Nov. 21, 1972 R. A. DREXLER ET AL 3,703,395

METHOD FOR DEVELOPMENT OF ELECTROSTATIC IMAGES

Original Filed Feb. 29, 1968 2 Sheets-Sheet 1

FIG. 1

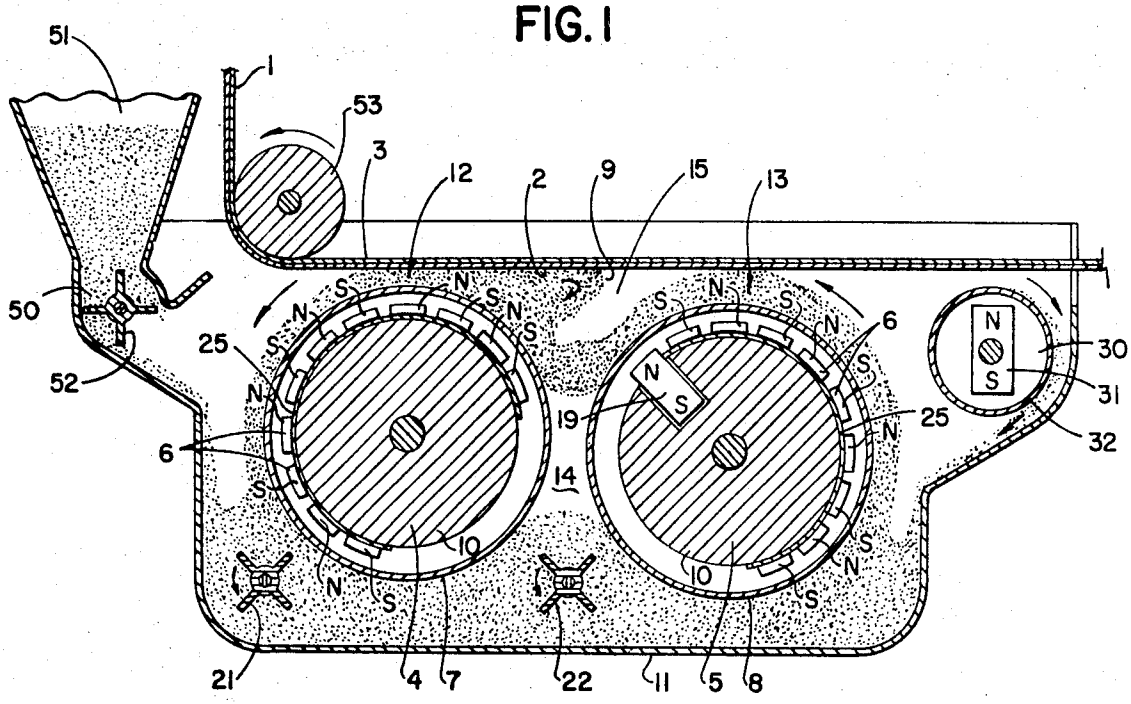
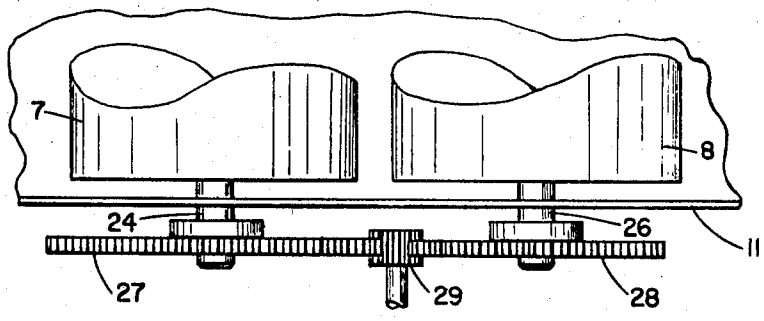


