle in accordance with the measured resistance of the mixture.

9. In a copying machine of the type in which a photoconductive member is imparted with an electrostatic charge and is developed by applying a mixture of carrier material and toner material combined in a predetermined mix ratio of carrier material to toner material, comprising:

a magnetic brush assembly for forming bristles of the mixture and moving the bristles into engagement with the material to develop the electrostatic image, the improvement comprising:

detecting means for sensing the electrical resistance of the portion of the mixture in the bristles, and dispensing means connected to and controlled by the detecting means for selectively adding the toner ma-

terial to the mixture in dependence on the resistance of the portion of the mixture in the bristles.

10. A method of automatically controlling the print density of copies developed by a mixture of developer material comprising a predetermined ratio of insulating toner powder and electrically conductive carrier particles, said mixture having a corresponding predetermined resistance, said method comprising the steps of:

monitoring the electrical resistance of the mixture and, automatically adding toner powder to said mixture in accordance with a decrease in the resistance of the mixture until the resistance reaches a value corresponding to said predetermined resistance value, thereby maintaining the ratio of insulating toner powder and electrically conductive particles.

11. A method of automatically controlling the print density of copies developed by a mixture comprising a predetermined ratio of insulating toner powder and electrically conductive carrier particles, said mixture a corresponding predetermined resistance, said method comprising the steps of:

forming a portion of the mixture into a brush-like mass, sensing the electrical resistance of the brush portion of the mixture on the mass, and

automatically adding toner powder to said mixture in accordance with a decrease in the resistance of the

mixture until the sensed resistance reaches a value corresponding to said predetermined resistance value, thereby maintaining the ratio of insulating toner powder and electrically conductive carrier particles.

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U.S. Cl. X.R.

117—66; 118—7, 9, 11, 637; 324—62