United States Patent

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[54] **APPARATUS FOR DEVELOPMENT OF ELECTROSTATIC IMAGES**
17 Claims, 2 Drawing Figs.

[52] **U.S. Cl.** **118/637**
[51] **Int. Cl.** **B05b 5/02**
[50] **Field of Search** ..... 118/637, 621, 637(Mc)10; 117/17.5; 95/(Inquired); 346/74(ES)

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ABSTRACT: Developer is fed into a cavity faster than it is discharged creating a developer accumulation in the cavity forming a soft, agitated development medium. In preferred embodiments, two magnetic brushes are arranged to create the accumulation in the form of a gently tumbling rollback from the contacting of one of the brushes with the image-bearing surface. In the preferred embodiments, the accumulation is accentuated by adjusting the spacing between the brushes and the image-bearing surface, adjusting the peripheral speed of the brushes and controlling the direction of movement of the image-bearing surface relative to the movement of the brushes.

Carrier carryout is reduced by directing a strong magnetic flux at the rollback area and by providing an auxiliary carrier scavenging mechanism.

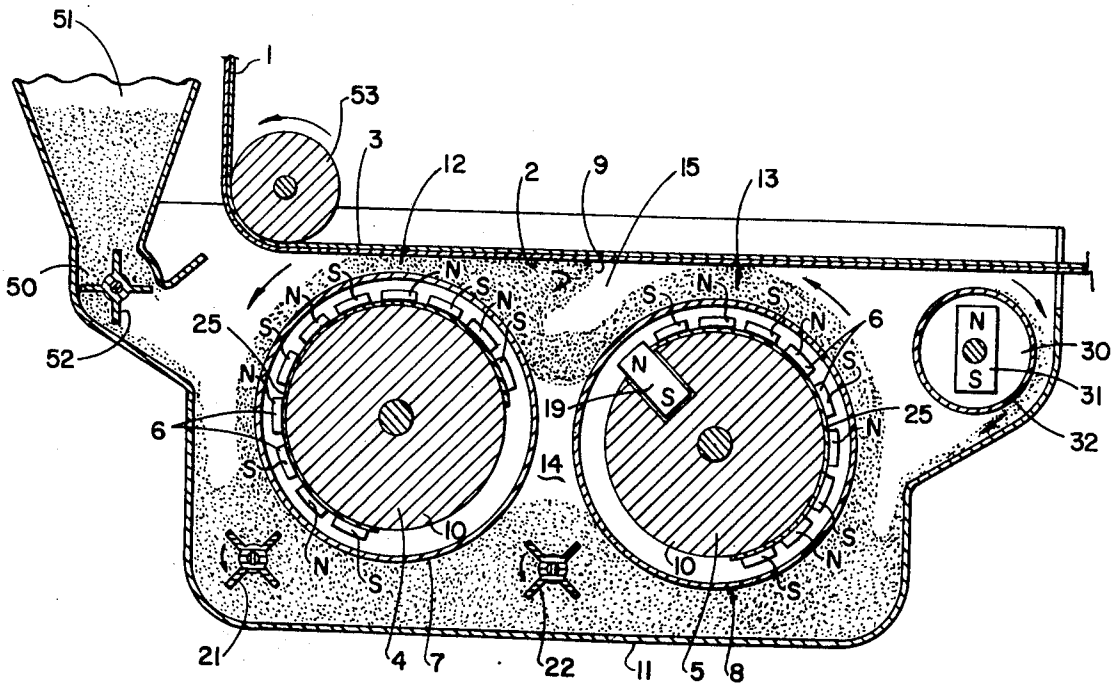


FIG. 1

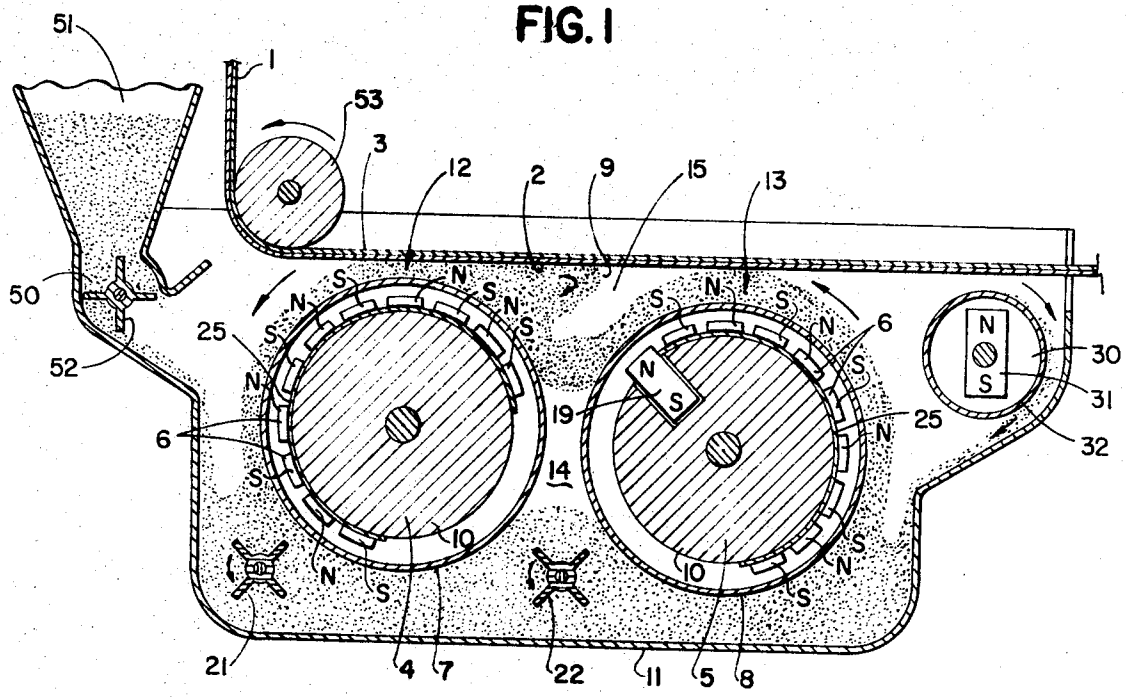
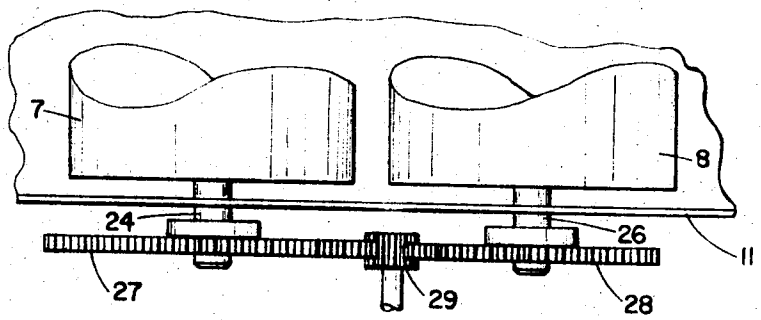


FIG. 2



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APPARATUS FOR DEVELOPMENT OF ELECTROSTATIC IMAGES

CROSS-REFERENCES TO RELATED APPLICATIONS

Reference is made to commonly assigned cofiled U.S. application Ser. No. 709,280, now U.S. Pat. No. 3,457,900, entitled "Single Magnetic Brush Apparatus for Development of Electrostatic Images" filed even date herewith in the name of Roger A. Drexler.

BACKGROUND OF THE INVENTION

This invention relates to electrostatic images (which term is meant to include all electrostatic charge patterns, regardless of the method of formation) and, more specifically, to methods and apparatus for developing electrostatic images carried on an insulating surface.

In electrography, it is common to form an electrostatic image on an insulating surface and to develop that image by applying toner particles thereto. The resulting toner image is then utilized. In the most common commercial applications, the toner is either transferred in image configuration to another surface and then fixed or is fixed to the insulating surface itself. In processes in which the toner is transferred from the insulating surface prior to fixing, the insulating surface generally is reused.

Triboelectric developing systems have been adapted to the general development of electrostatic images. In such systems, finely divided toner particles are held to the surface of much larger carrier particles by electrostatic charges created by triboelectrification, forming a mixture (herein called a developer). When the developer is brought into contact with an electrostatic image, the attraction of the image for the triboelectrically charged toner overcomes the attraction of the carrier for the toner and the image is developed.

