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ELECTROSTATIC PRINTING PROCESS AND APPARATUS

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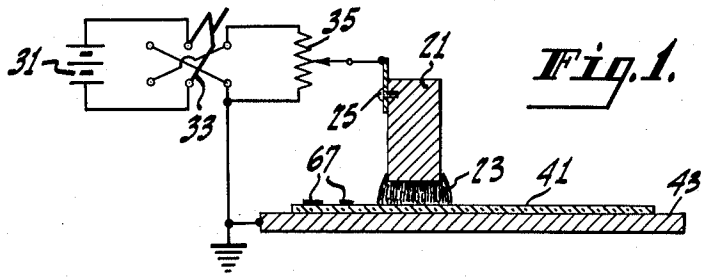


Fig. 1.

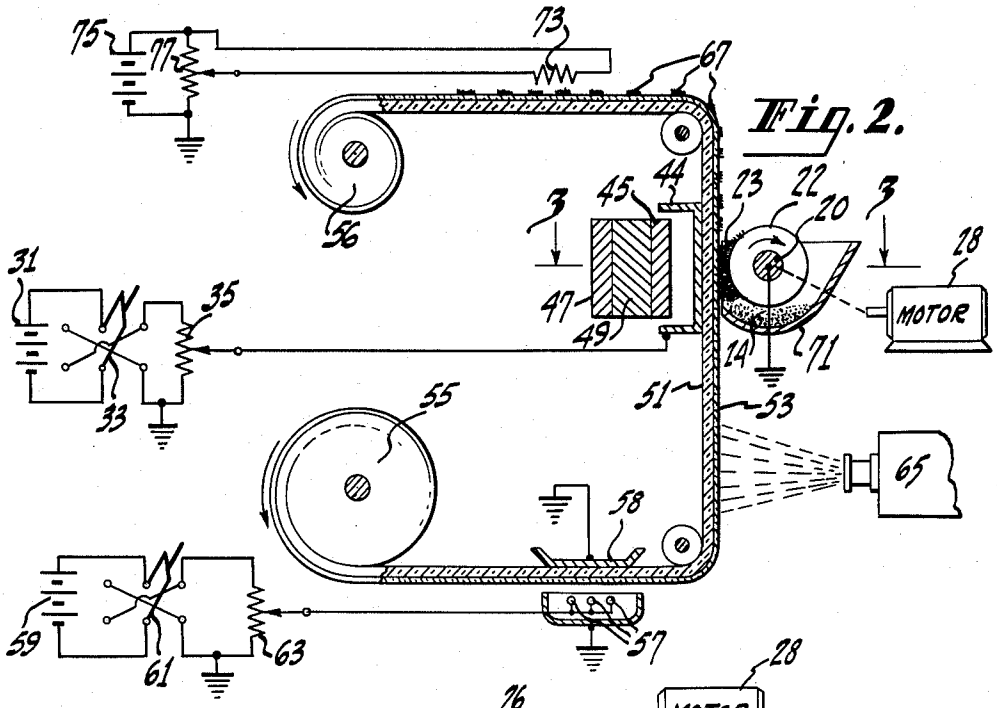


Fig. 2.

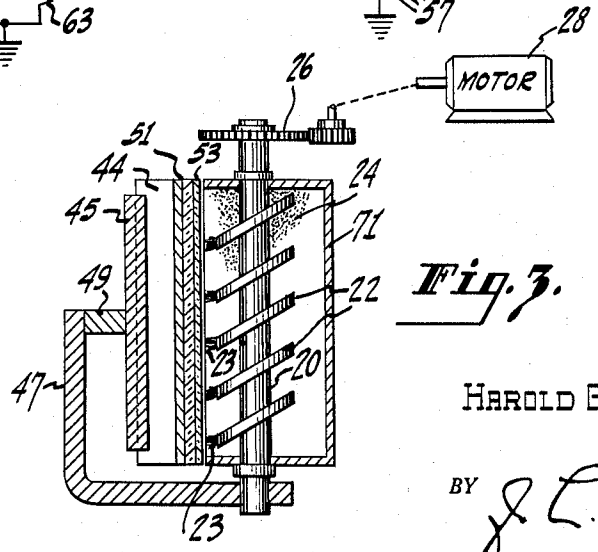


Fig. 3.

INVENTOR

HAROLD G. GREIG

BY J. C. Whittaker

ATTORNEY

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ELECTROSTATIC PRINTING PROCESS AND APPARATUS

Harold G. Greig, Princeton, N.J., assignor to Radio Corporation of America, a corporation of Delaware

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This invention relates to electrostatic printing and particularly, but not necessarily exclusively, to improved methods and means for developing electrostatic charge patterns and to improved electrostatic printing processes and apparatus.

