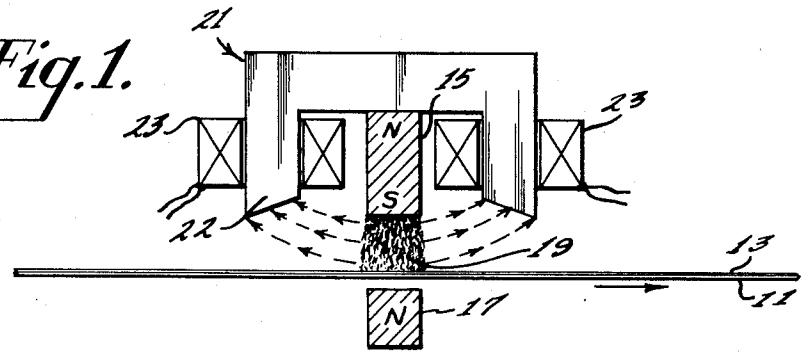
March 29, 1960 E. C. GIAIMO, JR 2,930,351

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

Filed Sept. 4, 1956 2 Sheets-Sheet 1

Fig. 1.



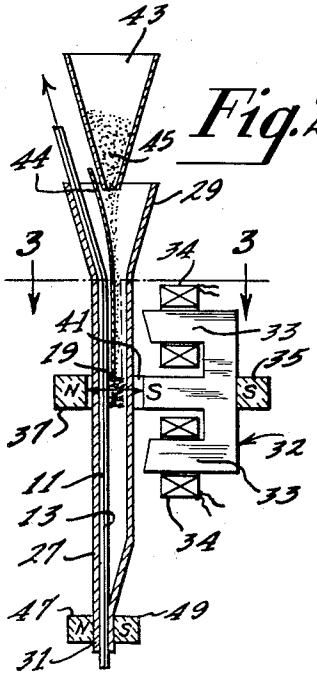
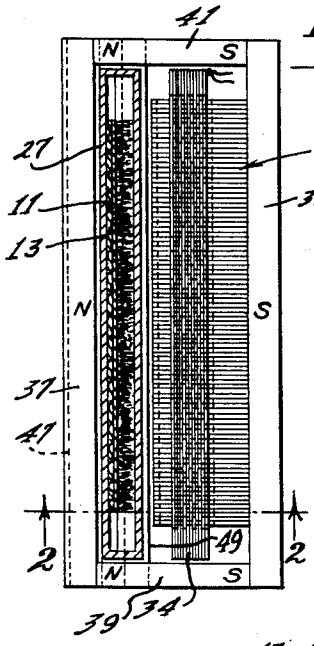


Fig. 2.

Fig. 3.



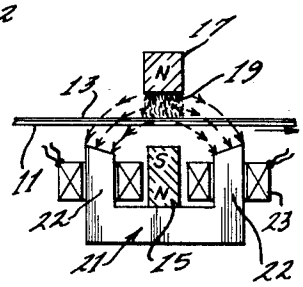


Fig. 4.

Fig. 5.

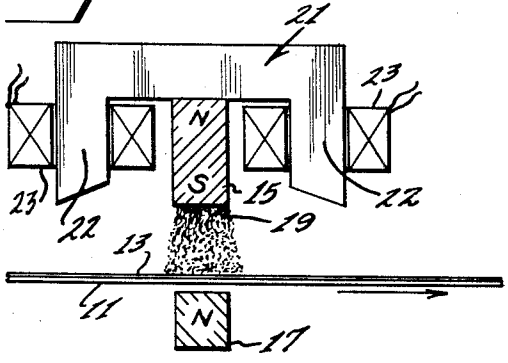
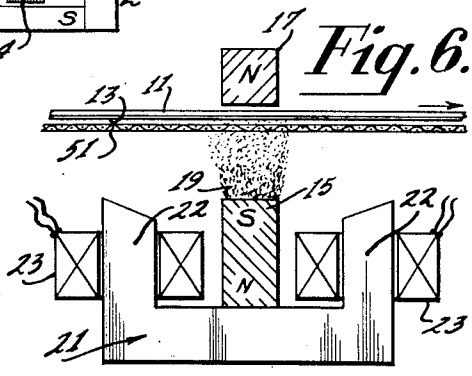


Fig. 6.