Among triboelectric developing systems, the most commonly used are cascade systems and magnetic brush systems. In cascade systems, gravity is used to roll developer across the image. Because cascade systems use gravity as their primary moving force, they are necessarily speed limited. In automatic machines, a cascade recirculation system generally requires substantial machine space.

In magnetic brush systems, the carrier particles are ferromagnetic in nature. These ferromagnetic carrier particles are held to an applicator surface, for example, a nonmagnetic cylinder, in bristle formation by magnetic attraction. With the proper use of applicator, one or more magnets and developer, the bristles can be brushed across a surface carrying an electrostatic image. The electrostatic attraction of the toner for the image overcomes the triboelectrically created attraction between toner and ferromagnetic particles and the image is developed. Areas of the image exerting less attractive force on the toner than is exerted by the carrier are cleaned of toner as they are brushed. This is commonly aided by application of an electrical bias to the carrier through the applicating surface of the brush. Magnetic brushes also have been designed to give either fringe or solid area development by adjusting the conductivity of the carrier. They can also be made to tone areas of less charge and clean areas of greater charge giving what is known in the art as a reverse development.

Commercial applications of magnetic brush development have been quite extensive. However, such applications generally have been concentrated in the area of development of electrostatic images formed on a nonreusable insulating surface, such as zinc oxide coated paper. That is, the toner image is fixed to the insulating surface carrying the electrostatic image rather than being transferred prior to fixing.

In applying magnetic brush development to systems in which the surface to be toned is to be reused after utilization of the toner pattern, certain problems are accentuated. For example, repeated rubbing by the fairly coarse bristles of the magnetic brush has a tendency both to scratch the insulating surface and to create a toner scum on it. These problems are particularly severe when the insulating surface is photoconductive, as in xerography, because of difficulties in proper image formation on a scratched or scummed photoconductive surface.

Additionally, a powder transfer process greatly increases image degradation caused by carrier carryout. More specifically, small carrier particles are commonly picked up by the insulating surface in the toning operation and have the effect at toner transfer of holding a large area of the transfer surface away from the photosensitive surface thereby inhibiting powder transfer. This problem is much reduced if no transfer of toner is included in the process, as is the case when the powder is fixed to the toned surface.

SUMMARY OF THE INVENTION

It is an object of this invention to effectively tone an electrostatic image.

It is another object of this invention to minimize surface scratching and scumming resulting from magnetic brush development of a reusable insulating surface.

It is another object of this invention to improve triboelectric developer agitation in magnetic brush development thereby providing good quality development with low toner concentrations.

It is another object of this invention to reduce carrier carryout in magnetic brush development.

It is another object of this invention to effectively tone areas desired to be solid black.

It is another object of this invention to provide a magnetic brush developing apparatus with a soft, well-mixed toning medium and reduced carrier carryout, which is particularly adapted for use with a reusable photoconductive surface.

According to the invention, scratching and scumming are reduced by a developer feed and discharge arrangement which provides a substantial developer accumulation in a cavity accessible to the image-carrying surface. This accumulation gives a soft, less abrasive toning medium which, in turn, gives effective toning, including toning of solid areas.

It is a feature of a preferred form of this invention that the feed and discharge arrangement is so constructed to gently tumble the developer accumulated in the cavity, giving thorough mixing and triboelectric charging, and thereby providing effective toning at remarkably low on toner concentrations.

Although the accumulation of toner can be created and agitated with a number of forms of apparatus within the concept of this invention, it is a preferred feature of this invention to position two cylindrical magnetic brushes so that portions of their outer surfaces form a cavity with the insulating surface to be toned. One brush (herein called the "feed brush") is rotated rapidly to bring developer into the cavity and barely contacts the image-bearing surface which is moving in the opposite direction. The other brush (herein called the "discharge brush") is rotated at a slower speed in the same direction. It picks up developer from the feed brush and brushes it lightly across the insulating surface while carrying the developer out of the cavity. Because of the position and rates of rotation of the two brushes, the form of the magnetic fields created by the brushes, and/or the relative direction of motion of the image-bearing surface, there is a buildup of developer in the cavity. This accumulation of developer is in the form of a rollback from the discharge brush, although it may fill the cavity. Because this developer is not as closely associated with the magnetic fields of the brushes as developer actually being carried by the brushes, it is softer and not as bristly or coarse, giving less abrasion and scumming of the insulating surface. The motion of the brushes and the image-bearing surface causes developer to tumble gently, giving thorough and constant mixing of toner and carrier and good triboelectric charging.

