United States Patent

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[73] Assignee **RCA Corporation**

[54] **APPARATUS FOR MONITORING AND CONTROLLING THE CONCENTRATION OF POWDER PARTICLES IN A MIXTURE OF POWDER AND MAGNETIC PARTICLES**
21 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **118/7,** 117/17.5, 118/9, 118/637, 222/57
[51] **Int. Cl.** **G03g 13/08**
[50] **Field of Search** 118/7, 9, 621, 637; 117/17.5; 222/52, 57; 355/14

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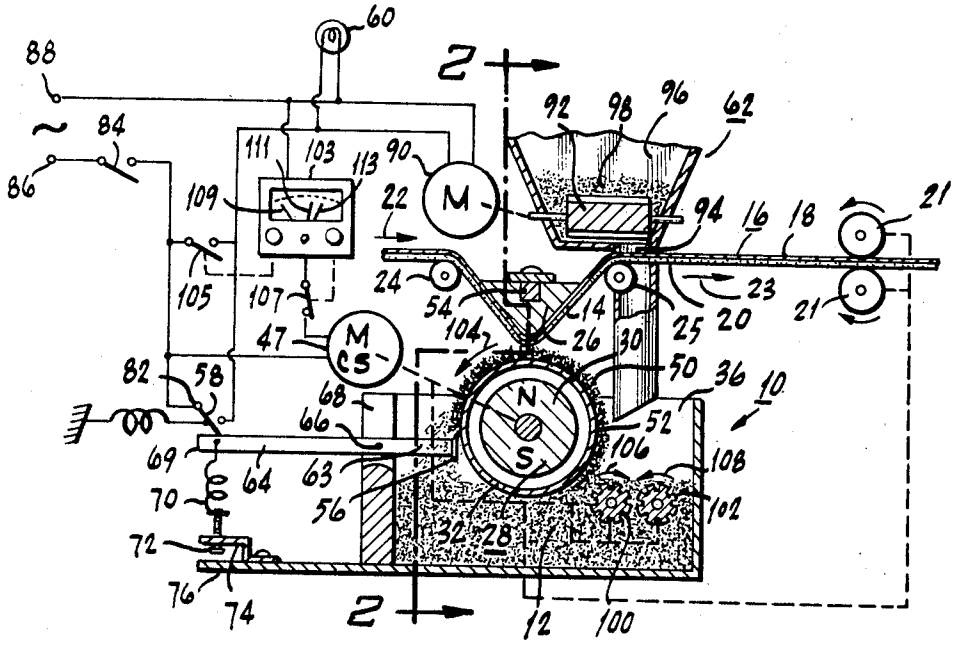
ABSTRACT: A magnetic brush is disposed to rotate in a source of developer mix, and a scraper member is disposed adjacent to the applicator surface of the magnetic brush to scrape developer mix therefrom. The physical force exerted on the scraper member by the scraping action is an inverse relationship to the concentration of toner particles in the developer mix. A sensor switch is coupled to the scraper member and is actuated when the force on the scraper member exceeds a predetermined value. The switch is included in a control circuit which is designed either to indicate the need for replenishment of toner particles in the developer mix or to actuate a toner particle replenisher means which adds toner particles to the developer mix.



