June 5, 1962 M. A. LACE 3,037,478

APPARATUS FOR DEVELOPING ELECTROPHOTOGRAPHIC SHEET

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Fig. 1

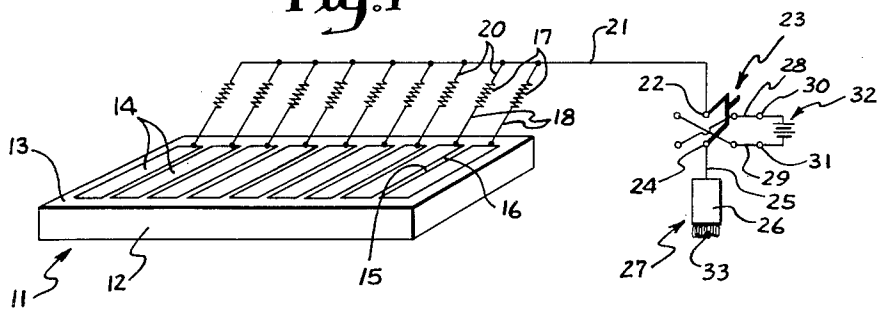


Fig. 2

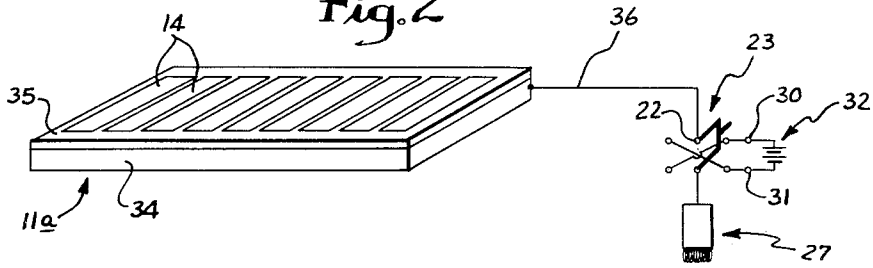


Fig. 3

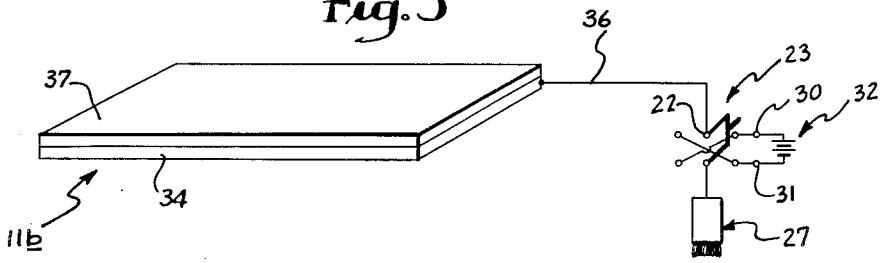
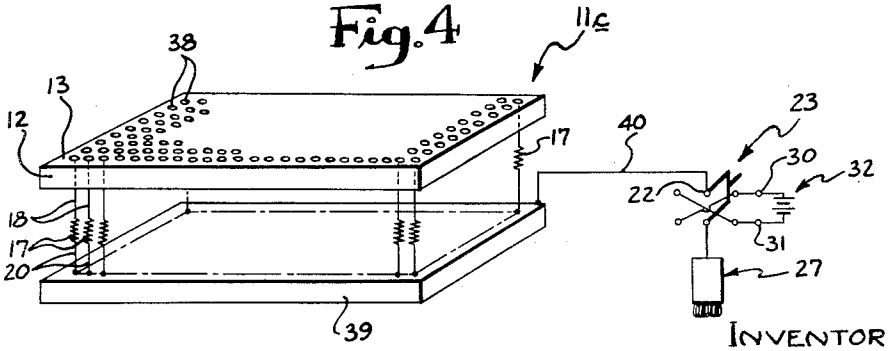


