

[54] **MAGNETIC BRUSH DEVELOPER SYSTEM**

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

[58] Field of Search 118/623, 636, 637, 118/640; 117/17.5; 355/3

[56]

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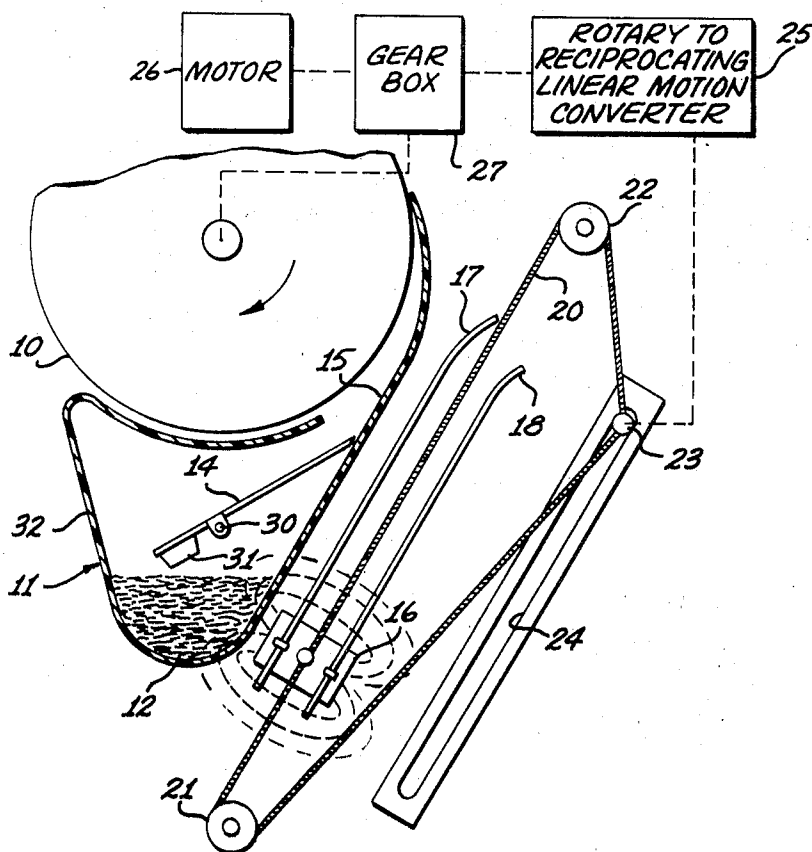
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[57]

ABSTRACT

Apparatus for applying dry toner to a surface bearing an electrostatic image is disclosed using a mixture of magnetic particles and toner in a trough having a wall extending upwardly and progressively close to the image surface. A magnet is moved upwardly parallel to that wall for carrying a quantity of the mixture into contact with the surface. A gate in the trough permits a quantity of fresh mixture to pass upwardly along the wall and the spent mixture to move downwardly over the gate to the opposite side of the trough.