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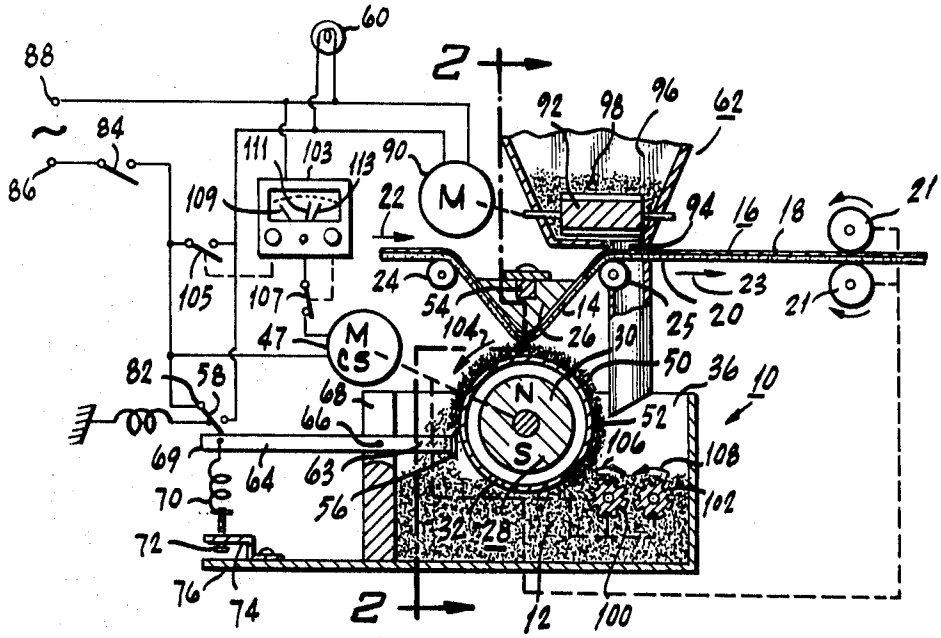

Fig. 1.

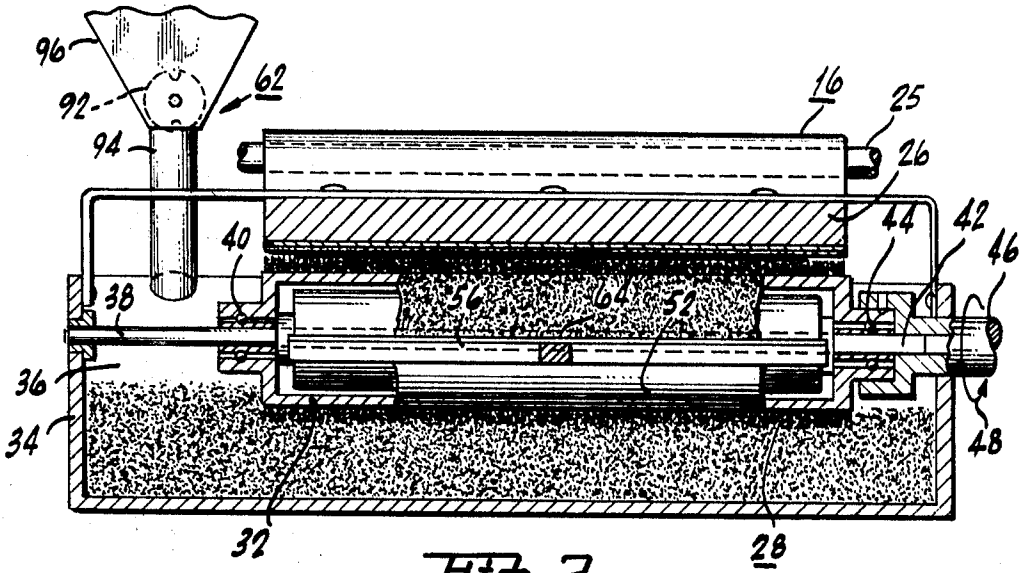

Fig. 2.

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APPARATUS FOR MONITORING AND CONTROLLING THE CONCENTRATION OF POWDER PARTICLES IN A MIXTURE OF POWDER AND MAGNETIC PARTICLES

BACKGROUND OF THE INVENTION

This invention relates to apparatus for monitoring and controlling the concentration of powder particles in a mixture comprising the powder particles and magnetic particles. More particularly, the invention relates to apparatus for monitoring and controlling the concentration of toner particles in a particulate developer mix comprising a triboelectric mixture of electroscopic toner particles and magnetic carrier particles. The apparatus of the present invention is particularly useful in electrostatic printing systems wherein electrostatic charge patterns are rendered visible by the application thereto of a particulate triboelectric developer mix of pigmented toner particles and magnetic carrier particles.