INVENTOR.
Edward C. Giaimo, Jr.
BY Morris Pakula
ATTORNEY.

March 29, 1960 E. C. GIAIMO, JR 2,930,351

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

Filed Sept. 4, 1956 2 Sheets-Sheet 2

Fig. 7.

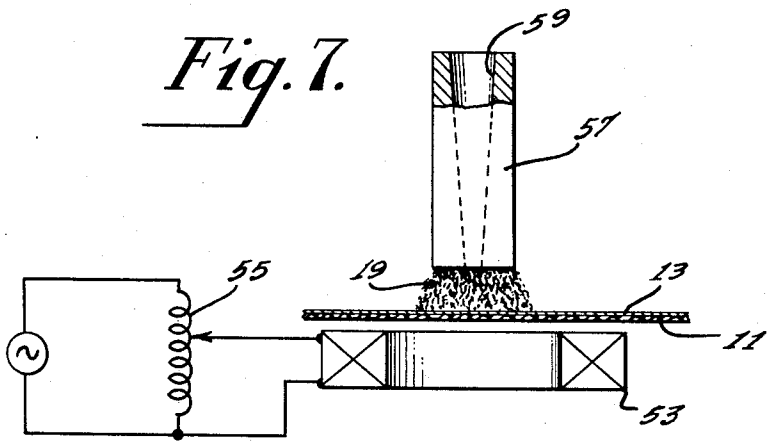
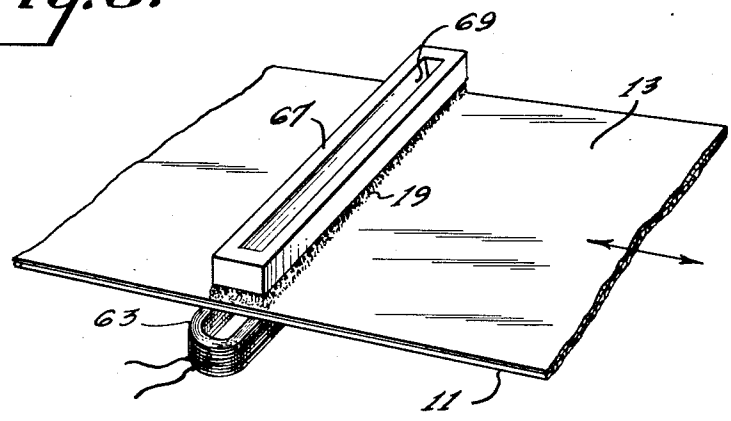


Fig. 8.



INVENTOR.
Edward C. Giaimo, Jr.
BY Morris A. Pabst
ATTORNEY.

United States Patent Office 2,930,351
Patented Mar. 29, 1960

2,930,351

APPARATUS FOR DEVELOPING ELECTROSTATIC IMAGE

Edward C. Giaimo, Jr., Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Application September 4, 1956, Serial No. 607,689

8 Claims. (Cl. 118—637)

This invention relates to electrostatic printing, and more particularly to novel methods and means for developing a surface bearing an electrostatic charge image.

In a typical electrostatic printing process, a sheet or web on which a print is to be made is provided with coating of a photoconductive insulating material on one surface. An electrostatic charge is applied uniformly to the photoconductive surface and the charged surface is then exposed through a transparency, the charge bleeding off the surface where it is exposed to light. There remains, then, a latent charge image. The charge image is developed by contacting the surface with an electroscopic developer powder having a charge opposite to that of the surface, the powder adhering to the surface where it is exposed to light. There remains, then, a latent charge image. The charge image is developed by contacting the surface with an electroscopic developer powder having a charge opposite to that of the surface, the powder adhering to the surface in conformity with the charge image. The developed image is then fixed by heating, for example. The developer powder is mixed with magnetic carrier particles to form a magnetic developer mix. The mix is carried by a magnetized member providing a magnetic field which forms a brush of the developer mix. This brush is engaged with the image bearing surface and the developer powder particles are drawn from the brush due to the electrostatic attraction.

An object of this invention is to provide improved and novel methods and means for presenting electroscopic developer powder adjacent to a charged image bearing surface and for releasing the powder to the surface.

Another object of this invention is to provide improved and novel methods and means for agitating a magnetic brush formed from a mixture of magnetic carrier particles and developer particles to affect release of the developer particles.