An electrostatic printing process is that type of process for producing a visible record, reproduction or copy which includes as an intermediate step, converting a light image or electrical signal to a latent electrostatic charge pattern on an electrically-insulating substrate. The process may also include converting the charge pattern into a visible image which may be a substantially faithful reproduction of an original except that it may be different in size and color.

A typical electrostatic printing process may include first producing a uniform electrostatic charge upon the surface of a photoconductive insulating material, such as selenium, anthracene, or zinc oxide dispersed in an electrically-insulating, film-forming vehicle. Then, the charged surface of the photoconductive material is exposed to a light image incident upon the charged surface, discharging the portions irradiated by the light rays, while leaving the remainder of the surface in a charged condition, thereby forming a latent electrostatic image substantially corresponding to the light image. The latent electrostatic image is developed by applying a developer powder which is held electrostatically to selected areas of the surface. The visible powder image thus formed may be fixed directly to the photoconductive surface or it may be transferred to another surface upon which the visible image may be desired and then fixed thereon.

A typical developing technique utilizes a magnetic brush comprising a developer mix including magnetically-responsive carrier particles and developer powder particles maintained in a loose mass by a magnetic field. When the loose mass is swept across the surface bearing a latent electrostatic image, the magnetic particles carry the developer powder particles to the desired point of contact and at the same time, provide an electrostatic charge upon the developer powder particles by triboelectricity. The electrostatically-charged developer powder particles brought into contact with the surface bearing the latent electrostatic image are retained on selected areas of the surface by electrostatic attraction in substantial configuration with the electrostatic image.

An object of the invention is to provide improved methods and means of electrostatic printing.

Another object is to provide improved methods and means for developing latent electrostatic charge patterns and electrostatic images with a magnetic brush.

Another object is to provide an improved magnetic brush for electrostatic printing.

Another object is to provide improved methods and means for developing either a direct or reverse image from a single latent electrostatic image.

A further object is to provide improved methods and means for controlling the contrast value of the visible powder image and to control spurious deposit of developer powder particles in the background of a visible powder image developed with a magnetic brush.

In general, the processes of the invention comprise establishing a unidirectional electric field between a latent electrostatic image and a magnetic brush during the development of said latent electrostatic image. By varying the strength and direction of the electric field, the contrast of the developed image may be varied, the developed image may be reversed and the spurious deposit of developer powder particles in the background of the developed image may be controlled. Apparatus in accordance with the invention includes a magnetic brush and means for establishing a desired unidirectional electric field between said brush and an electrostatic image during the development of said electrostatic image.

The foregoing objects and other advantages will be more fully described in the following detailed description when read in conjunction with the accompanying drawing in which:

FIGURE 1 is a partially sectional, partially schematic view of a first improved apparatus for carrying out the processes of the invention,

FIGURE 2 is a partially sectional, partially schematic view of a second improved apparatus for carrying out the processes of the invention, and

FIGURE 3 is a sectional view along section lines 3—3 of FIGURE 2.

Similar reference characters are applied to similar elements throughout the drawing.

Referring to FIGURE 1, a first improved apparatus for carrying out the process of the invention comprises a developer brush adapted to be contacted across the surface of an electrically-insulating layer bearing a latent electrostatic image. The developer brush comprises a magnetic pole piece **21**, a mass of developer mix **23** including magnetically-responsive carrier particles and developer powder particles held together and to the pole piece **21** by magnetic attraction and connection means **25** for a source of biasing voltage attached to the pole piece **21**.

A preferred carrier material for the developer mix consists of "alcoholized iron," that is, iron particles free from grease and other impurities soluble in alcohol. These iron particles are preferably relatively small in size, being in their largest dimension about 0.002 to 0.008 inch. Satisfactory results are also obtained using a carrier consisting of iron particles of a somewhat wider range of sizes up to about 0.001 to 0.020 inch.

A preferred developer powder may be prepared as follows: a mixture comprising 200 grams of 200 mesh Piccolastic resin 4358 (an elastic thermoplastic resin composed of polymers of styrene, substituted styrene and its homologs), marketed by the Pennsylvania Industrial Company, Clairton, Pa., and 12 grams of Carbon Black G marketed by the Eimer and Amend Co., New York, N.Y. are thoroughly mixed in a stainless steel beaker at about 200° C. The mixing and heating should be done in as short a time as possible. The melt is poured upon a brass tray and allowed to cool and harden. The hardened mix is then broken up and ball milled for about 20 hours. The powder is screened through a 200 mesh screen and is then ready for use as a developer powder. This powder takes on a positive electrostatic charge when mixed with iron powder. It therefore will develop the negatively charged areas of an electrostatic image. About 2 to 10 grams, but preferably 5 grams, of the developer powder and about 100 grams of the magnetic carrier material are blended together giving the preferred developer mix. Other ratios of developer powder to magnetic carrier material may be used.