10 Claims, 6 Drawing Figures



3 Sheets-Sheet 1

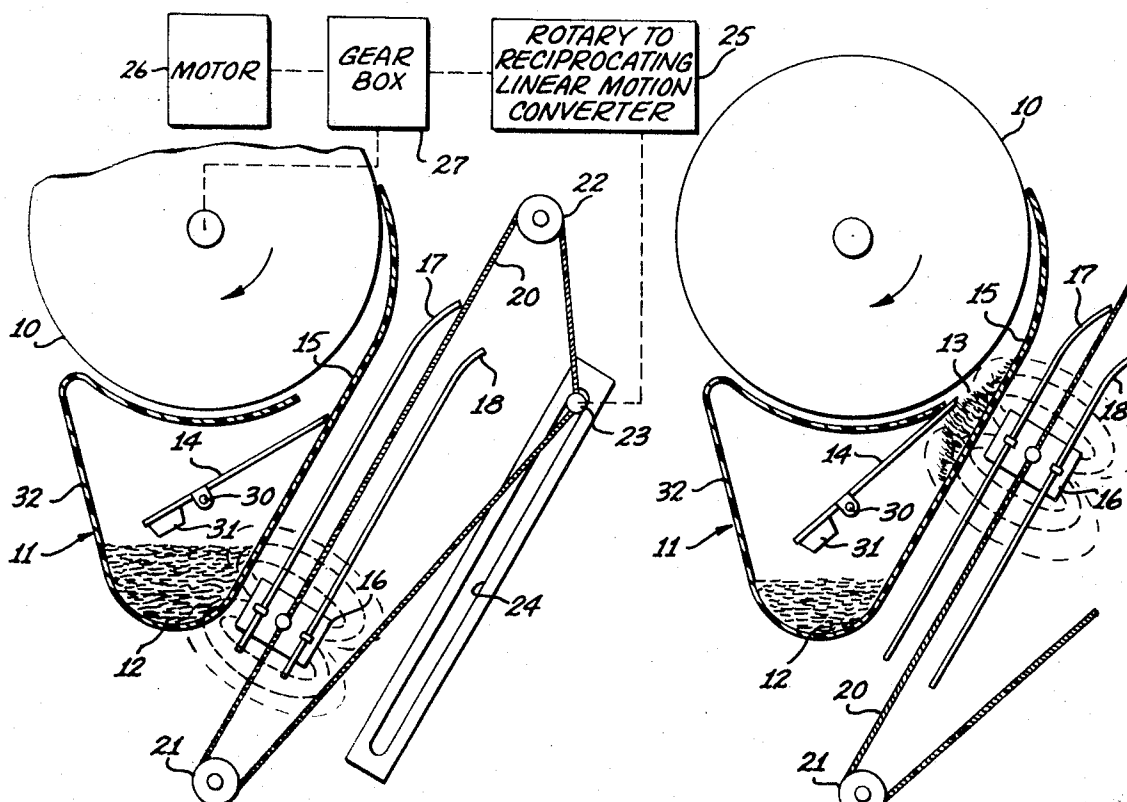


FIG. 1a

FIG. 1b

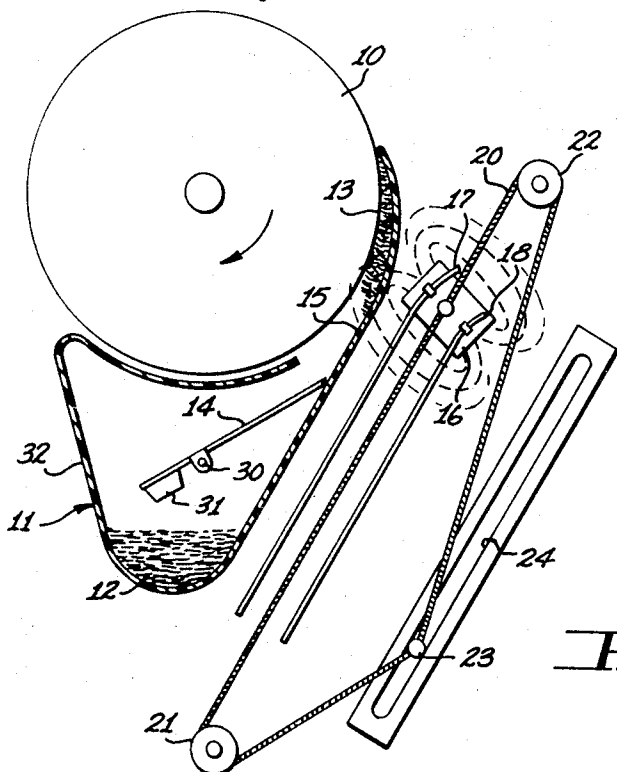


FIG. 1c

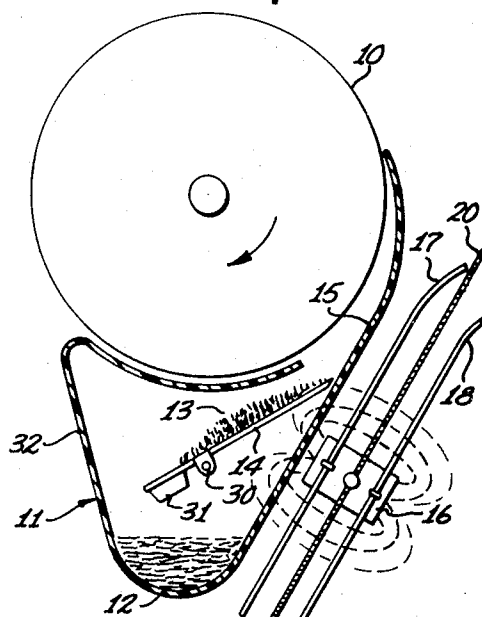


FIG. 1d

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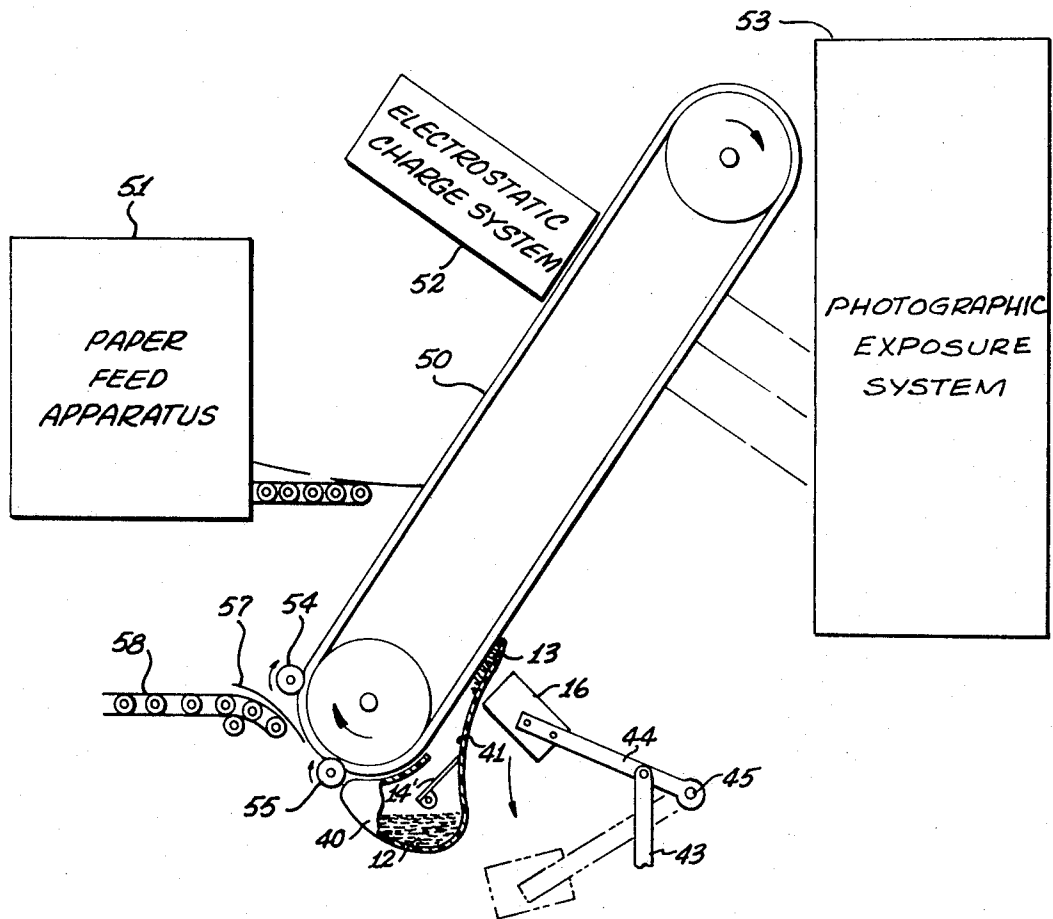


FIG. 3

MAGNETIC BRUSH DEVELOPER SYSTEM

BACKGROUND OF THE INVENTION

This invention relates to a mechanism for developing electrostatic images on a surface, and more particularly to a magnetic brush system for developing electrostatic images.