Fig. 4



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Fig. 5

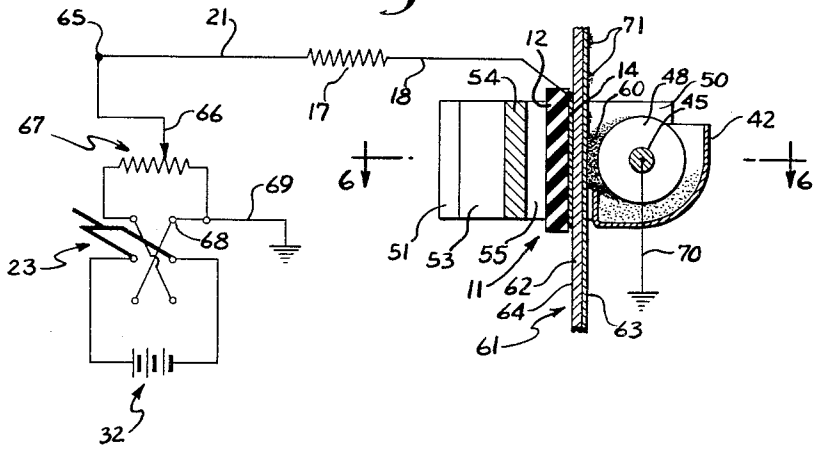
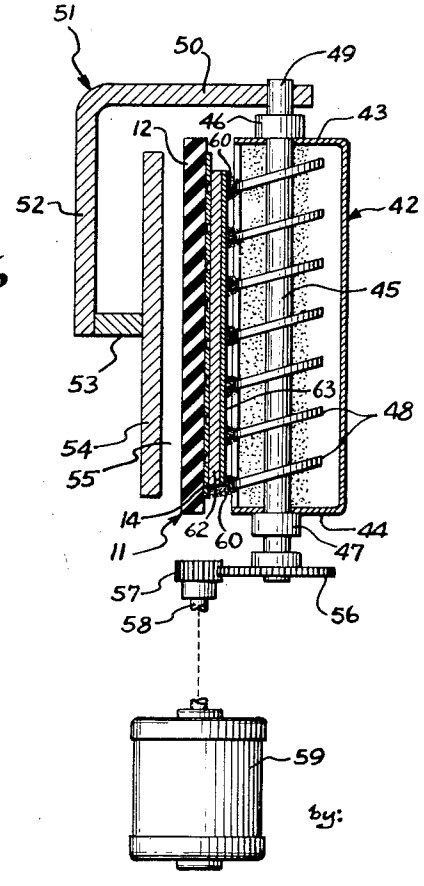


Fig. 6



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APPARATUS FOR DEVELOPING ELECTROPHOTOGRAPHIC SHEET

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8 Claims. (Cl. 118—637)

This invention relates to a novel apparatus and method for magnetic brush development of latent electrostatic images on electrophotographic sheets or plates.

In the electrophotographic process the surface of a photoconductive insulating material is first provided with a uniform electrostatic charge. The charged surface of the electrophotographic sheet or plate is then exposed to a light image, thereby discharging the charges on those areas of the surface irradiated by light while leaving the remainder of the surface in a charged state so as to form a latent electrostatic image substantially corresponding to the light image. The latent electrostatic image is then developed by applying a powdered toner which adheres to the charged areas of the surface. The powder may then be fixed directly to the electrophotographic sheet or may be transferred to another surface and fixed thereon.

The so-called magnetic brush system is one of the presently preferred techniques for developing the latent electrostatic image, that is, for applying the toner particles to the surface of the sheet bearing the electrostatic image. The magnetic brush comprises a magnet to which is adhered a developer mix including iron filings and toner particles held to the magnet in the form of a fibrous mass by the magnetic field. When the mass is wiped over the surface bearing the latent electrostatic image, the toner particles are retained on the charged areas of the sheet surface by electrostatic attraction due to the electrostatic charge developed upon the toner particles by a triboelectric reaction with the iron filings.