The magnetic pole piece **21** comprises an iron bar with a permanently magnetized pole at one end thereof. The magnetic pole produces an external magnetic field which attracts and holds the mass of developer mix **23**. The attracted mass of developer mix is loosely held and easily deformable to the contours of a surface with which it

may be in contact. At the other end of the iron bar, there is provided a threaded hole and screw for connecting a source of biasing voltage to the developer brush.

A battery 31 or other source of biasing voltage is connected to the magnet 21 through the connection means 25, a double-pole, double-throw reversing switch 33 and a potentiometer 35. Thus, the applied biasing voltage may be changed in polarity and varied in magnitude.

An electrically-insulating layer 41 bearing a latent electrostatic image is placed upon a grounded conducting backing plate 43. The switch 33 and the potentiometer 35 are adjusted such that a positive voltage of about 700 volts with respect to ground is applied to the magnet 21, and the developer mix 23 of the brush is contacted across the surface of the layer 41. During the period of contact, a unidirectional field appears between the mass of developer mix 23 and the backing plate 43 due to the biasing voltage applied between the brush and the backing plate 43. The unidirectional field is in addition to the electric field of the latent electrostatic image. Developer powder particles 67 from the mass of developer mix 23 deposit in areas of the layer 41 having a negative electrostatic charge producing a visible powder image thereon.

The visible powder image produced by the above-described procedure has a very high contrast characteristic and a minimum amount of spurious deposit in the background areas. This set of characteristics is considered ideal for line drawings and line prints. By reducing the biasing voltage and therefor the unidirectional field, the contrast between the dark and light areas of the image is reduced, making it possible to obtain any desired contrast characteristic over a very wide range of contrast values. When the voltage is reduced to zero, the magnetic brush as heretofore described will develop the negatively charged areas of the layer 41. However, a moderate amount of developer powder frequently deposits spuriously in the background areas of the visible image. Such spurious deposit may be reduced to a minimum value by biasing the magnetic brush according to the method of the invention.

If the switch 33 is reversed and an increasing voltage applied to the magnet 21, a value is reached where the negatively charged areas of the layer 41 are no longer developed, and instead the positively charged areas of the layer 41 are developed producing a reverse image. The contrast of the reverse image increases and the amount of spurious deposit in the background areas of the reverse image decreases as the negative voltage is increased in magnitude.

According to the invention, a direct or reverse visible image may be obtained from the same latent electrostatic image. A direct visible image is a developed image wherein the developed areas correspond to the dark areas of the original. Where a photoconductive process is utilized to produce the latent electrostatic image, the developed areas of the visible image are the unexposed areas of the photoconductive layer. A reverse visible image is a developed image wherein the developed areas correspond to the light areas of the original. Also, by adjustment of the applied voltage below the dielectric breakdown of the layer in which the latent electrostatic image resides, any desired contrast characteristic over a wide range may be obtained for either the positive or the reverse image. Thus, one may simply and quickly adjust an electrostatic printing apparatus to produce line prints of high contrast value, continuous tone prints of intermediate contrast value and, in each case, the print may be direct or reverse.

The developer powder particles of the developer mix may be chosen from a large class of materials, for example; zinc, copper, carbon, sulphur, gum copal, gum sandarac, nylon, polystyrene, sealing wax and other natural or synthetic resins or mixtures thereof. The developer powder particles may be coated with a thin layer of a material for the purpose of modifying the physical or electrical properties of the developer powder. It is preferred, however, to use a pigmented thermoplastic synthetic resin.

The magnetic carrier particles of the developer mix may be chosen from a large class of powdered magnetically-attractable materials such as iron, steel, alloys of aluminum, nickel and cobalt and other magnetic materials.

The developer powder and the magnetic carrier powder may be combined in any desired proportion to produce the developer mix provided the magnetic carrier particles are able to carry the developer powder particles. It is preferred that 2 to 10 parts of developer powder be mixed with 100 parts of magnetic carrier powder.