The usual technique for developing latent (electrostatic) images is to bring a developer mix into contact with the surface containing the latent image under the force of gravity, such as by flowing the developer mix over the surface. The mix consists of a developer powder or toner and a carrier comprised of relatively large particles of some material separated in the triboelectric series from the toner. The electrostatic charges produced by triboelectric effects of the carrier and toner hold the toner and carrier together.

The use of ferromagnetic particles as a carrier for ordinary toner has been suggested in combination with an elongated magnet to provide a magnetic brush for sweeping developer powder over the latent image. As the magnetic brush is swept across the image, and toner is attracted by the electrostatic charge of the image, the quantity of toner on the end of the brush is rapidly depleted. Therefore, the image cannot be developed uniformly, particularly if it is relatively large. In other words, as toner carried by the magnetic brush is used up, the density of the toner deposited on the charged surface of the latent image becomes progressively less. It would be desirable to provide a magnetic brush developer system that is easily replenished with toner and which will maintain a more uniform density of the toner against the plane of the image being developed as the brush is swept over that plane.

SUMMARY OF THE INVENTION

The present invention relates to a mechanism for developing electrostatic images on a surface using a magnetic brush to carry toner from a trough across the image using an elongated magnet. A mixture of carrier particles and toner is picked up to form a brush and the magnetic brush thus formed is moved upwardly and into contact with the plane of the latent image. After lifting a quantity of developer powder into contact with the plane of the image, with the longitudinal axis of the magnet parallel to that plane, the magnetic brush is moved progressively closer to that plane so that as developer powder is deposited on the latent image, the gap between the magnet and the image bearing surface is decreased to continually bring additional developer powder into closer proximity with the image bearing surface. Once the image bearing surface has been completely swept by the magnet, the remaining mixture of magnetic particles and toner is returned to the trough.

In accordance with a further feature of the present invention, the trough containing the supply of magnetic particles and toner is extended upwardly along the desired path of the magnetic brush for developing an electrostatic image such that the mixture is never in direct contact with the magnet. A gate normally closed against the extended sidewall of the trough is opened to allow a quantity of the mixture to be carried by the magnet up against the image bearing surface and then closed. The unused mixture is returned to the trough over the closed gate by either reversing the direction of the moving magnet so that it carries the mixture back or by removing the magnetic field and allowing the

force of gravity to move the mixture back into the trough. Since the gate is closed while the mixture is being returned to the trough, the used mixture is returned to the opposite side of the trough from which mixture is to be taken to form the magnetic brush for the next developing cycle, thus mixing and evenly distributing the toner through the mixture for the magnetic brush system as it is repeatedly used.

BRIEF DESCRIPTION OF THE FIGURES

FIGS. 1a to 1d illustrate diagrammatically the organization and operation of a first embodiment of the present invention for use with a conventional electrostatic image drum.

FIG. 2 illustrates diagrammatically the organization of a second embodiment of the present invention also for use with a conventional electrostatic image drum.

FIG. 3 illustrates diagrammatically the adaptation of the second embodiment of FIG. 2 to an electrostatic copying system using an electrostatic image paper.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1a to 1d of the drawings, a first embodiment of a magnetic brush system is disclosed for applying dry toner to a latent electrostatic image on a drum 10 indicated diagrammatically. The image is formed in a conventional manner by charging the surface of the drum uniformly at one station as it rotates, and then producing the electrostatic image by photographic exposure at a second station in advance of a third image-developing station. A fourth station is provided to transfer the developed image onto a sheet of paper. Only the third station is illustrated.

The magnetic brush system for developing electrostatic images consists of a trough 11 made of nonmagnetic material for holding a supply 12 of a mixture of toner and carrier. The toner consists of a dry nonmagnetic powder and the carrier consists of relatively large particles of magnetic material selected to have a substantial triboelectric effect on the dry nonmagnetic powder. In practice, any commercial toners in widespread use may be mixed with clean and dry iron particles because they are generally comprised of pigmented rosin particles, and a substantial triboelectric charge is produced on the rosin particles by the frictional effects of the iron particles in the mixture.

