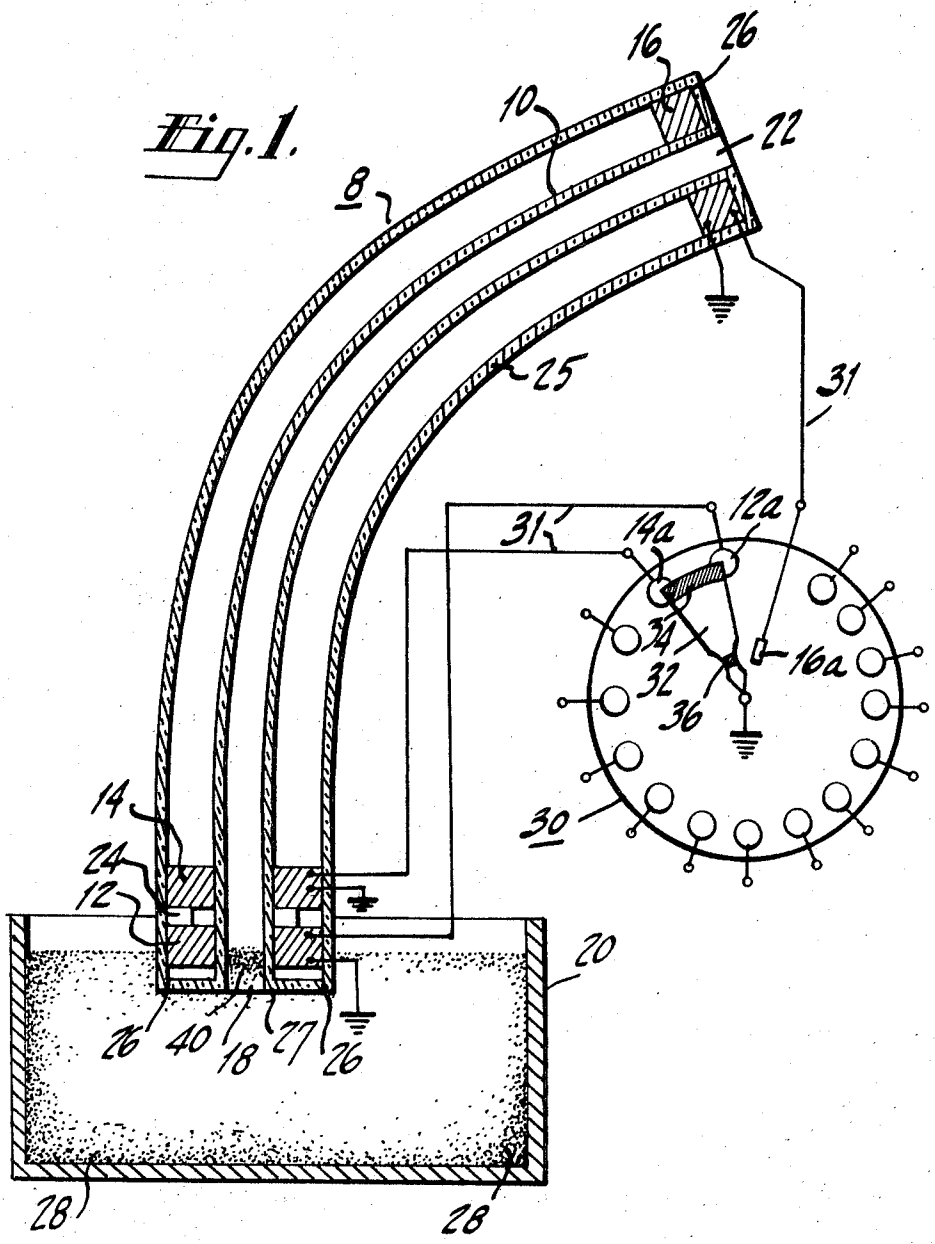
Sept. 30, 1969 R. G. OLDEN 3,469,911

ELECTROMAGNETIC PUMPING APPARATUS FOR USE IN ELECTROPHOTOGRAPHY

Filed Jan. 30, 1967 3 Sheets-Sheet 1

Fig. 1.