A quantity of the developer mix maintained in a loose mass by a magnetic field and means for establishing a unidirectional electric field between the developer mix and the latent electrostatic image during the development of said image are the essential structural components of the improved magnetic brush of the invention. It is preferred to utilize a permanent bar magnet for providing the magnetic field for maintaining the developer mix in a loose mass and voltage connection means attached to the bar magnet for electrical connection to the developer mix. However, other structures may be used, such as electromagnets or other magnetic field producing means. Similarly, the biasing voltage may be applied to the mass of developer mix of the brush as shown in FIGURE 1 or may be applied to the backing plate 43 with the developer mix connected to ground, as subsequently described in FIGURE 2.

Any positive or negative voltage may be used to bias the magnetic brush of the invention so long as there is no electrical breakdown in the brush or in the layer 41 upon which the electrostatic image resides. It is preferred, however, to use a voltage between −1000 and +1000 volts D.C.

The theory underlying the processes of the invention is not completely understood. It is believed that a "virtual ground plane" is automatically and inherently provided by the magnetic brush immediately adjacent to the electrostatic image. The extreme closeness of the "virtual ground plane" to the latent electrostatic image greatly enhances the image field effect. By applying an electric field in the desired polarity in addition to the image field, the image field is effectively further enhanced or suppressed, to produce a wide range of direct or reverse contrast values in the developed visible image. This effect may be due to contact charging of the developer powder particles at the brush ends or to an electric field additional to the electrostatic image field or both.

Referring to FIGURES 2 and 3, the improved methods and means of the invention may be embodied in an improved continuous electrostatic printing process and apparatus. A continuous web comprising a paper substrate 51 having on one surface thereof a photoconductive insulating coating 53 comprising a powdered photoconductor, such as zinc oxide, dispersed in an electrically-insulating, film-forming vehicle is unwound from a roll 55. The continuous web first passes a station where a uniform negative electrostatic charge is produced on the photoconductive coating 53, for example, by corona discharge from a series of wires 57 connected to a voltage source 59 through a double-pole, double-throw reversing switch 61 and a potentiometer 63. The surface of the coating 53 may also be charged by rubbing or by contact with a biased conductive roller.

The continuous web next passes to a station where an electromagnetic radiation image is produced upon the surface of the photoconductive coating 53, for example, by projection from a photographic transparency image by means of a projector 65. The continuous web now has produced thereon a latent electrostatic image substantially corresponding to the electromagnetic radiation image which was projected thereon.

The continuous web next advances to a station where

the latent electrostatic image residing on the surface of the photoconductive coating **53** is developed by the method of the invention. A grounded rotary pole piece **20** of a magnetic structure is provided with spaced parallel inclined elliptical discs **22** facing the photoconductive coating **53**. A magnetic field is maintained between a fixed magnetic pole piece **45** spaced from the elliptical discs **22** and on the opposite side of the web through magnetic pieces **47** and **49** and through the gap therebetween. A reservoir **71** holds a quantity of developer mix in contact with the discs **22**. A shield **44** located between the fixed pole piece and the web is maintained in contact with or closely spaced behind the paper substrate **51** and is connected to a voltage source **31** through a double-pole, double-throw reversing switch **33** and a potentiometer **35**. The switch **33** and the potentiometer **35** are adjusted to provide the desired biasing voltage upon the shield **44** for example, a positive voltage of 700 volts. As the rotary pole piece **20** rotates in a clockwise direction, developer mix forms on the periphery of the discs **22** in brush-like filaments **23** and is carried upwardly and swept across the surface of the photoconductive coating **53** passing the station. Developer powder particles **67** deposit upon areas of positive polarity producing a reverse visible powder image on the photoconductive coating **53** in substantial configuration with the latent electrostatic image. According to the invention, direct or reverse visible powder images may be produced and the background color value and the contrast value of the visible image may be varied by adjusting the biasing voltage to the shield **44** as previously described in FIGURE 1.

The continuous web bearing the visible powder image thereon now passes to a station where the visible image is fixed to the photoconductive coating **53**. For this purpose a radiant heater comprising a resistance wire **73** connected to a voltage source **75** through a potentiometer **77** is maintained in closely spaced relationship with the visible powder image. Heat radiated from the wire **73** softens the thermoplastic resin of the developer powder causing it to adhere to the photoconductive coating **53**. The visible powder image may be fixed to the photoconductive layer **53** by other means for example, by spraying with an adhesive or by coating with a softener for either the photoconductor **53** or the developer powder particles. The visible powder image may also be transferred to another surface and fixed thereon by any convenient means. The continuous web bearing the fixed visible image is now wound upon the roll **56**. The continuous web may of course be cut into convenient lengths and stacked in piles or utilized directly.

There have been described improved methods and means of electrostatic printing including improved methods and means for developing latent electrostatic charge patterns and electrostatic images with an improved magnetic brush. There have also been described methods and means for producing direct or reverse visible images and for controlling the contrast value of the visible powder image developed according to an improved electrostatic printing process.