It has heretofore been discovered that improved results can be obtained by applying a bias potential or unidirectional electric field between the electrostatic image and the magnetic brush during the development step. The contrast of the developed image may be controlled by varying the voltage of the applied potential. Also, either a direct or reversed image may be developed, as desired, in accordance with the direction of the applied electrostatic field.

As heretofore practiced, the electrophotographic sheet bearing the electrostatic image on its front surface is placed with its rear surface against a metal back-up plate, and the bias potential is applied between the plate and the magnetic brush. This technique involves a serious disadvantage when developing the marginal areas of an electrophotographic sheet having a width less than the width of the metal back-up plate. More specifically, when the magnetic brush contacts such a sheet along an edge thereof so as to overlap said edge, at least part of the developer mass is in electrical contact with the metal back-up plate, thereby short-circuiting the applied bias potential and drawing sufficient current to cause the bias voltage to drop substantially below the desired value.

A primary object of the present invention is to provide a novel apparatus and method which enable the electrophotographic sheet to be developed by the magnetic brush technique along the marginal edge areas of the sheet while a bias potential is applied between the magnetic brush and the back-up plate, while preventing any substantial reduction in the bias voltage due to contact of the metal brush with the back-up plate.

In the drawings:

FIG. 1 is a schematic perspective view illustrating a first embodiment of the apparatus and method of the present invention;

FIG. 2 is a schematic perspective view illustrating a second embodiment of the invention;

FIG. 3 is a schematic perspective view illustrating a third embodiment of the invention;

FIG. 4 is a schematic perspective view illustrating a fourth embodiment of the invention;

FIG. 5 is a schematic sectional view of a system utilizing a rotary magnetic brush and which may embody the invention in any of the four forms thereof illustrated in FIGS. 1 to 4 inclusive; and

FIG. 6 is a sectional view taken substantially on line 6—6 of FIG. 5.

Referring first to FIG. 1, the reference numeral **11** designates generally a back-up plate adapted to contact the rear surface of the electrophotographic sheet bearing on its front surface a latent electrostatic image to be developed. The back-up plate **11** comprises a substantially rectangular insulating plate or block **12** composed of an electrical insulating material such as polystyrene, "Lucite," "Bakelite" or similar phenol-formaldehyde resin, wood or the like. Secured to or imbedded within the upper surface **13** of the insulating plate **12** are a plurality of rectangular conductive strips **14**. The upper surfaces of the latter may be coplanar with, or extend above, the upper surface of plate **12** so as to contact the rear surface of the electrophotographic sheet.

The strips **14** may be in the form of thin foil or thick plates and may be composed of any suitable conductive metal such as copper, bronze or aluminum. The strips **14** are in parallel contiguous relation, and have their respective adjacent edges **15**, **16** spaced from each other whereby each of the strips **14** is electrically insulated from the respective strips adjacent thereto.

The width of each conductive strip **4** is preferably about 1/32 inch, but may be considerably greater as shown in the drawing for clarity in illustration. The width of each space between adjacent strips **14** is preferably about .030 inch. In the event that the paper is moved longitudinally of the back-up plate **11** during the development step, as shown in the embodiment of FIGURES 5 and 6, the conductive strips **14** may be oriented angularly with respect to the direction of paper movement; that is, diagonally with respect to the longitudinal axis of back-up plate **11** rather than transversely thereto as shown in FIGURE 1. This angular orientation of the strips **14** will eliminate any undesirable effect of discontinuity due to the insulating spaces between the spaced strips **14**.