With the lessening of the influence of the magnetic field, there may be a tendency toward more carrier carryout on the insulating surface. It is a feature of this invention to reduce

this carrier or iron carryout by careful placement of a strong magnet in the feed brush so that it creates a substantial magnetic attractive force directly in the rollback area.

It is also a feature to further reduce carryout, by the feed brush itself which touches the insulating surface so lightly or not at all that it does very little toning, but is close enough to scavenge away from the surface, carrier that may have adhered thereto despite the action of the strong magnet.

It is also a feature of this invention to do further carrier scavenging with an auxiliary magnetic scavenging structure more fully described below.

Other objects and inventive features will appear from the more specific description of the preferred embodiments of the invention below.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic cross-sectional view of a magnetic brush assembly constructed according to the invention.

FIG. 2 is a fragmentary top view showing the drive train of the magnetic brush assembly of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to FIGS. 1 and 2, an electrostatic charge pattern carried on an insulating surface 2 of a web 1 driven by drive roller 53 and having a conductive backing 3 is to be toned. The surface 2 is moved past a discharge magnetic brush 4 and a feed magnetic brush 5 mounted in a developer trough 11 or other reservoir means. The brushes can be constructed individually according to a variety of designs known in the prior art. According to FIG. 1, a preferred design for this application includes a stationary core 10 of nonmagnetic material around which is mounted a stationary magnetic pole piece 25 that may be made of soft steel or other magnetic material. Mounted around part of the circumference of the pole piece 25 is a series of permanent magnets 6, for example, rubber-bonded barium ferrite magnetic strips or poles. Concentric with the arrangement of these elements and on the outside thereof are rotatable, preferably surface-roughened, nonmagnetic rollers 7 and 8. Each brush is constructed so that, as the rollers 7 and 8 rotate, developer particles are held on its surface and moved with the roller while in the field of the magnetic strips. The magnetic strips 6 are arranged so that a section of each roller is not in enough of the influence of the magnetic field to hold the developer on the roller.

As shown in FIG. 1, the two magnetic brushes 4 and 5 are arranged so that the feed brush 5 feeds developer to the discharge brush 4. If a close doctor blade is not used with the discharge brush to define a short bristle size, a rollback 9 of developer will occur at a point just prior to contact of the discharge brush with the insulating surface. This rollback can be enhanced by several features shown in the drawing. First, the brushes are rotated so that they move in a direction opposite to the movement of the insulating surface 2 at the points of contact therewith. Second, the feed brush 5 is rotated at a faster rate than the discharge brush 4. Third, the feed brush is spaced farther from the insulating surface 2 than the discharge brush. Either of the second or third features, if accentuated, are sufficient alone to create an accumulation of developer in cavity 15 and, hence, a usable rollback. However, a preferred form of the invention uses all three features in combination to create a rollback of developer of substantial size, which may substantially fill the cavity 15 between the brushes and the insulating surface.

With a substantial accumulation of developer in the rollback cavity 15, this arrangement does most of its effective toning in the softer rollback area 9 with very little toning done in areas 12 and 13 of stiffer bristle. The developer in the rollback which contacts the surface 2 is not held as firmly by the magnetic fields of either brush as the developer in bristle formation on the rollers and is therefore less abrasive to the surface 2. In addition, it is constantly being gently tumbled, giving good triboelectric charging and effective mixing.

Obviously, developer cannot build up in the rollback cavity indefinitely. Excess toner fed into the brush after the rollback is built up overflows at the ends of the cylinders and falls into the reservoir 11 to be reused.