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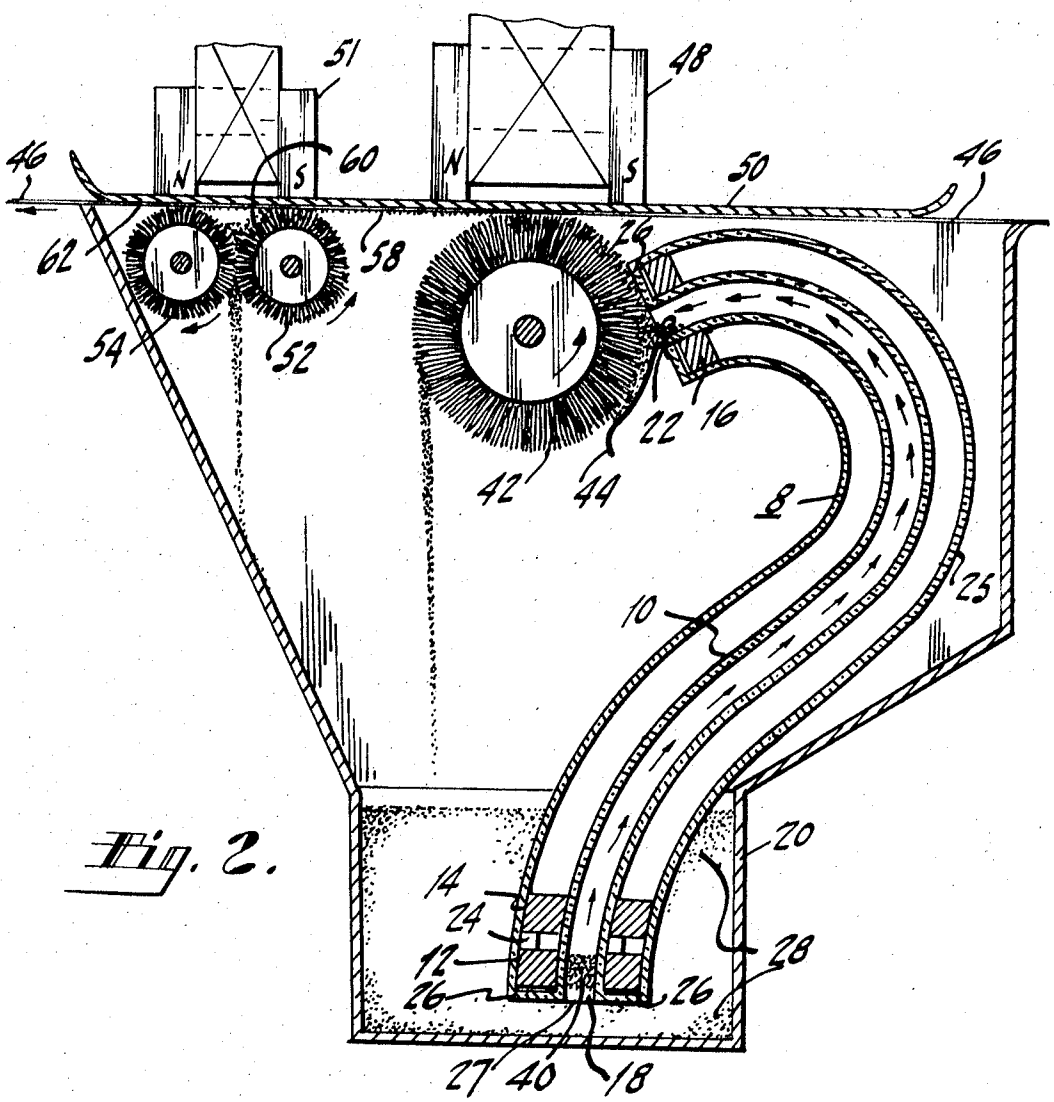


Fig. 2.