In many prior-art electrostatic printing systems of the type wherein electrostatic charge patterns on an insulating surface are developed by a triboelectric developer mix of toner and magnetic particles, only the toner particles are consumed in the developing process and the magnetic particles remain and are continuously reused. Consequently, it is necessary to replenish the developer mix with additional toner particles periodically or continuously to maintain the concentration of toner particles in the developer mix within predetermined limits and to insure developed prints of proper density. If, for example, the concentration of toner particles in the developer mix is less than an optimum concentration, the density of the developed charge patterns is too light. On the other hand, if the concentration of the toner particles in the developer mix is too high, the excessive toner particles tend to adhere to the nonimage areas of the print, providing prints with a "dirty" grayish background.

It has been proposed to monitor the concentration of toner particles in a developer mix by photoelectric methods, such as by measuring the light reflected from samples of developer mix, or by measuring the light from developed electrostatic charge patterns, but such apparatus is relatively complex, requires delicate adjustments, and is affected by external conditions, such as dust, the color of the pigment toner, and the color of the recording element involved.

SUMMARY OF THE INVENTION

A magnetic brush is disposed to move with respect to a mixture of toner particles and magnetic particles and to cause a layer of the mixture to adhere to its applicator surface. A scraper member is disposed adjacent to the applicator surface of the magnetic brush so as to remove at least a portion of the layer of the mixture and to produce forces on both the member and the magnetic brush, the amplitude of each force being a function of the concentration of the toner particles in the mixture. Monitoring means are responsive to at least one of the forces to indicate whether the concentration of toner particles is at least above or below a desired value.

A toner-feed mechanism may be provided which is responsive to the force produced on the scraper member and/or the magnetic brush to cause replenisher toner particles from the toner-feed mechanism to be added to the developer mix.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view, in cross section, and with parts broken away, of a portion of an electrostatic printing system embodying the present invention; and

FIG. 2 is a cross-sectional view, with parts broken away, of the electrostatic printing system taken along the line 2–2 of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawing, there is shown a portion of an electrostatic printing system **10** embodying the novel apparatus for monitoring and controlling the concentration of

electroscopic powder particles in a particulate mixture, such as a source **12** of developer mix. Suitable developer mixes, including pigmented toner particles and magnetic carrier particles of the type useful in the present invention, are described in U.S. Pat. No. 2,874,063, issued on Feb. 17, 1959, to H. G. Greig, for Electrostatic Printing.

The developer mix is used to develop electrostatic charge patterns on an insulating surface **14** of a recording element **16**. The recording element **16** may comprise a substrate, such as a web **18** of paper, coated with a photoconductive layer **20**, such as photoconductive zinc oxide in a suitable, film-forming, resin binder, as described, for example, in U.S. Pat. No. 3,052,539, issued on Sept. 4, 1962, to H. G. Greig for Electrostatic Printing. Means, including a pair of driver rollers **21**, move the recording element **16** (in the direction of the arrows **22** and **23**) over rollers **24** and **25** and under a shoe **26** adjacent to a magnetic brush **28** for the developing purposes.

Electrostatic charge patterns formed on the insulating surface of the photoconductive layer **20**, as, for example, by the electrostatic printing process described in the aforementioned U.S. Pat. No. 3,052,539, are developed by the developer mix from the source **12** with the aid of the magnetic brush **28**. The magnetic brush **28** may be constructed substantially in accordance with the teachings in U.S. Pat. No. 3,040,704, issued on June 26, 1962, to W. H. Bliss, for Apparatus for Developing Electrostatic Printing. Briefly described, the magnetic brush **28** comprises a nonrotating permanent magnet **30** fixedly disposed within a rotatable, nonmagnetic hollow drum **32**. One end of the magnet **30** is permanently fixed to a wall **34** of a reservoir **36** containing the source **12** of developer mix by a rod **38** that extends through the inner race of a ball bearing **40**. The other end of the magnet **30** is supported by a rod **42** that extends into the inner race of a ball bearing **44**. The drum **32** has its ends fixed to the outer races of the ball bearings **40** and **44** for rotation around the fixed permanent magnet **30**. The outer race of the ball bearing **44** and the drum **32** are fixed to a rod **46** which, in turn, is coupled to a constant-speed motor **47** for rotating the drum **32** in the direction of the arrow **48**. The motor **47** is also coupled to the rollers **21** for rotating them in the directions indicated for moving the recording element **16**.