The trough is situated near the image drum 10 in order that a quantity 13 of mixture may be raised from the bottom of the trough past a gate 14 as shown in FIG. 1a up a side 15 which is initially straight and then curves upwardly and progressively closer to the image drum. This curved portion of the side 15 brings the quantity of mixture in contact with the image drum as that quantity is lifted progressively higher on the side of the trough. The initial contact will cause toner to be attracted by the opposite charge of the latent image on the drum, thus developing the image. As the image drum rotates in a direction opposite to the direction in which the quantity 13 is being lifted, a fresh supply of toner is continually brought in contact with the electrostatic image on the drum.

The quantity of mixture is lifted out of the trough by an elongated magnet 16 guided by a pair of rails at each end, such as rails 17 and 18 at the near end of the elongated magnet which has a length substantially equal to the length of the cylindrical drum 10. The trough,

which is shown in end view only like the drum and magnet, also has a length substantially equal to the length of the cylindrical drum. The trough also has end covers (not shown) which extend up the side 15.

The magnet is pulled up the rails by a cable 20 wrapped around pulleys 21 and 22. Both ends of the cable are connected to a pin 23 driven along a slot 24 by a rotary-to-reciprocating, linear motion converter 25. The converter is in turn driven by a motor 26 through a gear box 27 in synchronism with the drum. The gear box may include two gear trains in order to produce a plurality of cycles of the converter for one revolution of the drum.

The field of the magnet indicated by dotted lines will orient the magnetic particles of the mixture quantity lifted out of the trough to form a brush. This orientation improves as the quantity of the mixture is lifted to a higher point on the side 15 so that when in proximity to the surface of the image drum the magnetic particles are aligned almost normal to the side 15. To orient these magnetic particles in the best direction for developing, which is with the majority very nearly aligned normal to the side 15 in the upper curved portion, the guide rails are bent at their upper ends in a direction away from the drum to thus rotate the magnet about its longitudinal axis as shown in FIG. 1c.

As the magnet is driven back down the rails, the quantity 13 of mixture is returned to the trough over the gate 14 as shown in FIG. 1d. The gate, which extends the length of the trough is pivoted on a rod 30 and balanced by a weight 31 such that the gate will rest lightly on the side 15. In that manner the gate will open under slight force from the quantity of mixture being lifted and thereafter close so that the quantity of mixture being returned to the trough will be deposited near the side 32 of the trough remote from the magnet. That assures a fresh mixture for each cycle of operation. The toner may be replenished from time to time through a door (not shown) in the side 32. As the mixture is recirculated by the magnetic brush system, the added toner will be mixed in.

An alternative embodiment is shown in FIG. 2 wherein like components are referred to by the same numerals as in FIGS. 1a to 1d. It employs a trough 40 having a curved side 41 to allow the magnet 16 to follow a path which is a segment of a circle, rather than a straight line as with the previous embodiment. This may simplify the mechanism employed to produce the cyclic motion of the magnetic brush system. For example, the gear box may drive a cylinder 42 having at each end an arm 43 through which a force is applied to a bar 44 pivoted on a support rod 45. The cylinder 42 and arm 43 thus function as reciprocating crank means to drive the magnet 16 in the desired path. The cylinder 42 could be replaced by a disc or crank arm at each end of the magnet, but the mass of the solid cylinder is desired for smoother operation in the continuous mode, i.e. for continuous operation for more than one cycle.

The magnet is attached in a canted position relative to the bar 44 in order that the field of the magnet orient the magnetic particles in the best direction for developing the latent image on the drum, which is in a position where the flux lines of the magnet between the upper end of the side 41 and the drum are nearly in line with the radius of the drum to place the "bristles" of the magnetic brush in an upright position with respect to the drum surface at the upper end of the quantity 13.

The orientation at the lower end of the quantity is less important because, owing to the direction of rotation of the drum, a given segment of the image will have been fully developed before that lower end of the quantity is proximate that given segment. In that respect, the second embodiment is the same as the first. The principal difference is a curved side for the trough to permit the path of the magnet to follow a segment of a circle.