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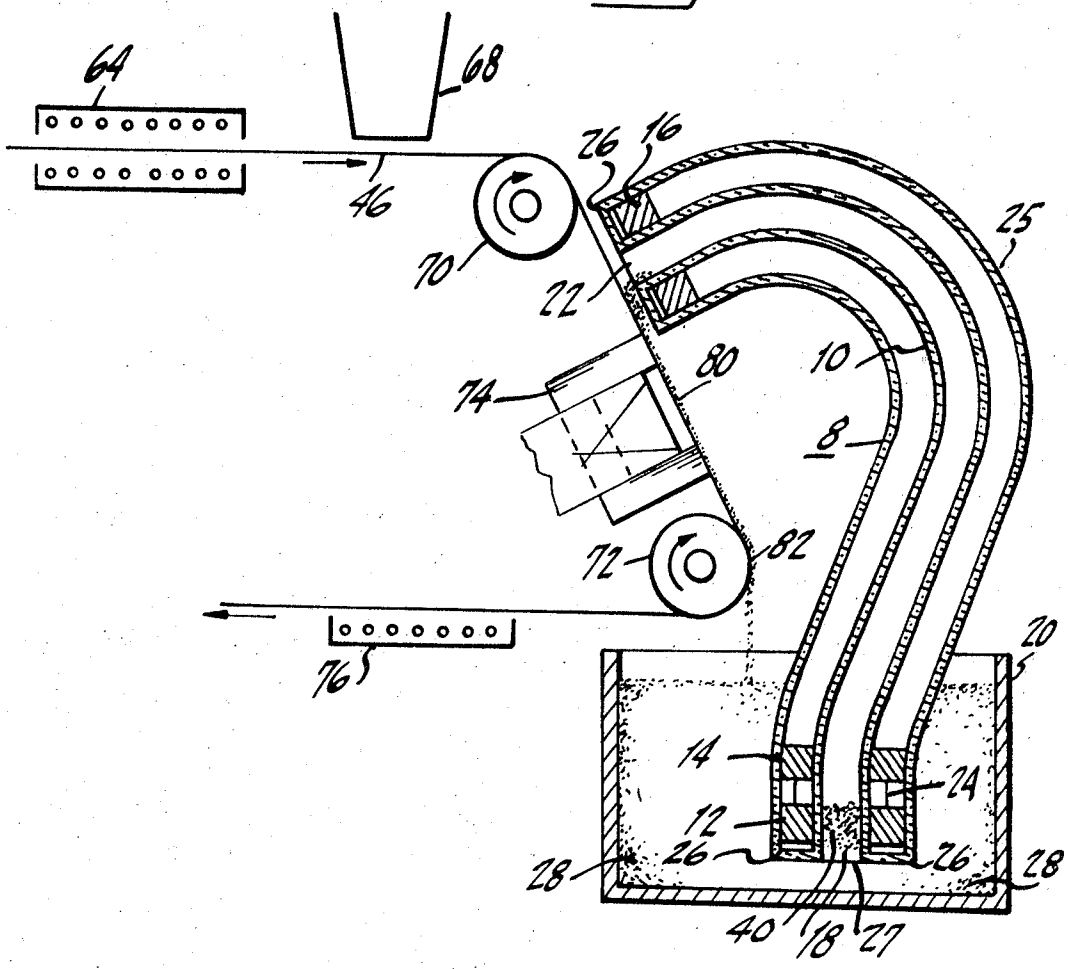
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ELECTROMAGNETIC PUMPING APPARATUS FOR USE IN ELECTROPHOTOGRAPHY

Filed Jan. 30, 1967 3 Sheets-Sheet 3

Fig. 3.