FIG. 2



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METHOD FOR DEVELOPMENT OF ELECTROSTATIC IMAGES

Original Filed Feb. 29, 1968 2 Sheets-Sheet 2

FIG.3

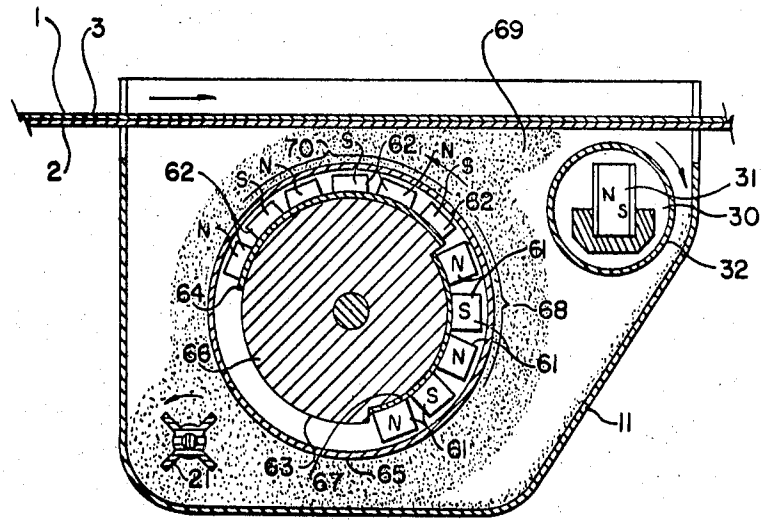
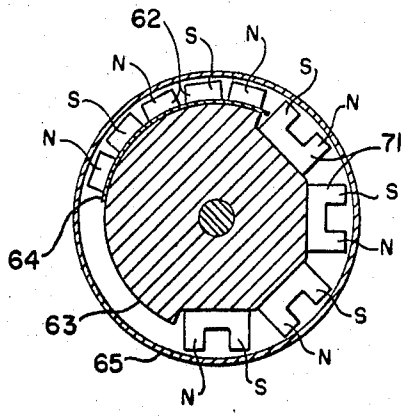


FIG.4



United States Patent Office 3,703,395 Patented Nov. 21, 1972

3,703,395

METHOD FOR DEVELOPMENT OF ELECTROSTATIC IMAGES

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Original application Feb. 29, 1968, Ser. No. 709,281, now Patent No. 3,543,720, dated Dec. 1, 1970. Divided and this application July 20, 1970, Ser. No. 63,961

Int. Cl. G03g *13/08, 15/08*

U.S. Cl. 117—17.5 1 Claim

ABSTRACT OF THE DISCLOSURE

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.

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a division of U.S. application Ser. No. 709,281, filed Feb. 29, 1968, now U.S. Pat. No. 3,543,720 dated Dec. 1, 1970.

Reference is made to commonly assigned co-filed 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 wtih 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 non-magnetic 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 non-reusable 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 provide 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 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 build up 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.

FIG. 3 is a schematic cross-sectional view of an alternative magnetic brush assembly constructed according to the invention.

FIG. 4 is a schematic cross-sectional view of an alternative magnet arrangement for the magnetic brush assembly of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Accordinng 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 non-magnetic 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, non-magnetic 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 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 area **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 ito 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 scavening 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 non-

magnetic 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.

FIGS. 3 and 4 show an alternative design invented by R. A. Drexler, one of the co-inventors herewith and included in said above-mentioned co-pending application. According to FIGS. 3 and 4, a single magnetic brush **63** is constructed essentially the same as each magnetic brush in FIG. 1 except that a feed portion **68** of the brush contains stronger magnets than a discharge portion **70**. Strong feed magnets **61** are attached to a pole piece **67** on a central core **66**, and weaker discharger magnets **62** are attached to a pole piece **64**. The magnets **61** in the feed portion, being stronger, hold more developer on an outside surface of a rotating roller **65** than is held by the same roller under the influence of weaker magnets **62** in the discharge portion **70**, and a rollback is created in a rollback cavity **69**. In this embodiment, the rollback cavity **69** is defined by the rotating roller **65** in the discharge portion of the magnetic brush together with the insulating surface **2**, and is open on one side as well as both ends.

In FIG. 4 is shown an alternative design for the apparatus of FIG. 3 in which the magnets associated with the feed portion of the magnetic brush are not strips as shown in FIG. 3 but are horseshoe magnets **71** embedded in core **66**.

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 ¼ 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 ¼ inch long. The axes of cylinders **7** and **8** are offset with respect to the insulating surface **2** by 1/16 inch with the periphery of feed cylinder **8** approximately 3/16 inch and discharge cylinder **7** approximately ⅛ 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 tribo-electric 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. A method of developing an electrostatic charge pattern on an insulating surface, said method comprising:
   (a) moving the insulating surface in a first direction across a development zone;
   (b) magnetically transporting a developer mixture of iron particles and toner particles from a reservoir to the development zone at a first transport rate and from a direction opposite to said first direction; and
   (c) magnetically transporting the developer mixture out of the development zone at a second transport rate which is sufficiently less than said first transport rate to provide a substantial accumulation of developer mixture in the development zone, which accumulation is subjected to a lesser magnetic attraction than the magnetic attraction during its transport;
   whereby the movement of insulating surface causes the accumulation to roll back and tumble in the development zone causing an increased degree of contact between the particles of the developer mixture and the insulating surface.

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