A further object of this invention is to provide novel and improved methods and means for producing a cloud of developer powder for development of a latent electrostatic image.

A still further object of this invention is to provide an improved and novel magnetic means for producing a powder cloud from a magnetic brush formed of a mixture of magnetic carrier particles and developer particles.

In accordance with the present invention, a magnetic brush comprising a mass of magnetic carrier particles and developer powder particles is formed under the influence of a unidirectional magnetic field. An alternating magnetic field is provided having flux lines which intersect the flux lines of the unidirectional magnetic field in the area of the magnetic brush. The two fields, acting together, agitate the brush causing the developer powder particles to be released from the magnetic brush. This facilitates attraction to a charged surface. The magnetic brush may be in actual contact with the charged surface or it may be spaced from the charged surface wherein a cloud of developer powder particles are released from the brush for deposit on the surface. The released toner

particles may be released in the area of a mesh screen for grading or sifting of the particles prior to deposit on a charged surface.

The novel features of the invention, as well as additional objects and advantages thereof, will be understood more fully from the following description when read in connection with the accompanying drawing, in which:

Figure 1 is a diagrammatic sectional view of an apparatus embodying the present invention in one form;

Figure 2 is a sectional view in elevation of apparatus embodying the present invention in modified form;

Figure 3 is a sectional view in plan taken on the line 3—3 of Figure 2 looking in the direction of the appended arrows;

Figure 4 is a diagrammatic sectional view illustrating another modified arrangement of an apparatus embodying the invention;

Figure 5 is a diagrammatic sectional view illustrating a modified arrangement of the apparatus of Figure 1;

Figure 6 is a diagrammatic sectional view of a further modification of apparatus embodying the invention;

Figure 7 is a sectional view of a still further modification of apparatus embodying the present invention; and

Figure 8 is a perspective view of a modified form of the apparatus of Figure 7.

Referring now in more detail to the accompanying drawing, Figure 1 illustrates one form of apparatus in accordance with the present invention. A sheet or web **11** carrying an insulating photoconductive layer or surface **13** is moved through a path defined in the apparatus in the direction of the arrow. A pair of magnetic pole pieces **15** and **17** are disposed on opposite sides of the path and oppose each other. The pole piece **15** is polarized to have a south magnetic pole adjacent to the photoconductive surface **13**. A mass of magnetic developer mix **19** is maintained on the face of the pole piece **15**, facing the photoconductive surface, by the magnetic field of the pole piece. The developer mix **19** is an intimate mixture of magnetic carrier particles and developer powder particles. The developer powder, which will hereafter be called toner, includes colored particles and preferably includes plastic particles which will be softened upon the application of heat to fix the toner to the surface **13**. The pole piece **17** is polarized to have a north magnetic pole adjacent to the sheet **11** so that a unidirectional magnetic field is provided between the pole pieces. The magnetic flux lines are substantially parallel between the two pole pieces and hence confine the mass of developer mix to form a magnetic brush which sweeps the surface **11** as it is moved with respect to the brush.

In the electrostatic printing process, the photoconductive surface is charged uniformly so that it retains, for a time, either a positive or a negative surface charge. The charged surface is immediately exposed through a transparency, for example, and portions of the charge are bled off the surface where it is exposed to light to form a latent charge image corresponding to the image of the transparency. If it is assumed that the surface charge is a negative charge, the carrier and toner are chosen, with regard to the triboelectric series, so that when the particles are mixed the toner particles will assume a positive charge and the carrier particles a negative charge.

When the magnetic brush **19** is then contacted with the charged surface **13**, the positively charged toner particles are attracted away from the carrier particles and adhere to the charged portions of the surface **13**. The charged surface is then developed by the toner and this development may be made permanent by fixing the toner through the application of heat.