Since the drum **32** of the magnetic brush **28** is disposed in the magnetic filed of the permanent magnet **30**, and since the drum **32** is also rotated in the source **12** of the developer mix which comprises magnetic particles, the developer mix forms a bristle-brushlike layer **50** on the applicator surface **52** of the drum **32**. Thus, electrostatic charge patterns produced on the insulating surface **14** of the photoconductive layer **20** are developed by the developer mix by brushing the charge patterns with the layer **50** of developer mix as the recording element **16** is moved around the shoe **26**. A permanent magnet **54** is disposed within the shoe **26** to provide a cooperating magnetic field with that of the permanent magnet **30** of the magnetic brush **28** to stiffen the brushlike layer **50** of developer mix at the point of its application to the photoconductive layer **20**.

Since only toner particles of the developer mix are consumed in the developing process, it is desirable to remove the layer **50** of developer mix, including the magnetic carrier particles and the unused toner particles, from the applicator surface **52** of the drum **32** after it has passed the recording element **16**, that is, downstream from the recording element **16**, for remixing with the source **12**. To this end, a scraper member **56**, such as a doctor blade of nonmagnetic material, for example, is disposed parallel to the longitudinal axis of the drum **32** and substantially in contact with the applicator surface **52**. Thus, the layer **50** of developer mix on the applicator surface **52** is removed by a shearing action as the drum **32** is rotated past the scraper member **56**. The continuous removal of the layer **50** from the applicator surface **52** provides for very efficient mixing of the particles in the developer mix.

In removing the layer **50** from the rotating drum **32**, we have discovered that a (shearing) force is produced on the

scraper member 56 that is an inverse relationship to the concentration of the toner particles in the developer mix. For example, the greater the percentage of toner particles in the developer mix, the less is the force produced on the scraper member 56 while shearing the developer mix from the drum 32. Conversely, as the toner particles in the developer mix are consumed, depleting the percentage of toner particles, the force produced on the scraper member 56 in removing the layer 50 from the applicator surface 52 increases.

Sensing means, such as a normally open, single-pole, single throw sensing switch 58 and monitoring (signal) means, such as a signal lamp 60, and toner-replenishing means, such as a (powder) toner-feed mechanism 62, are cooperatively associated with the scraper member 56 to respond to predetermined forces produced on the scraper member 56 while removing the developer mix from the applicator surface 52 of the drum 32. To this end, the scraper member 56 is fixed, adjacent the center thereof, by any suitable means, to one end 62 of a lever arm 64. The lever arm 64 is pivoted at a point intermediate its ends for rotation in a vertical plane about a pivot pin 66, the pin 66 being secured in a wall 68 of the reservoir 36. The other end 69 of the lever arm 64 is fastened to one end of a spring 70, and the other end of the spring 70 is secured to an adjusting screw 72. The screw 72 is threadably engaged in a bracket 74 whose end, in turn, is fastened to a base member 76 by any suitable means. The forece exerted on the end 69 of the lever arm 64 (in a counterclockwise direction) by the spring 70 can be adjusted by rotating the screw 72. It is within the contemplation of the present invention to employ other force-adjusting means also, such as weights and counter weights.