INVENTER

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United States Patent Office 3,469,911
Patented Sept. 30, 1969

3,469,911

ELECTROMAGNETIC PUMPING APPARATUS FOR USE IN ELECTROPHOTOGRAPHY

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Filed Jan. 30, 1967, Ser. No. 612,684
Int. Cl. G03g 15/02
U.S. Cl. 355—3 1 Claim

ABSTRACT OF THE DISCLOSURE

An electromagnetic pumping apparatus for transporting a powdered developer of iron and toner particles from a reservoir to a developing station in an electrostatic printing machine. The pump comprises a thin-walled tube of nonmagnetic material surrounded by a number of electric coils which are energized in sequence. As the coils are sequentially energized the developer is caused to move along the tube, from the reservoir to the developing station. The switching device that energizes the coils is such that two adjacent coils are always energized at any particular time and the last coil in the sequence is energized for a period shorter than that of the other coils.

Background of the invention

This invention relates generally to improved means for circulating a magnetic developer material through an electrostatic printing machine or the like, and more particularly to improved apparatus for conveying magnetic developer material from a reservoir to a developing station in such machines.

In electrophotography it is common to apply a uniform electrostatic charge to the surface of a photoconductive layer. The charge on selected areas is then dissipated by exposing the surface to a light image. Finely divided developer particles which adhere to the charged areas of the surface by electrostatic attraction are applied to the resulting pattern of charges, rendering the pattern visible. A magnetic brush including a mixture of magnetic carrier particles and nonmagnetic developer particles is a convenient way to develop the electrostatic image. Permanent visible images can be obtained, for example, by using thermoplastic developer particles which can be heat fused to the photoconductive layer.

The powder developer used in many electrostatic printing machines consists of finely divided iron particles and thermoplastic toner particles. Methods presently used to transport this developer from a reservoir to the area where the electrostatic image is developed involve various problems. Mechanical conveyors cause dusty operation and consume a large amount of space. Screw feeds necessitate locating the reservoir close to the developing area, are limited in capacity and slow machine operation. Both of these methods of moving developer are mechanically complicated and therefore present maintenance problems. A gravity feed is mechanically simpler and consumes no power but it necessitates placing the developer reservoir high in the machine, and such an arrangement limits the size of the reservoir. This method also necessitates locating the reservoir close to the developing area.

Experience has shown that clear, crisp electrostatic prints can be obtained when the electromagnetic developer is continually supplied with fresh developer material. This can be done if the magnetic developer material is circulated from a fairly large reservoir, and the unused portion is returned to the reservoir to be recirculated.

Summary of the invention

The invention comprises an electromagnetic pumping apparatus to transport magnetic developer material from a reservoir to a developing station in an electrostatic printing machine or the like. The novel magnetic pumping apparatus includes a hollow tube of a nonmagnetic material surrounded by a plurality of electric coils spaced along its length. When the coils are energized in succession by a rotating switch, the magnetic developer material is moved along the tube. One end of the tube extends into the reservoir of developer material and the other end is disposed adjacent to the electromagnetic developing area. The magnetic pump supplies a developer mixture consisting of iron and toner particles to a magnetic brush which applies the toner particles to an electrostatic image.

In one embodiment of the invention the magnetic pump deposits the developer material on a rotating brush which in turn brushes the developer particles onto the electrostatic image. An electromagnet mounted behind the electrostatic image completes the magnetic developer brush. In another embodiment the magnetic pump cascades the developer material directly across the electrostatic image which has an electromagnet mounted behind it to form a magnetic developing brush. After passing through the magnetic developing brush in both embodiments, excess developer material falls back into the reservoir where it can be recirculated by the magnetic pump.

The magnetic pump involves no moving parts thereby decreasing maintenance problems. It allows the reservoir to be placed in any convenient location within an electrostatic printing machine since it can transport the magnetic developer material to a developing area above the reservoir and at any distance from it. The pumping apparatus can be built with a sufficient capacity to supply developer material at any practical rate to the magnetic developer. Dust is kept at a minimum since the powder developer moves through an enclosed tube. Since the invention can raise the developer mixture to a developing area at a higher level, gravity can be utilized to return excess developer to the reservoir allowing a circulation of the developer and the reuse of the iron particles. When a large reservoir is employed, individual particles of developer are rested between circulations for a far greater period of time than they are in use, so that the developer mixture is always fresh at the developing area. This freshness is important in producing clean, crisp prints from an electroprinting machine.