What is claimed:

1. A process for developing a latent electrostatic image residing upon a surface comprising contacting said latent image with a mix comprising magnetic carrier particles and developer powder particles, said mix being maintained in a mass by a magnetic field and establishing between said mass and said surface a unidirectional electric field in addition to the electric field emanating from said electrostatic image.

2. A process for developing a latent electrostatic image residing upon the surface of an electrically-insulating layer comprising contacting said surface with a mix comprising magnetic carrier particles and developer powder particles, said mix being maintained in a mass by a magnetic field and establishing through said layer to said mass a unidirectional electric field in addition to the electric field emanating from said electrostatic image.

3. In electrostatic printing, a method for developing a latent electrostatic image residing in an insulating layer comprising contacting with one surface of said layer a developer brush comprising a quantity of magnetic particles intermixed with a quantity of colored dielectric particles said magnetic and dielectric particles being maintained in a loose mass by a magnetic field, spacing an electrode from said brush and on the side of said layer opposite to said brush and applying a voltage between said electrode and said developer brush.

4. In electrostatic printing, a method for developing a latent electrostatic image upon a first surface of an insulating sheet comprising securing a mass of magnetic developer mix in a magnetic field to form a developer brush, contacting said developer brush across said first surface, contacting an electrode to said sheet on a second surface opposite to said first surface and applying a voltage between said electrode and said mass of developer mix.

5. In an electrostatic printing process comprising the steps of forming an electrostatic image and then applying to said electrostatic image a mass of a developer mix including magnetically-responsive carrier particles and developer powder particles held together and to a magnetic pole piece by magnetic attraction, the step comprising applying an electric field between said electrostatic image and said mass of developer mix to control the attraction between said developer powder particles and said electrostatic image.

6. Apparatus for developing a latent electrostatic image comprising means for contacting an electrically-conducting mass of powder particles including developer powder particles across a surface bearing said electrostatic image, and an electric circuit for applying to said mass a voltage of a predetermined magnitude and polarity with respect to the region immediately behind said surface.

7. A method for developing a latent electrostatic image comprising contacting an electrically-conducting mass of powder particles including developer powder particles to the surface bearing said latent electrostatic image, and simultaneously applying to said mass an external voltage of a predetermined magnitude and polarity with respect to the region immediately behind said surface.

8. Apparatus for developing an electrostatic image on a surface through the use of a magnetically responsive developer mix comprising magnetic field producing means for forming said developer mix into a magnetic brush and electrical connection means for applying a biasing voltage between said magnetic brush and said surface.

9. A device for developing electrostatic images residing upon a surface of a sheet through the use of a developer mix including carrier particles of magnetic material intermixed with developer powder particles, said device comprising magnetic field producing means for maintaining said developer mix in a loose mass and means for establishing an electric field in addition to the electric field emanating from said electrostatic image between said mass and said surface when said mass is contacted to said surface.

10. A device for developing electrostatic images through the use of a developer mix including carrier particles of magnetic material intermixed with a colored developer powder of a different material, said device comprising a magnet having an external magnetic field for forming said developer mix into a brush in contact with a pole of said magnet and means connected to said magnet for producing in said brush a desired biasing voltage with respect to some fixed voltage.

11. A device for developing electrostatic images residing in a sheet of insulating material through the use of a developer mix including magnetic carrier particles intermixed with developer powder particles, said device comprising means for producing a magnetic field to form said mix into a brush, means for contacting said brush

across one surface of said sheet, an electrode in contact with the opposite surface of said sheet, and means for applying a voltage between said electrode and said developer mix.

12. A device for developing a latent electrostatic image on a surface through the use of a developer mix including magnetically-responsive carrier particles and developer powder, said device comprising a magnetic pole piece for forming said mix into a loose mass and for holding said mix in contact with said pole piece by magnetic attraction and electrical connection means for applying to said pole piece a bias voltage with respect to said surface.

13. In an electrostatic printing device, apparatus for developing latent electrostatic charge patterns residing in an insulating layer through the use of a developer mix including magnetic carrier particles and developer powder particles, said apparatus comprising magnetic means for forming said mix into a loose mass and for contacting said mix across one surface of said layer and means for establishing a unidirectional electric field transversely through said contacted surface.

14. In apparatus for developing an electrostatic image on a surface including a magnetic field-producing, electrically-conductive member for forming a magnetically-responsive developer mix into a magnetic brush, the improvement comprising an electrical connection associated with said member for applying to said magnetic brush a bias voltage with respect to said surface.

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