In developing a charged surface with a simple brushing action, as above described, only the toner particles which are held in the magnetic brush near the charged

surface of the sheet are freed from the magnetic brush to participate in the development. This means that a large percentage of the toner held in the brush is not useful in the development process. It is desirable then to provide a means to permit a substantial portion of the toner particles held in the brush to assist in the development process. This is accomplished, in accordance with the present invention, by providing an alternating magnetic field, the flux lines of which intersect the flux lines of the unidirectional magnetic field provided by the pole pieces 15 and 17 in the area of the magnetic brush. One form of apparatus for providing this alternating field, comprises a U-shaped laminated magnetic core 21, the vertical legs 22 of which extend downwardly on either side of the pole piece 15. Each of the core legs 22 carries a coil 23, the coils being connected together to induce a flux flow through the core in one direction (at a particular instant) and being connected to a source of alternating current (not shown) for the purpose of alternating the flow of magnetic flux through the core. The alternating current may be a 60 cycle current, for example.

The combination of the unidirectional field and the alternating field produces a turbulence or agitation within the brush and effectively reduces the attraction between the carrier particles and the toner particles so that more of the toner is released to be attracted to the charged surface and participate in the development of the surface. It is believed that the magnetic particles of the brush are themselves polarized and tend to align themselves along the flux lines of the unidirectional field. When the alternating field is then applied, the particles tend to oscillate to become aligned with the flux lines of the alternating field to produce the agitation. The brush remains substantially confined within the unidirectional field, as it would be without the application of the alternating field, but is more efficient in presenting more of the toner to participate in the development of the image. The intensity of the agitation may be varied by regulating the amount and frequency of the alternating current.

Figures 2 and 3 of the accompanying drawing illustrate a modified form of apparatus in accordance with the invention and including a magnetic structure similar to that above described. The apparatus comprises a trough 27 which, when viewed from the top, is narrow and elongated. The top portion 29 of the trough is flared outwardly, as viewed from an end, to facilitate the introduction of toner into the trough. The bottom portion 31 of the trough is substantially closed, having a slot just wide enough to permit the passage of a coated web 11. The web 11 is caused to move (by means not shown) in a direction upwardly through the trough as indicated by the arrow. The upward direction is preferable for reasons which will become apparent.

The width of the trough, in its intermediate portion, is substantially wider than the thickness of the web 11 in order to permit the formation of a brush of developer mix 19 within the trough.

The structure for providing the magnetic fields includes a plurality of E-shaped laminations stacked in a horizontal direction to provide a core 32 which extends substantially across a side of the trough 27. The core is disposed so that the end faces of the three legs face the side of the trough 27 and lie adjacent thereto. A magnetic pole piece 35 lies contiguous to the core 33 opposite from the central core leg. A magnetic pole piece 37 is disposed on the opposite side of the trough 27 and opposes the central leg of the pole piece 35. The two pole pieces 35 and 37 extend beyond the length of the core 32 and the trough 27 and are connected at either end of the trough by permanent magnets 39 and 41. The magnets are arranged so that their ends, polarized south, lie adjacent the pole piece 35 and their ends, polarized north, lie adjacent the pole piece 37. The end of the central leg of the core 32 adjacent the trough 27 is then polarized south by induction from the pole piece 35. This magnetic structure then provides a unidirectional magnetic field passing through the trough 27 and extending substantially the full length of the trough to bridge the width of a web 11 passing through the trough.

The outer legs 33 of the core 32 carry coils 34 arranged and connected in the manner described with reference to Figure 1 to provide an alternating magnetic field. A magnetic brush 19 of carrier particles is formed within the trough and is maintained in the unidirectional magnetic field. The web 11 is moved along one surface of the trough with its photoconductive surface 13 facing inwardly so that the surface is swept by the magnetic brush as the web is drawn through the trough.

A hopper 43 is disposed above the trough and partially within the upper flared portion 29. The hopper contains a supply of toner 45 and dispenses the toner uniformly across the length of the trough. A barrier 44 extends across the length of the trough and downwardly from the hopper to the area of the magnetic brush 19. This barrier keeps the toner being dispensed from contacting the upwardly moving sheet 11 which has already been developed. As the toner is dropped into the trough, it is retained by the magnetic brush and the agitation of the brush provides intimate mixing of the carrier and toner particles to provide the desired electrostatic charge on the toner particles in the manner previously described. The charged toner particles are then attracted to the charged surface of the web 11 as it moves through the trough to develop the latent image thereon. Assuming a continuous developing process, the toner is dispensed into the brush at a uniform rate corresponding to the rate at which the toner is attracted to the surface.