Ferromagnetic carrier particles in the rollback area have a tendency to be occasionally carried away by the insulating surface. This can be reduced by "aiming" a strong magnet 19 in the second brush at the rollback 9. The strength of this magnet is preferably worked out empirically for the softness desired in the rollback and the carryout permissible. Further, the feed brush, which lightly contacts the insulating surface after the surface passes the rollback area, is effective to remove some of those carrier particles actually picked up by the electrostatic image in toning.

A scavenging device 30 can also be used. It includes a stationary single strong magnet 31 placed in close proximity with the insulating surface 2 and a rotatable nonmagnetic roller 32 between the magnet and surface 2 to carry out ferromagnetic particles attracted toward the magnet.

Many alternative mechanisms may be used to drive the rollers 7 and 8 at different speeds. One such mechanism is shown in FIG. 2 in which a single drive gear 29 connected to a source of power, not shown, drives a gear connected by a shaft 26 to roller 8 and drives a gear 27, which has a larger diameter than gear 28, and is connected through a shaft 24 to roller 7. The difference in the diameters of the gears will cause roller 8 to be rotated at a faster speed than roller 7. Alternatively, the gears can be made the same size and the rotations per minute of the rollers 7 and 8 be made equal, but the second roller 8 be made of larger diameter than the first roller 7, thereby providing a greater peripheral speed. Alternatively, the size and speed of rotation of the rollers can be made equal, but the strength of the magnets and, hence, the size of the bristles in the feed brush made greater than in the discharge brush.

Similarly, many alternative means may be used for replenishing toner used up in the process. For example, as shown in FIG. 1, a toner dispenser 50 including a hopper 51 allows toner to fall at a regular rate onto a paddle wheel 52 which rotates and feeds toner into the trough 11. Fresh toner is circulated gradually toward the bottom of the feed brush 5 by paddle wheels 21 and 22, where it is picked up by the second brush to begin use in the process.

In addition to producing a softer medium which is less harmful to a photoconductive or other insulating surface, the broad soft development surface also gives excellent image resolution. The rollback action provides a continuous soft mixing of toner and carrier helping to maintain the proper polarity of charge on the toner at the development area. This continuous mixing combined with the effectiveness of the toning allows for substantial variations in overall toning concentrations with toning results that are very close in quality. If the brushes are used as development electrodes, the apparatus will give especially uniform blacks in solid image areas.

As an example of the invention, two brushes are constructed as shown in FIG. 1. The rotating cylinders 7 and 8 are made 3 inches in diameter and one-fourth inch apart at their closest outside points. The strip magnets 6 have enough magnetic attraction for iron particles of +80—120 mesh to produce bristles approximately one-fourth inches long. The axes of cylinders 7 and 8 are offset with respect to the insulating surface 2 by one-sixteenth inch with the periphery of feed cylinder 8 approximately three-sixteenths inch and discharge cylinder 7 approximately one-eighth inch from insulating surface 2, respectively, at their closest points. With surface 2 moving at 20 inches a second, feed cylinder 8 is rotated at 65 r.p.m. and discharge cylinder 7 is rotated at 40 r.p.m. Excellent toning is obtained at these speeds with bias adjustments as in prior magnetic brushes. As toner concentration is varied from 3 to 6 percent by weight, no difference in print quality is noticeable to the naked eye. This remarkable and highly useful feature is believed to be due to the excellent mixing and triboelectric charging obtained as the developer tumbles in the rollback cavity 15. Although 65 and 40 r.p.m. appear to be

optimum speeds for these parameters, little difference actually is noticed if the cylinders 8 and 7 are rotated at a variety of other speeds, for example, at 40 and 30 r.p.m., respectively. The parameters giving best results with any particular equipment, developer and type of image are preferably worked out empirically with that equipment, developer and type of image.

The invention has been described in detail with particular reference to preferred embodiments thereof, but it will be understood that variations and modifications can be effective within the spirit and scope of the invention as described hereinabove and as defined in the appended claims. For example, although the invention has been described with reference to magnetic brush means for transporting toner into and out of a rollback cavity, it can be seen by such description that other means of creating a soft tumbling development medium can be used within the spirit of the invention. For example, fiber brushes, rollers with ridges, etc., could also be used to create a similar effect.