The sensing switch 58 is disposed above the end 69 of the lever arm 64 so that it can be closed when the lever arm 64 is rotated very slightly about the pin 66 due to a shearing force of a predetermined amplitude on the scraper member 56 while removing the layer 50 of developer mix from the applicator surface 52. One terminal 82 of the sensing switch 58 is connected to one terminal of a single-pole, single-throw, starting switch 84; and the other terminal of the switch 84 is connected to a power input terminal 86, which with a power input terminal 88 is adapted to be connected to a source of suitable input electrical energy.

The signal lamp 60 is connected to be energized when both the serially connected switches 58 and 84 are closed. A motor 90 for operating the toner-feed mechanism 62 is electrically connected in parallel with the lamp 60 so that both will be energized simultaneously. The motor 90 is mechanically coupled to a slotted shaft 92 that is disposed directly above a chute 94 of a hopper 96 of the toner-feed mechanism 62. The hopper 96 is filled with replenisher toner particles 98 that are adapted to fall through the chute 94 when the slotted shaft 92 is rotated. The replenisher toner particles 98 fall into the source 12 of developer mix in the reservoir 36 and are mixed with the developer mix by any suitable mixing means, such as oppositely rotatable mixing screws 100 and 102. The mixing screws 100 and 102 are coupled to the motor 47 for rotation thereby, the motor 47 being connected to be energized through the series connected including the starter switch 84 and a current-indicating meter, such as a double-set point meter relay 103. A normally open sensing switch 105, included within the meter relay 103, is connected in parallel with the sensing switch 58. A normally-closed switch 107, also included within the meter relay 103, is connected in series with the starter switch 84 for monitoring purposes in a manner to be hereinafter described.

The apparatus for monitoring and controlling the concentration of toner particles in a source 12 of developer mix, in one embodiment of the invention, operates as follows: Let it be assumed, initially, that the concentration of toner particles in the source 12 of developer mix is a desired concentration for the development of electrostatic images on the recording element 16. The starter switch 84 is closed and the constant-speed motor 47 is energized to rotate (1) the drum 32 in the direction of the arrow 104, (2) the mixing screws 100 and 102 in the direction of the arrows 106 and 108, respectively, and (3) the rollers 21 to move the recording element 16 in the direction of the arrows 22 and 23. Let it also be assumed that electrostatic images are provided on the surface 14 of the photoconductive layer 20 of the recording element 16, in accordance with the teachings of the aforementioned U.S. Pat. Nos. 3,052,539 and 3,040,704.

The bristlelike layer 50 of developer mix on the applicator surface 52 of the drum 32 brushes against the photoconductive layer 20 and develops the charge patterns thereat by depositing electrostatic toner particles thereon from the developer mix. At least a portion of the layer 50 of developer mix is removed by the scraper member 56 at the location downstream from the recording element 16. This action produces a force on the scraper member 56, creating a positive moment of the force (in a clockwise direction) about the pin 66 against the negative moment of the counter force produced by the spring 70. The layer 50 of developer mix that is removed by the scraper member 56 falls into the reservoir 36 where it is remixed with the source 12 of developer mix by the mixing screws 100 and 102.

The amplitude of the force produced on the scraper member 56 while removing the layer 50 of developer mix from the applicator surface 52 is a function of the percentage of toner particles in the developer mix, that is, the force is inversely proportional to the quantity of toner particles in the source 12 of developer mix. Hence, since only the toner particles from the developer mix are consumed in the development of the charge patterns on the photoconductive layer 20, the percentage of toner particles in the layer 50 decreases as the developing process continues, and the force produced upon the scraper member 56 (in a clockwise direction) increases. When it is observed the developed charge patterns on the insulating surface 14 of the recording element 16 begin to lose density, that is, when they are not as dark as they should be, the adjusting screw 72 is turned, so as to decrease the tension on the spring 70, until the lever arm 64 rotates clockwise very slightly to close the sensing switch 58.