Brief description of the drawings

FIG. 1 is a cross-sectional side view of the novel magnetic pumping apparatus with a partial schematic diagram of its accompanying electric circuit;

FIG. 2 is a cross-sectional side view of one embodiment of the invention; and

FIG. 3 is a cross-sectional view of a second embodiment of the invention.

Description of the preferred embodiments

Referring to FIG. 1 of the drawings the novel magnetic pumping apparatus **8** comprises a thin-walled tube **10** of nonmagnetic material surrounded by a number of coils, such as coils **12**, **14** and **16**. The intake end **18** of the tube **10** extends into a reservoir **20** of magnetic developer material. The exhaust end **22** of tube **10** is located adjacent to and in operative relation with a magnetic developer station. The tube **10** can be of any desired cross-sectional configuration.

The coils, for example coils **12**, **14** and **16**, are spaced equally along the length of the tube **10**. Each coil consists of a plurality of turns of electrically conducting wire. Spacers **24** separate the coils the desired distance and pre-

vent electrical contact between them. The spacers **24** are constructed of electrically nonconducting material and may have any suitable shape. A nonmagnetic and nonconducting housing **25** encases the coils **12**, **14** and **16**, thereby preventing iron particles from coming into contact with them. The housing **25** is a tube having a diameter which is large enough to enclose the magnetic pump tube **10** and its surrounding coils. The housing has the same shape as tube **10** and is closed at ends **18**, **22** by a disk of nonconducting material **26** having an aperture **27** to allow access to tube **10**. The coils **12**, **14** etc. are completely enclosed in the space between the walls of tube **10** and housing **25**.

The reservoir **20** may be fabricated from any material having sufficient structural strength. It can be made in any convenient shape but should be large enough to hold an adequate supply of developer material **28**. Magnetic pump tube **10** with its surrounding coils **12**, **14** and **16** and housing **25** extends into reservoir **20** to a point near the bottom to insure that all of developer material **28** is periodically circulated through tube **10** to the remainder of the apparatus.

Coils **12**, **14** and **16** are energized by a switch **30**. The switch **30** has a number of fixed switch contacts **12***a*, **14***a*, for example, arranged in a circle around the circumference of the switch. The switch contacts are small metallic disks having terminals to which wires **31** are attached. The wires **31** link the fixed switch contacts **12***a*, **14***a*, etc. to the corresponding coils **12**, **14**, etc. that they energize. A rotating switch arm **32** is mounted on a shaft which extends through the center of the switch **30**. A rotating contact **34** is attached to the end of the switch arm **32** so that contact **34** passes across fixed switch contacts **12***a*, **14***a*, etc. Rotating contact **34** is wide enough to engage two adjacent switch contacts, such as **12***a* and **14***a*, simultaneously. Fixed switch contact **16***a* is narrower than the other switch contacts **12***a*, **14***a*, etc. and is offset from the circle of switch contacts and placed closer to the center of switch **30** so that the rotating contact **34** does not engage it. A second rotating contact **36** is mounted on the rotating arm **32**. Contact **36** is located closer to the center shaft of the switch **30** than the rotating contact **34** so that it will engage fixed contact **16***a*. Contact **36** is narrower than contact **34** so that fixed contact **16***a* is only engaged for a short time.