The carrier particles normally will be maintained in the area defined by the unidirectional field, however a magnetic trap is provided at the bottom of the trough to prevent any carrier particles from dropping out of the trough. This trap comprises magnetic pole pieces 47 and 49 disposed on opposite sides of the bottom portion 31 of the trough and connected by suitable magnetic structure to provide an additional unidirectional field through the trough. Any carrier particles which drop in this area are trapped by this field. The provision for the upward movement of the web through the trough aids in preventing excess developer mix particles from being withdrawn from the trough at the bottom.

Figure 4 of the accompanying drawing illustrates, diagrammatically, another modified arrangement of apparatus in accordance with the invention wherein the alternating field producing the core structure is disposed on the side of the web opposite from the magnetic brush. The web 11, having a photoconductive upper surface 13, moves in a horizontal direction as indicated by the arrow. The magnetic brush 19 is maintained on the lower surface of an upper pole piece 17 adjacent the photoconductive surface 13. A lower pole piece 15 opposes the upper pole piece 17 on the opposite side of the web and the magnetic field produced by the two pole pieces confines the unidirectional magnetic field which maintains the magnetic brush 19. A U-shaped core 21 has its vertical legs 22 extending upwardly on either side of the pole piece 15. Each of the legs 22 carries a coil 23, the coils being connected as previously described. The alternating field produced by the coils 23 passes through the web 11 so that its flux lines intersect the flux lines of the unidirectional field in the area of the magnetic brush to produce the desired agitation. The advantage of this arrangement is that most of the magnetic structure is positioned on the side of the sheet away from the magnetic brush to facilitate the supplying of toner to the magnetic brush.

Figure 5 of the accompanying drawing illustrates a modified arrangement of the apparatus of Figure 1 wherein the magnetic brush supporting structure is spaced from the photoconductive surface **13** to permit the formation of a magnetic brush which does not physically engage he photoconductive surface **13**. The magnetic brush is again maintained by pole pieces **15** and **17** and the alternating magnetic field is provided by means of a U-shaped core **21** and coils **23**. By adjusting the geometry of the developing apparatus and the intensity of both the unidirectional and the alternating fields, it is possible to obtain a cloud of toner particles. The magnetic brush is agitated to such an extent that the toner particles are physically thrown from the magnetic brush and are then readily attracted to the charged surface **13**. With powder cloud development, a print can be obtained which is superior from the standpoint of half tone definition. Since the toner particles are freed from their bond with the carrier particles, they are much more sensitive to variations of charge on the surface **13** and will more accurately develop the charge image with respect to the variations of charge density in the image. A further advantage of this type of development is that the surface charge need not be as strong since it is not necessary to pull the toner particles away from the carrier particles. By making the structure adjustable to either engage the brush with surface **13**, as in Figure 1, or to position the brush away from the surface **13**, as in Figure 5, the apparatus may be utilized to take advantage of either powder cloud development or brush development. In the brush development, large printed areas are developed more densely than with the powder cloud development.

Figure 6 of the accompanying drawing illustrates a further modification of apparatus embodying the present invention for powder cloud development. In this arrangement the sheet **11** is carried in a horizontal direction with its photoconductive surface **13** facing downwardly. The pole piece **15** and the core **21** and coils **23** are disposed beneath the sheet **11** facing the coated surface. The magnetic brush **19** is maintained on the pole piece **15** which is opposed by the pole piece **17** positioned above the sheet **11**. A screen **51** is positioned between the pole piece **15** and the photoconductive surface **13**. This screen is of a desired mesh size allowing only toner particles of a certain maximum size to pass through the screen in the form of a cloud and be deposited on the surface **13**. The apparatus is preferably arranged inverted, as shown, to prevent clogging of the screen by larger toner particles. It is particularly advantageous to screen the toner particle size for the development of prints having fine lettering or where accurate edge definition is important. Such a technique is useful in the manufacture of printed circuits and printing plates.