Upon the closing of the sensing switch 58, the signal lamp 60 lights, indicating that additional replenisher toner should be added to the reservoir 36 to replenish the source 12 with additional toner particles. In the absence of an automatically operated toner-feed mechanism, the replenisher toner particles can be added manually in an amount sufficient to reduce the force on the scraper member 56 and to open the normally biased open sensing switch 58, whereby to extinguish the signal lamp 60. The adjustment is only necessary to calibrate the apparatus, and, once it is calibrated for a particular developer mix, it need not be adjusted again, unless a different developer mix is used.

The addition of replenisher particles 98 to the reservoir 36 is accomplished automatically upon the closing of the sensing switch 58 and the energizing of the motor 90. This action causes the slotted shaft 92 to rotate and the replenisher toner particles 98 to fall through the chute 94 into the reservoir 36 at a rate greater than the depletion rate of the toner particles. When a sufficient amount of the replenisher toner particles 98 have been added to the source 12 of developer mix, the force produced on the scraper member 56 is reduced, reducing the clockwise moment of the force about the pin 66. Consequently, the tension produced by the lever arm 64 on the spring 70 is reduced and the sensing switch 58 is opened. This action turns off the lamp 60 and stops the motor 90, indicating that the toner particles in the source 12 of developer mix is of a sufficient concentration to develop the charge patterns on the recording element 16 with an acceptable density. The developing process will continue without replenishment of the developer mix until enough toner particles are consumed from the source 12 of developer mix to again actuate the sensing switch 58.

The force on the scraper member 56, produced by the magnetic brush 28, produces an equal and opposite force on the

magnetic brush **28**. The force on the magnetic brush **28** produces a torque which tends to oppose the normal rotation of the drum **32** of the magnetic brush **28**, thereby causing the constant-speed motor **47** to draw current that varies with the force on the magnetic brush **28**. Hence, the motor current of the constant-speed motor **47** can be used as a means to monitor and to control the concentration of toner particles in the developer mix, in accordance with another embodiment of the invention. In the operation of this latter embodiment, let it be assumed that the concentration of toner particles in the source **12** of developer mix is a desired concentration, and the input voltage to the input terminals **86** and **88** is substantially constant. The starter switch **84** is closed and the constant-speed motor **47** is energized through the meter relay **103**. The current-indicator pointer **109** of the meter relay **103** will indicate a value of current that is related to the forces on both the scraper member **56** and the magnetic brush **28**. Hence, the value of current indicated by the current-indicator pointer **109** is also an indication of the concentration of toner particles in the developer mix. The scale of the meter relay **103** associated with the current-indicator pointer **109** can be calibrated in terms of percent concentration of toner particles in the developer mix. Thus, the meter relay **103** monitors the concentration of toner particles in the developer mix.

As the toner particles in the developer mix are consumed in developing charge patterns on the recording element **16**, the force on the magnetic brush **28** increases and the current necessary to drive the constant-speed motor **47** increases also. The decrease in the concentration of toner particles in the developer mix is monitored by observing the increase in current on the meter relay **103**.

When it is observed that the developed charge patterns on the insulating surface **14** of the recording element **16** begin to lose density, as when the concentration of toner particles in the developer mix decreases and the current to the constant-speed motor **47** consequently increases, the normally open sensing switch **105** of the meter relay **103** is caused to close by adjusting an adjustable relay-release indicator **111**, in a manner known in the art. This action energizes both the signal lamp **60** and the motor **90**, causing replenisher toner particles **98** to fall into the reservoir **36**. After the sufficient amount of toner particles **98** have been added to, and mixed with, the source **12** of the developer mix, the force on the magnetic brush **28** is reduced, causing the current to the constant-speed motor **47** to decrease below the value set by the relay-release indicator **111** to close the sensing switch **105**. Consequently, the sensing switch **105** opens, the toner-feed mechanism **62** is deenergized, and the developing process continues until enough toner particles are consumed once more to increase the force on the magnetic brush **28**. This action causes the current to the constant-speed motor **47** to increase and to close the sensing switch **105** again, thereby repeating the replenishing toner cycle.