We claim:

1. Developing apparatus for use in applying toner to an electrostatic image carried on an insulating surface, said apparatus comprising:
- means defining a cavity adjacent to said insulating surface;
- developer feed means for feeding developer into said cavity at a first rate;
- developer discharge means for discharging developer from said cavity at a second rate which is less than said first rate; and
- whereby a substantial quantity of developer accumulates in and is continuously circulated through said cavity in contact with said insulating surface.

2. Developing apparatus for use in applying toner to an electrostatic image carried on a moving insulating surface, said apparatus comprising:
- means defining a cavity adjacent to said insulating surface;
- developer feed means for feeding developer into said cavity at a first quantity per unit of time;
- developer discharge means for discharging developer from said cavity at a second quantity per unit of time; and
- said first quantity per unit of time being greater than said second quantity per unit of time thereby causing a substantial accumulation of freely tumbling developer in said cavity in contact with said insulating surface.

3. Developing apparatus for applying toner to an electrostatic image carried on a moving insulating surface to form a toner image defined by said electrostatic image said apparatus comprising:
- means defining a cavity at a developing position;
- first magnetic brush feed means for feeding developer into said cavity at a first rate; and
- second magnetic brush means for discharging developer from said cavity at a second rate less than said first rate so as to create an accumulation of developer in said cavity and tumble developer accumulated in said cavity through a path touching said moving insulating surface.

4. Developing apparatus for use in applying toner to an electrostatic image carried on an insulating surface, said apparatus comprising:
- means for moving said insulating surface in a first direction;
- a developer comprising a mixture of toner powder and carrier powder;
- developer feed means and developer discharge means, portions of which combine with a portion of said insulating surface to define a rollback cavity;
- said feed means including means to feed developer into said rollback cavity in a direction generally opposite said first direction and at a first rate, and said discharge means including means to discharge developer from said rollback cavity at a second rate less than said first rate; and
- said feed means and discharge means including means cooperating with said insulating surface to tumble developer accumulated in said cavity through a path a portion of which contacts said insulating surface.

5. Developing apparatus for use in applying toner to an electrostatic image carried on a moving insulating surface, said apparatus comprising:
- means defining a cavity adjacent to said insulating surface;
- magnetic brush means for feeding developer into said cavity at a first quantity per unit of time; and
- magnetic brush means for discharging developer from said cavity at a second lesser, quantity per unit of time, whereby a substantial accumulation of freely tumbling developer is provided in said cavity in contact with said insulating surface.

6. A developing apparatus for use in applying toner to an electrostatic image carried on an insulating surface moving in a first direction, said apparatus comprising:
- means defining a cavity adjacent said insulating surface;
- first magnetic brush means for feeding developer into said cavity at a first rate;
- second magnetic brush means for discharging developer from said cavity at a second rate which is less than the rate at which developer is fed into said cavity by said first magnetic brush means; and
- said first and second magnetic brush being adapted to feed developer through said cavity in a second direction opposite to said first direction and being located with respect to said moving insulating surface so as to provide a gently tumbling accumulation of developer in said cavity.

7. A developing apparatus for use in applying toner to an electrostatic image carried on a moving insulating surface, said apparatus comprising:
- a developer comprised of a mixture of toner powder and magnetically attractable carrier powder;
- reservoir means for holding said developer;
- magnetic means for feeding developer from said reservoir means to a rollback cavity, cavity, and by a portion of said magnetic means and a portion of said insulating surface, and for discharging developer from said rollback cavity back to said reservoir means, said magnetic means including:
  - a. feed magnetic brush means for moving developer from said reservoir into said rollback cavity; and
  - b. discharge magnetic brush means for moving developer from said rollback cavity into substantial contact with said moving insulating surface and then into said reservoir;
- means for operating said feed and discharge magnetic brush means to move developer at predetermined rates, said predetermined rates being so chosen relative to the movement of said insulating surface to create a substantial accumulation of developer in said rollback cavity.

8. Apparatus according to claim 7 wherein at least a portion of said magnetic means is adapted to cooperate with said moving insulating surface to form a means for tumbling said developer accumulated in said rollback cavity.