The reference numeral **17** designates a series of conventional resistors which may be of the carbon-deposited or wire-wound or other suitable type. Each of the resistors **17** is of a high resistance value, preferably in the range between 100,000 ohms to 50 megohms. One end of each of the resistors **17** is connected by a lead **18** to a respective one of the conductive strips **14**. The opposite ends of all the resistors **17** are connected by leads **20** to a common lead **21** which is in turn connected to the terminal **22** of a double-pole double-throw switch indicated generally at **23**. The other terminal **24** of the latter is connected by a lead **25** to the magnet **26** of a magnetic brush **27** of any conventional or suitable type. The switch **23** is also connected by leads **28**, **29** to the terminals **30**, **31** of any suitable source of direct-current electric potential indicated schematically by the symbol for a battery and designated generally by the reference numeral **32**.

It will thus be seen that upon closing of the double-pole double-throw switch **23**, the voltage of the electric potential source **32** will be applied between the magnetic brush **27** and the conductive strips **14**, with the resistors **17** in series between the respective conductive strips **14** and one

of the terminals of the electric potential source **32**. Upon reversing the switch **23**, the polarity of the applied bias potential will be reversed. The voltage between the terminals **30**, **31** of the electric potential source **32** may be in the range of 50 to 1500 volts, with the range of 200 to 800 volts being preferred for typical electrophotographic techniques such as those employed with the well-known zinc oxide resin-coated paper.

After the electrophotographic sheet has been exposed to a light image so as to form a latent electrostatic image on the front surface thereof, the sheet is placed with its rear surface against the back-up plate **11** and in contact with the conductive metal strips **14**. The switch **23** is closed so as to apply the voltage of the electric potential source **32** between the strips **14** and the magnetic brush **27**. The latter may be of either the rotary type shown in FIGURES 5 and 6 and to be described in detail below, or may be of the conventional manual type which is held in the hand and manually applied during the development process. As the magnetic brush **27** moves over and in contact with the sheet front surface bearing the latent electrostatic image, the developer powder or toner particles, electrostatically charged by triboelectric interaction with the iron filings in the mass of developer mix **33** magnetically held to one end of the magnet **26**, are wiped off and adhere to the charged areas of the front surface of the electrophotographic sheet so as to form a visible image thereon.

It will be apparent that as the magnetic brush **27** is wiped over, or otherwise moves with respect to, the marginal areas of the electrophotographic sheet so as to overlap an edge of the latter, a portion of the mass of developer mix **33** will contact the back-up plate **11**. If the latter were simply in the form of a unitary conductive metal plate, as heretofore employed in the art before the advent of the present invention, and if this metal plate were connected directly to one of the terminals **30**, **31** of the electric potential source **32** without the interposition of the series resistors **17**, as has heretofore been the practice, it will be apparent that the potential source **32** would be short-circuited at the point where the magnetic brush developer mass **33** were to contact the back-up plate. This would cause a large current to be drawn from the electric potential source **32** so as to reduce the applied bias potential below the desired value, and the entire back-up would then be at the same potential as the brush.

However, in the present invention the conductive strips **14** are spaced and electrically insulated from each other and are connected to the electric potential source **32** through relatively high value resistors **17**. It will thus be seen that when the magnetic brush **27** overlaps an edge of the electrophotographic sheet, the developer mass **33** will contact one or a few of the conductive strips **14** and a short circuit of the potential source **32** will be prevented by reason of the fact that the resistors **17** are in series with the conductive strips **14** and the potential source **32**. As a result, the voltage of the applied bias potential is maintaind at substantially the same value during development of the marginal edge areas of the electrophotographic sheet as during development of the intermediate areas thereof. Furthermore, only those few conductive strips **14** which actually contact the brush will be at zero potential with respect to the brush, and all of the other strips **14**, constituting practically the entire area of the back-up plate **11** will be maintained at the full bias potential with respect to the brush.