If the hopper **96** is emptied of replenisher toner particles **98**, the toner particles in the developer mix will decrease during the developing process until the increasing force on the magnetic brush **28** cause the current through the meter relay **103** to reach a shutoff value. An adjustable shutoff indicator **113** of the meter relay **103** is adjusted to this value to open the normally closed switch **107** and to deenergize the constant-speed motor **47**, thereby stopping the apparatus. Thus, the shutoff indicator **113** monitors the concentration of toner particles in the developer mix to the extent that it prevents the development process from continuing when the concentration of toner particles in the developer mix is below a useable value.

We claim:

1. Apparatus for developing an electrostatic image comprising:

a. magnetic means for applying developer mix including toner particles and magnetic particles to the electrostatic image,

b. mix removal means adjacent to said magnetic means for removing excess developer mix therefrom, the force exerted between said mix removal means and said magnetic means by the removal of developer mix from said magnetic means being an inverse relationship to the concentration of toner particles in said mix, and

c. control circuit means including sensor means responsive to said force exerted on said mix removal means for sensing the concentration of toner particles in said developer mix.

2. Apparatus according to claim **1** wherein said control circuit means includes indicator means which is energized when the toner particle concentration of the developer mix being removed from said magnetic means is below a predetermined value.

3. Apparatus according to claim **1** further including toner particle replenishing means coupled to said control circuit means for adding toner particles to said developer mix when the concentration of toner particles in the developer mix being removed from said magnetic means falls below a predetermined value.

4. In a system wherein substantially only powder particles are consumed from a particulate mixture comprising powder particles and magnetic particles, apparatus for monitoring the concentration of said powder particles in a source of said mixture comprising:

a magnetic brush having an applicator surface adapted to contact said mixture and to move with respect thereto, whereby a layer of said mixture is attracted and adhered to said applicator surface,

moving means to move said magnetic brush so that portions of said applicator surface are moved into and out of said mixture substantially continuously,

a scraper member disposed adjacent to said applicator surface when said magnetic brush is moving to remove at least a portion of said layer from said applicator surface and to produce forces on said member and said magnetic brush, the amplitude of each of said forces being a function of the concentration of said powder particles in said mixture, and,

monitoring means responsive to at least one of said forces to indicate whether said concentration is at least above or below a desired value.

5. In a system as described in claim **4** wherein said monitoring means comprise a lever arm pivoted for rotation in said system, said scraper member being fixed adjacent to one end of said lever arm, whereby said force produced on said scraper member tends to urge said lever arm in one direction; and counterforce means associated with said lever arm urging said lever arm in an opposite direction to said one direction.

6. In a system as described in claim **5** wherein said counterforce means are adjustable.

7. In a system as described in claim **5** wherein said applicator surface comprises a cylindrical surface,

said scraper member comprises a doctor blade of nonmagnetic material fixed to said one end of said lever arm and disposed against said cylindrical surface, and

said monitoring means comprises sensing means disposed adjacent said lever arm to be actuated by a slight movement of said lever arm, and signal means in an electrical circuit with, and adapted to be actuated by, said sensing means, whereby to monitor the concentration of powder particles in said mixture.

8. In a system as described in claim **7** said apparatus having, in addition,

a powder-feed mechanism, and

means connecting said powder-feed mechanism in circuit with said sensing means to control the operation of said powder-feed mechanism in response to a predetermined amplitude of said force on said scraper member.

9. In a system as described in claim **4** wherein said moving means comprises a motor, and

said monitoring means comprises a meter, having current indicating means, connected to indicate the current to said motor, whereby the amplitude of said current is a

function of the concentration of powder particles in said mixture.

10. In a system as described in claim 9 wherein said monitoring means comprises, in addition, a sensing switch and means to actuate said sensing switch when said current reaches a first predetermined value, and means in circuit with said sensing switch to replenish said source with powder particles.