Figure 7 of the accompanying drawing illustrates a still further modification of apparatus embodying the invention for either magnetic brush development or powder cloud development. In this arrangement, the sheet **11** is disclosed in a horizontal plane with its photoconductive surface **13** facing upwardly. A flat coil **53**, which may have a toroidal configuration, is disposed beneath the sheet **11** of a plane parallel to the sheet so that a portion of the magnetic flux lines pass upwardly through the sheet. The coil **53** is connected to a source of alternating current through a control **55** for varying the intensity of the alternating magnetic field. A pole piece **57**, which may be in the form of a bar magnet, is disposed above the sheet over the coil **53**. The carrier particles of the magnetic brush **19** are maintained on the polarized end of the pole piece **57** adjacent the sheet **11**. The pole piece is provided with a vertically extending aperture **59** extending completely through the pole piece. This aperture is provided for supplying developer powder to the magnetic brush during development to replace the powder that is deposited on the sheet.

With this arrangement the flux lines of the unidirectional magnetic field created by the pole piece **57** and of the alternating magnetic field produced by the coil **53** will be intersecting in the area of the magnetic brush **19** since, in each case, the flux lines diverge as they extend away from their respective field sources. It will be apparent that the pole piece **57** may be spaced from the sheet **11** to provide either contact development or powder cloud development of the surface **13**.

Figure 8 of the accompanying drawing illustrates a modified form of the apparatus of Figure 7. In this arrangement, means are provided for moving a coated web **11** along a horizontal path. A rectangular coil **63**, connected to a source of alternating current, is disposed beneath the web **11** having its longitudinal dimension extending perpendicular to the direction of movement of the web **11**. A rectangular pole piece **67** lies above the web **11** in vertical alignment with the coil **63**. Both the coil **63** and the pole piece **67** are of sufficient length to bridge the width of the web **11**. A magnetic brush **19** is maintained on the lower face of pole piece **67**, which is again spaced from the surface **13** of the web **11** to provide for either contact or powder cloud development of the surface. The flux lines of the unidirectional and alternating magnetic field intersect in the area of the brush **19** to produce the desired agitation in the brush. The pole piece **65** is provided with an elongated slot **69** which extends vertically through the pole piece and is of sufficient length to bridge the width of the web **11**. The aperture **69** is provided to permit the feeding of non-magnetic toner particles to the magnetic brush to replace the toner particles which are deposited on the surface **13** as the web passes through the apparatus. Figure 8, then illustrates another form of apparatus which may be mechanized for continuous operation.

An advantage of all of the arrangements described above is that the development of the charged image is accomplished by smaller toner particles. It appears that the larger toner particles, probably due to their greater mass, are thrown further from the brush and are not as strongly attracted to the charged surface. The smaller particles, more readily attracted to the charged surface, develop the surface and the larger particles, when they do deposit on the surface, do not participate in the development and may be readily removed from the surface prior to the fixing of the image.

What is claimed is:

1. In apparatus for developing a surface bearing an electrostatic charge image, means for supporting a member having an electrostatic image bearing surface, means providing a unidirectional magnetic field having flux lines passing through a member supported by said first named means, means for presenting a quantity of magnetic developer mix in an area acted upon by said unidirectional magnetic field adjacent to the image bearing surface of a member supported by said first named means, said developer mix including magnetic carrier particles adapted to be maintained and supported in a loose mass under the influence of said unidirectional magnetic field, and means providing an alternating magnetic field having flux lines intersecting the flux lines of said unidirectional field in said area, said alternating magnetic field being adapted to agitate said quantity of developer mix supported in said unidirectional magnetic field.

2. In apparatus for developing a surface bearing an electrostatic charge image, means defining a path for a member having an electrostatic image bearing surface, means providing a unidirectional magnetic field having flux lines passing through a portion of said path, means for presenting a quantity of magnetic developer mix adjacent to said path portion to be acted on by said unidirectional magnetic field, said developer mix including magnetic carrier particles adapted to be maintained and sup-

ported in a loose mass under the influence of said unidirectional magnetic field, and means providing an alternating magnetic field having flux lines intersecting the flux lines of said unidirectional field adjacent to said portion of said path, said alternating magnetic field being adapted to agitate said quantity of developer mix supported in said unidirectional magnetic field.

3. In apparatus for developing a surface bearing an electrostatic charge image, means defining a path for a member having said charged surface, means providing a unidirectional magnetic field transversely bridging said path in one area thereof and having flux lines passing through said path, a quantity of magnetic carrier particles supported and maintained in the form of a brush adjacent to said path under the influence of said unidirectional magnetic field, means providing an alternating magnetic field having flux lines intersecting the flux lines of said unidirectional magnetic field adjacent to said one area of said path, means for supplying developer powder particles to said brush for intimate mixture with the carrier particles thereof, and said magnetic fields agitating said brush to release said developer powder particles for deposit on the image bearing surface of a member lying in said path.