9. Apparatus according to claim 7 wherein said means for operating said feed and discharge magnetic brush means is adapted to move the developer being moved by said feed brush faster than the developer being moved by said discharge brush, thereby contributing to said accumulation of developer.

10. Apparatus according to claim 7 wherein said discharge brush means is adapted to move developer in a direction opposite to the movement of said insulating surface, thereby creating a rollback of developer.

11. Apparatus according to claim 7 wherein a portion of said feed magnetic brush means is positioned close enough to said insulating surface to remove ferromagnetic particles deposited on said surface by said discharge brush means and by said developer accumulated in said cavity.

12. Apparatus according to claim 10 wherein said feed magnetic brush means includes a strong magnetic flux producing means whose lines of force extend substantially into said rollback of developer.

13. Apparatus according to claim 7 including an auxiliary magnetic means positioned subsequent to said magnetic means in the path of said insulating surface for removing ferromagnetic particles deposited on said insulating surface by said magnetic means and by said developer accumulated in said cavity.

14. Electrographic developing apparatus for use in applying toner to an electrostatic charge pattern carried on a moving insulating surface to form a toner pattern defined by said charge pattern, said apparatus comprising:

a reservoir for holding magnetic brush developer;

magnetic means for moving developer from said reservoir to a rollback cavity defined by portions of said magnetic means and said insulating surface and from said rollback cavity back to said reservoir, said means including:

a. feed magnetic brush means for moving developer from said reservoir into close proximity with said moving insulating surface and then into said rollback cavity; and

b. discharge magnetic brush means for moving developer from said rollback cavity into substantial contact with said moving insulating surface and then into said reservoir, said feed and discharge magnetic brush means each having:

1. magnetic flux producing means, and

2. a rotatable nonmagnetic cylinder, a portion of which cylinder is positioned within the influence of said magnetic flux producing means, said flux producing means being positioned to attract developer to the outer surface of said cylinder portion, said magnetic flux producing means being arranged in said feed magnetic brush means and said discharge magnetic brush means so that developer in said reservoir is attracted by the magnetic flux producing means of said feed magnetic brush means and held on its corresponding cylinder when rotated until said developer comes under the attraction of the magnetic flux producing means of said discharge magnetic brush means, said magnetic flux producing means of said discharge magnetic brush means being positioned to attract developer from said feed magnetic brush means to the cylinder of said discharge magnetic brush means and hold said developer on said cylinder as it rotates said developer into contact with said insulating surface and then returns it to said reservoir, means for rotating the cylinders of said magnetic brush means at predetermined peripheral rates said predetermined rates being so chosen relative to the movement of said insulating surface to create a substantial accumulation of tumbling developer in said cavity.

15. Apparatus according to claim 14 wherein the cylinders of said magnetic brush means are positioned so that at their closest points the outer surface of the cylinder of said feed magnetic brush means is farther from the insulating surface than the outer surface of the cylinder of the discharge magnetic brush means.

16. Apparatus according to claim 14 wherein said means for rotating the cylinders includes means to rotate the cylinder of said feed brush means at a faster peripheral speed than the peripheral speed of the cylinder of said discharge brush means.

17. Apparatus for developing an electrostatic image carried on a moving insulating surface comprising:

a trough for magnetic brush developer powder;

a first and second magnetic brush operatively located with respect to said trough, each brush having a rotatable nonmagnetic cylinder;

a series of stationary magnetic poles accurately spaced in cylindrical formation inside each cylinder and spaced from said cylinder;

portions of said first and second magnetic brushes being positioned relative to said moving insulating surface to define a rollback cavity therewith; and

means for rotating the cylinders of said magnetic brushes in a direction opposed to the movement of said insulating surface and at rates providing an accumulation of gently tumbling developer in said rollback cavity.

Disclaimer

3,543,720.—*Roger A. Drexler* and *Conrad Altmann*, Rochester, N.Y. APPARATUS FOR DEVELOPMENT OF ELECTROSTATIC IMAGES. Patent dated Dec. 1, 1970. Disclaimer filed Jan. 23, 1973, by the assignee, *Eastman Kodak Company.*

Hereby enters this disclaimer to claims 1 through 13 of said patent.

[*Official Gazette May 22, 1973.*]