11. In a system as described in claim 10 wherein said meter comprises a meter relay having a switch connected in series with said motor, and means to actuate said switch when said current reaches a second predetermined value.

12. In an electrostatic printing system of the type wherein electrostatic charge patterns on an insulating surface are developed by a developer mix from a source comprising a mixture of both electroscopic toner particles and magnetic carrier particles, and wherein only the toner particles are consumed in the developing process, the improvement comprising:

a magnetic brush having an applicator surface adapted to be disposed in contact with said developer mix and movable with respect thereto, said magnetic brush having a magnetic field to attract a layer of said developer mix onto said applicator surface when said applicator surface is moving with respect to said developer mix,

moving means to move said magnetic brush adjacent to, and with respect to, said insulating surface to brush said insulating surface with said layer of developer mix, whereby to develop said electrostatic charge patterns,

a scraper member disposed adjacent to said applicator surface and adapted to remove at least a portion of said layer of said developer mix from said applicator surface when said applicator surface is moving downstream from said insulating surface, the removal of said developer mix from said toner applicator surface producing a force on said member and said magnetic brush that is a function of the concentration of toner particles in said developer mix, and

means responsive to said force to monitor the concentration of said toner particles in said developer mix.

13. In an electrostatic printing system as described in claim 12 wherein;

said means responsive to said force comprises a lever arm pivoted for rotation in said system, said scraper member being fixed adjacent to one end of said lever arm, whereby to tend to rotate said lever arm by said force in one direction,

counterforce means cooperatively associated with said lever arm tending to rotate said lever arm in an opposite direction to said one direction, sensing means disposed to be actuated by said lever arm when said lever arm is rotated slightly, and signal means connected to said sensing means to monitor at least a predetermined concentration of toner particles in said developer mix.

14. In an electrostatic printing system as described in claim 13 wherein;

said counterforce means are adjustable.

15. In an electrostatic printing system as described in claim 12 wherein;

said means responsive to said force comprises a sensing switch cooperatively associated with said scraper member, and

signal means connected in circuit with said sensing switch to monitor whether said concentration of said toner particles in said developer mix is at least above or below a predetermined concentration.

16. In an electrostatic printing system as described in claim 12 wherein;

said means responsive to said force comprises a sensing switch and a toner-feed mechanism connected in circuit with said sensing switch, said toner-feed mechanism comprising a hopper for replenisher toner particles and means for conveying said replenisher toner particles to said source of developer mix, whereby to control the concentration of toner particles in said developer mix.

17. In an electrostatic printing system of the type described in claim 12 wherein;

said applicator surface defines a cylindrical drum,

said moving means comprises a motor coupled to said drum, and circuit means to energize said motor whereby to rotate said drum, and

said means responsive to said force comprises a meter connected in circuit with said motor to indicate the current drawn by said motor, said current being a function of said concentration.

18. In an electrostatic printing system of the type described in claim 17 wherein;

said meter comprises a meter relay having a sensing switch and means to actuate it when said current reaches a first predetermined value,

a toner-feed mechanism, and

circuit means connecting said sensing switch to energize said toner-feed mechanism.

19. In an electrostatic printing system of the type described in claim 18 wherein;

said meter relay comprises, in addition, a second switch connected in series with said motor, and adjustable means to actuate said second switch when said current to said motor reaches a second predetermined value.

20. Apparatus utilizing a mixture of two different kinds of particles, one kind being consumed by the functioning of the apparatus and requiring replenishing, comprising:

mixture handling means,

removal means adjacent said handling means to remove the excess of the other kind of said particles from said handling means, the force exerted between said removal means and said handling means being related to the concentration of said one kind of particles in said mixture, and

control means to control the replenishing of said mixture by the addition of said one kind of particles to said mixture, said control means including sensing means responsive to said force exerted on said removal means for sensing the concentration of said one kind of particles in said mixture.

21. Apparatus as described in claim 1, wherein the other kind of particles in said mixture are magnetic particles, and said handling means are magnetic means.