4. In apparatus for developing a surface bearing an electrostatic charge image, means defining a path for a member having said charged surface, means comprising a pair of magnetic pole pieces opposing each other on opposite sides of said path and transversely bridging said path, means for magnetizing said pole pieces to provide a unidirectional magnetic field having flux lines passing through said path, means for maintaining and supporting a mass of developer powder particles and magnetic carrier particles adjacent to said path under the influence of said unidirectional field, and means providing an alternating magnetic field having flux lines intersecting the flux lines of said unidirectional field adjacent to said path.

5. In apparatus for developing a surface bearing an electrostatic charge image, means defining a path for a member having said charged surface, a first magnetic system comprising a pair of magnetic pole pieces opposing each other on opposite sides of said path, a second magnetic system including opposed pole faces defining an air gap in the plane of said pole pieces, said pole pieces and said pole faces bridging said path in a direction transverse to said path, means producing a unidirectional magnetic field between said pole pieces, means producing an alternating magnetic field between said pole faces, and means associated with one of said pole pieces for supporting and maintaining a mass of magnetic developer mix in the form of a brush adjacent said path for engagement with a charged surface of a member lying in said path.

6. In apparatus for developing a surface bearing a latent electrostatic charge image, means defining a path for a member having said charged surface, a magnetic system for producing a unidirectional magnetic field having flux lines passing through a segment of said path, means for maintaining and supporting a mass of magnetic developer mix in the form of a brush adjacent to and spaced from said path segment under the influence of said unidirectional field, a magnetic system for providing an alternating magnetic field having flux lines intersecting the flux lines of said unidirectional field in the area of said brush, and a screen disposed intermediate said brush maintaining means and said path for preventing developer particles of larger size from being deposited on the surface of a member lying in said path.

7. Apparatus for developing a surface bearing an electrostatic charge image comprising means for supporting a member having an electrostatic image bearing surface, magnetic means providing a unidirectional magnetic field for directing magnetic flux to intersect a member supported by said first named means, means for presenting a quantity of magnetic developer mix adjacent to said image bearing surface in the field of said magnetic means, said developer mix including magnetic carrier particles maintained and supported in a loose mass under the influence of said unidirectional magnetic field, a flat coil disposed with respect to a member supported by said first named means so as to be on the side of said member opposite to and opposing said magnetic means, connection means for supplying alternating current to said flat coil whereby said coil produces an alternating magnetic field directed toward a member supported by said first named means, the flux lines of said alternating magnetic field being directed to intersect the flux lines of said unidirectional field adjacent to a member supported by said first named means.

8. Apparatus for developing a surface bearing an electrostatic charge image comprising means for supporting a member having an electrostatic image bearing surface, magnetic means providing a unidirectional magnetic field for directing magnetic flux perpendicularly to a member supported by said first named means, means for presenting adjacent to said image bearing surface a quantity of developer mix including electroscopic developer powder and magnetic carrier particles for mixing with developer powder to serve as a carrier therefor, said developer mix being supported and maintained in a loose mass under the influence of said unidirectional magnetic field, a flat coil disposed with respect to a member supported by said first named means so as to be on the side of said member opposite to and opposing said magnetic means, means for connecting said flat coil to an alternating current source whereby said coil produces an alternating magnetic field directed toward a member supported by said first named means, and the flux lines of said alternating magnetic field being directed to intersect the flux lines of said unidirectional magnetic field in the area of said mass of developer mix whereby said mass is agitated.

References Cited in the file of this patent

UNITED STATES PATENTS

1,218,916	Weatherby	Mar. 13, 1917
1,657,405	MacLaren	Jan. 24, 1928
2,174,328	Meston et al.	Sept. 26, 1939
2,184,348	Kirchner et al.	Dec. 26, 1939
2,470,889	Drescher	May 24, 1949
2,786,439	Young	Mar. 26, 1957

OTHER REFERENCES

Young et al.: "Electrofax" Direct Electrophotographic Printing on Paper, R.C.A. Review, Dec. 1, 1954, pp. 469–472 and 479–481.