Another feature of the second embodiment is a mechanically actuated and synchronized gate 14'. A cam 47 and cam follower 48, actuate a lever 49 to open the gate while a quantity of mixture is being lifted upwardly. At all other times it is closed firmly against the side. Like the trough, the gate assembly (gate and post or rod) is made of nonmagnetic material. For example, the trough may be formed from plastic material while the gate assembly may be made from brass.

FIG. 3 illustrates an adaptation of the features described with reference to the first and second embodiments to an electrostatic copying system using an electrostatic image paper deposited on an endless belt 50 by conventional paper feed apparatus and held onto the belt by air suction. For that purpose, the belt could be made of parallel endless tubes with passages from one to the other and passages from an end tube to an air pump through flexible hoses. The air pump would draw sufficient air through holes in the tubes on the outer side of the belt to hold a sheet of paper as it passes under an electrostatic charge system 52, a photographic exposure system 53 and the magnetic brush developing system. Pinch rollers 54 and 55 isolate a section of the endless belt from the air pump to allow the developed sheet of paper to be released. A guide 57 deflects the released sheet onto a conveyor belt 58 which passes the developed sheet through a heating station (not shown) where the developed image is fixed on the paper by heat and pressure.

The arrangement for this adaptation of the second embodiment of the invention to an electrostatic copying system using image paper has been shown only diagrammatically because, as in the first and second embodiments, what is considered to be the invention is a new and improved magnetic brush system for developing electrostatic images, whether it be on a drum for later transfer to a sheet of paper, or on the sheet of paper itself. Accordingly, it is to be understood that additional embodiments and modifications which will be obvious to those skilled in the art are included within the spirit and scope of the invention. For example, the magnet may be an electromagnet which is energized at appropriate times through a cam actuated switch synchronized with the drive mechanism for the magnet.

As an illustration, the magnet may be energized throughout a given cycle until it returns to the top of the closed gate, allowing gravity to carry the returned mixture to the bottom of the trough. As another example, the magnet may be driven in a circular path, relying completely on gravity to return the quantity of mixture to the trough. In the case of an electromagnet, the magnet may be deenergized at the appropriate time to allow gravity to take over control of the quantity early, thereby obviating any tendency to jam or pack mixture at the upper end of the trough's side.

Inasmuch as it is recognized that modifications and variations falling within the spirit of the invention will occur to those skilled in the art, it is not intended that the scope of the invention be determined by the dis-

closed exemplary embodiments, but rather should be determined by the breadth of the appended claims.

What is claimed is:

1. Apparatus for applying dry toner to a moving surface bearing an electrostatic image comprising
 - a trough for holding a mixture of dry toner and magnetic carrier particles, said trough having a wall extending upwardly and progressively closer to said image surface, said wall being a continuous extension of the bottom portion of said trough and said wall having its upper end portion curved in a direction toward said image bearing surface, and said trough being filled to a level insufficient to be in contact with said image bearing surface,
 - means for providing a magnetic field outside of said trough, and
 - means for moving said magnetic-field means upwardly parallel to said wall for lifting a quantity of said mixture from said trough and carrying it upwardly along said wall into progressively closer contact with said image surface, said magnetic field means being oriented with flux lines thereof approximately normal to said image surface while said quantity of mixture is in contact with said image surface.
2. Apparatus as defined in claim 1 including means within said trough for permitting said quantity of mixture lifted from said trough by said magnetic-field means to pass upwardly along said wall from a position of rest near the bottom of said trough, and for thereafter causing said quantity of mixture to pass downwardly along a path diverging from said wall.
3. Apparatus for applying dry toner to a surface bearing an electrostatic image to develop the image comprising
 - means for moving said surface past a developing station in a given direction with said surface exposed for receiving toner from below,
 - a trough at said station for holding a mixture of dry toner and carrier particles, said particles being of magnetic material separated in the triboelectric series from said toner, said trough being positioned below said surface and having a wall extending upwardly and outwardly in a direction opposite the direction of motion of said surface, said wall converging at its upper end portion toward but never in contact with said surface, said trough being made of non-magnetic material,
 - a mixture in said trough, said trough being filled with said mixture to a level insufficient to be in contact with said image bearing surface,
 - means for providing a magnetic field outside of said trough, and
 - means for moving said magnetic field means upwardly and outwardly along a path substantially parallel to said wall of said trough in a direction opposite the direction of motion of said surface with flux lines of said field passing through said wall approximately normal to said wall, to thereby move a quantity of said mixture upwards along said wall and against said surface.
4. Apparatus as defined in claim 3 including
 - a substantially flat and rigid sheet of non-magnetic material disposed between said wall and said image bearing surface,
 - means for supporting said sheet for rotation about an axis parallel to said wall and to the bottom of said