A source of electrical energy is connected to the rotating switch arm **32** so that the switch contacts **12***a*, **14***a*, etc. are energized as the contact **34** moves across them. Electrical energy is conducted from the fixed switch contacts through the wires **31** to the coils **12**, **14**, etc. When the coil **12** is energized, a magnetic field is produced which draws a slug **40** of magnetic developer material into tube **10** and holds it at the center of the coil **12**. Contact **34** on revolving arm **32** is wide enough to contact two adjacent switch contacts simultaneously so that the next coil on tube **10**, coil **14**, is energized before the magnetic field of coil **12** has collapsed and the slug **40** moves up the tube **10** toward coil **14** rather than falling back toward the reservoir **20**. As the rotating arm **32** moves across the other switch contacts in switch **30**, the corresponding coils are energized and the resulting magnetic fields move the slug **40** of developer along tube **10**. When the narrow contact **36** on rotating arm **32** engages contact **16***a*, coil **16**, the last of the series of coils, is energized. Since both the revolving contact **36** and the switch contact **16***a* are narrow, they touch for a short period of time and the coil **16** is only energized momentarily so that the slug **40** does not stop within its magnetic field but instead the slug **40** is ejected through discharge end **22** of tube **10**. The magnetic pump **8** can deliver a continuous supply of magnetic developer material if a plurality of rotating arms are used in the switch **30**.

A magnetic pump, similar to that shown in FIG. 1, was constructed having a tube diameter of ¾ inch and an over-all length of 8 inches. Twelve coils ½ inch in width were arranged equidistantly along its length with each coil containing approximately 2500 turns of number 35 wire. A current of about .820 ma. flowed through the coils. The coils were energized successively by a rotating switch arm similar to that shown in FIG. 1. This device pumped a standard developer material, consisting of toner and iron particles, well, raising it about 6 inches vertically and ejecting it through a curved portion of the tubing as shown in FIG. 1.

FIG. 2 shows an embodiment of the invention which is utilized in an electrostatic printing machine. The intake end **18** of the magnetic pump **8** extends into the reservoir **20** of magnetic developer material **28**. The discharge end **22** of the tube **10** is disposed adjacent to a rotating brush **42**. A trough **44** attached to the discharge end **22** of the tube **10** extends partially around the rotating brush **42**. The trough **44** is placed close to the surface of the rotating brush **42** and conforms closely to the shape of the brush. The cross-sectional configuration of tube **10** can be made to correspond to the cross-sectional area of the rotating brush **42**. The shape of the entire magnetic pumping apparatus **8** is made to conform to the space available in the electrostatic printing machine but the magnetic pumping apparatus is otherwise the same as described above in reference to FIG. 1.

The brush **42** consists of a solid central disk of suitable material with a shaft through its center to allow rotation. The circumference of the brush **42** is covered with a nonconducting material such as nylon velour. The brush **42** rotates at a speed about one half the speed at which the paper **46** moves across it in the same direction as the paper is moving.

Magnet **48** is an electromagnet which is mounted closely behind a platen **50** and directly above the brush **42**. The poles of magnet **48** form a magnetic developing brush with the rotating brush **42**. The platen **50** consists of a flat metal plate placed between the paper **46** and the electromagnets **48** and **51**.

Brushes **52** and **54** are smaller than brush **42** but are otherwise similar in construction. The brush **52** rotates in a counterclockwise direction while brush **54** rotates clockwise in a direction opposite to the motion of the paper. The second electromagnet **51** which is similar to magnet **48** is mounted behind the platen **50** and above brushes **52** and **54** so that it forms two additional magnetic brushes with brushes **52** and **54**.

Magnetic pump **8** transports magnetic developer material **28** from the reservoir **20** and deposits it on the rotating brush **42**. The trough **44** prevents the developer from falling back into the reservoir **20** and causes it to be picked up by the brush **42**. As the brush rotates, the powdered developer is brushed against the paper which has an electrostatic image on the side facing the brush **42**. The platen **50** holds the paper flat and insures uniform contact between the paper and the rotating brush so that developer is spread across all areas of the electrostatic image. Electromagnet **48** completes a magnetic developing brush with rotating brush **42** and attracts the magnetic developer to the paper **46** increasing the probability that toner particles will adhere to the charged areas of the electrostatic image.