trough at a distance from said wall to function as a gate, said sheet having its upper edge above said axis,

means for causing said sheet to rotate to a position which places its upper edge away from said wall to allow said quantity of mixture to be moved upwardly along said wall as said magnetic field producing means moves upwardly and outwardly along said path substantially parallel to said wall, and for causing said sheet to rotate back to a position which places its upper edge proximate said wall after said quantity of mixture has cleared said upper edge as it is moved upwardly, thereby causing said mixture to be returned to the bottom of said trough on a side of said trough remote from said wall after said image has been developed.

5. Apparatus as defined in claim 4

wherein said wall of said trough includes a first substantially flat portion extending from near the bottom of said trough to a point near said surface, and a second portion curved upwardly to cause said wall to converge toward said surface, and

wherein said means for moving said magnetic field producing means comprises means for guiding said magnetic field producing means along said path substantially parallel to said flat portion of said wall, and drive means for moving said field producing means upwardly on said guiding means and then downwardly on said guiding means in synchronism with said image surface moving means.

6. Apparatus as defined in claim 5 wherein said means for guiding said magnetic field producing means includes a portion at the upper end thereof for guiding said field producing means slightly away from said surface along a curved path, thereby causing said magnetic field producing means to orient the flux lines thereof, and thereby orient carrier particles of said mixture more nearly normal to said surface for optimum transfer of toner to said electrostatic image after said quantity has come in contact with said surface.

7. Apparatus as defined in claim 6

wherein said image surface moving means includes a motor and gear means for coupling said image surface to said motor, and

wherein said drive means for moving said field producing means includes means connected to said gear means for converting rotary motion to reciprocating linear motion, and means for translating said linear motion to said field producing means.

8. Apparatus as defined in claim 4

wherein said wall of said trough extending upwardly and outwardly has a complex curvature including a first curvature from near the bottom of said trough to near said surface, said first curvature having a fixed radius from a point outside of said trough, and a second curvature extending upwardly from said first curvature, the direction of said second curvature being toward said surface, said second curvature thus causing said wall to converge toward said surface, and

wherein said means for moving said magnetic field producing means comprises support bars pivoted at said point of said radius of said first curvature, drive means for swinging said bars to cause said magnetic field producing means to move upwardly in an arc along said first curvature and to a position past the end of said first curvature, and means for

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synchronizing said drive means with motion of said surface.

9. Apparatus as defined in claim 8 wherein said image surface is the surface of a cylinder, and motion of said surface is produced by a motor coupled to said cylinder by gear means, and wherein said drive means for swinging said bars is synchronized with said cylinder through said gear means.

10. Apparatus for applying dry toner to a moving surface bearing an electrostatic image comprising a trough for holding a mixture of dry toner and magnetic carrier particles, said trough having a wall extending upwardly and progressively closer to said image surface, said wall extending both upwardly and outwardly, and having a complex curvature including a first curvature having a fixed radius from a point outside of said trough, and a second curva-

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ture extending upwardly from said first curvature, the direction of said second curvature being opposite said first curvature, and said trough being filled to a level insufficient to be in contact with said image bearing surface,

means for providing a magnetic field outside of said trough, and

means for moving said magnetic-field means upwardly parallel to said wall for lifting a quantity of said mixture from said trough and carrying it upwardly along said wall into progressively closer contact with said image surface, said magnetic field means being oriented with flux lines thereof approximately normal to said image surface while said quantity of mixture is in contact with said image surface.

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