After the paper has passed through this first magnetic brush, the magnetic field decreases at point **58** and the excess developer is free to fall back into the reservoir **20**. The rotation of brush **42** also tends to remove excess developer from the paper at the limit of the magnetic field of magnet **48**. Brushes **52** and **54** perform a dual function. Together with electromagnet **51** they form a second magnetic developing brush to further fix the image but they also serve as cleanup brushes to remove excess developer from the paper **46**. This is especially the function of the brush **54** which rotates in a direction opposite to that of the brushes **42** and **52** and opposite to the direction in which the paper is moving. Excess de-

veloper which is brushed from the page at points **60** and **62** also falls back to the reservoir **20**.

The invention provides a continuous circulation of developer material through the electrostatic printing machine. When the reservoir **20** is large, the time during which individual particles of developer are used becomes small and a supply of fresh developer is always available to the magnetic developing brush.

FIG. 3 shows a second embodiment in which the invention is utilized in an electrostatic printing machine. The electromagnetic pump is similar in construction to that described in FIG. 1. A continuous web of paper **46**, which has been treated with a chemical such as zinc oxide to make it photosensitive, it passed through a corona generator **64** and is then exposed to a light image **68**. Various methods and apparatus for corona generation and photographic exposure are known in the art and these steps in the electroprinting process are not part of the subject invention.

The paper **46** is passed around two rollers **70** and **72**. These rollers are cylinders constructed of any suitable material with shafts through their centers allowing them to rotate. The rollers **70** and **72** are mounted so that the paper surface will slope downward from roller **70** to roller **72**. An electromagnet **74** similar to those in FIG. 2 is mounted behind the paper **46** and about midway between the rollers **70** and **72**. After the paper has passed around roller **72** the side having the electrostatic image moves across a heater **76**. The heater is not a part of the invention and various types are known in the art so a description will not be given.

A continuous web of photosensitive paper is passed through the corona generator **64** which gives it a uniform electrical charge. It is then exposed to a light image by lens **68** which dissipates the electrical charge on the exposed areas of the paper. The paper then passes over the roller **70**.

The magnetic pump **8** transports magnetic developer from the intake end **18** of tube **10** to its discharge end **22**. The discharge end **22** is disposed so that the magnetic developer is ejected onto the sloping surface of the paper at a point slightly above the electromagnet **74** and below roller **70**. The developer particles cascade down the sloping surface of the paper **46** and across the electrostatic image. The combination of the developer particles **80** moving across the paper and the electromagnet **74** mounted behind the paper forms a magnetic developing brush which causes the thermoplastic toner particles to adhere to the electrostatic image.

Excess magnetic developer moves down the sloping paper surface and falls back into reservoir **20** at point **82** in the area of the roller **72**. Since the side of the paper having the electrostatic image is facing downward after passing around the roller **72**, excess magnetic developer will fall from the electrostatic image into the reservoir **20**.

Finally, the developed electrostatic image passes over heater **76** which melts the thermoplastic toner particles and fuses them to the paper surface to form a light-fast image.

In this embodiment as in the previous one, the invention provides a continuous circulation of the magnetic developer through the electrophotographic machine and insures a continuing fresh supply of developer material to the magnetic brush.

What is claimed is:

1. In electrostatic printing apparatus including means for providing an electrostatic image on a recording medium, electromagnetic developing means for said image and a reservoir of electromagnetic developer material, the improvement comprising, electromagnetic pumping means for transporting a part of said developer material from said reservoir to said developing means, means for removing the unused portion of said developer material from said electrostatic image, said electromagnetic pumping means including a tube of nonmagnetic material, a plurality of electric coils surrounding said tube, means for energizing said coils in succession, the intake end of said tube extending into said reservoir of electromagnetic developer material and the discharge end adjacent to, and in operative relation with, said electromagnetic developing means, and said means for energizing said coils in succession comprising switching means which also momentarily energizes two adjacent ones of said coils and which energizes the last one of said successively energized coils for a shorter time than the others of said coils.

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