Referring to FIGURE 2 wherein is shown a second embodiment of the invention, the reference numeral **11*a*** indicates generally a back-up plate having a somewhat different construction than the back-up plate **11** of FIGURE 1. The back-up plate **11*a*** comprises a lower rectangular plate **34** which is made of a highly conductive material such as copper, bronze or aluminum. Superimposed upon the conductive plate **34** is a plate **35** composed of a high resistance semi-conductive material, such as any of the well-known conductive rubbers. As will be understood by those skilled in the art, the latter are rubber compositions to which a conductive material such as carbon black or superconductive carbon black has been added so as to enable the resistivity of the rubber to be reduced to a value as low as approximately 100 ohms per cm.^{3}. The resistivity of the conductive rubber employed for the semi-conductive plate **35** should be preferably in the range from 10^3 to 10^9 ohms per cm.^{3}. Instead of conductive rubber, the plate **35** may be composed of any other semi-conductive material having suitable mechanical characteristics and a resistivity in the above-noted range.

The term "semi-conductive," as used throughout this specification and the appended claims, will be understood to refer to the range of electrical resistivity between approximately 10^{-4} ohms per cm.^{3} to approximately 10^{11} ohms per cm.^{3}, in accordance with the accepted nomenclature as exemplified in the publication "Battelle Technical Review," August 1957, page 9.

Secured to or embedded within the upper surface of the semi-conductive plate **35** are a series of spaced contiguous conductive strips **14** which may be identical to those previously described with respect to the embodiment shown in FIGURE 1. The embodiment of FIGURE 2 also comprises a double-pole double-throw switch **23**, a direct-current source of electric potential **32** and a magnetic brush **27** arranged in the manner described above with respect to FIGURE 1. A lead **36** has one end connected to the conductive metal plate **34** and its opposite end to the terminal **22** of the switch **23**.

It will be seen that a portion of the semi-conductive material of plate **35** extends in series between the conductive plate **34** and each of the conductive strips **14**. That is, each of the portions of the semi-conductive material below a respective one of the strips **14** is in effect a component having a substantial electrical resistance of a value in the semi-conductive range. Each of these portions or components of plate **35** has the equivalent effect of a respective one of the resistors **17** of FIGURE 1.

When the magnetic brush **27** overlaps an edge of the electrophotographic sheet having its rear surface in contact with the upper surface of back-up plate **11*a***, whereby a portion of the magnetic brush is in direct contact with one or two of the conductive strips **14**, said portions or components of the semi-conductive material of plate **35** will be in series with the by-pass circuit thus established around the edge of the sheet, so as to prevent said circuit from constituting a low-resistance short-circuit across the terminals **30**, **31** of the electric potential source **32**. This prevents the drawing of a large current which would cause the bias potential to be reduced below the desired value during development of the marginal areas of the electrophotographic sheet when the magnetic brush **27** overlaps the edges of the latter. Furthermore, as noted above with respect to the embodiment of FIGURE 1, all of the strips **14**, with the exception of the one or few strips in contact with the brush, are maintained at the desired potential with respect to the brush.

Referring now to FIGURE 3, there is shown a third embodiment of the invention wherein the reference numeral **11*b*** indicates generally a back-up plate comprising a metal conductive plate **34** upon which is superimposed a semi-conductive plate **37** composed of wear-resistant conductive rubber. The plate **37** of FIGURE 3 preferably has substantially the same electrical characteristics as the plate **35** of FIGURE 2, except that the latter may be composed of soft rubber whereas plate **37** of the present embodiment is preferably composed of hard rubber required for wear-resistant characteristics. This is advantageous in the event that the embodiment shown in FIGURE 3 is employed in an arrangement wherein the electrophotographic sheet slides against the back-up plate **11*b*** during the development step in the manner shown in FIGURES 5 and 6. Since rubber is normally a highly

insulating medium, the relatively low resistivity (preferably in the range of 10^3 ohms per $cm.^3$ to 10^9 ohms per $cm.^3$) of the material of plate **37** is provided by incorporating carbon black or super-conductive carbon black therein in the manner well-known in the art.

Although the upper surface of plate **37** may be uniform and continuous, it comprises in effect a plurality of contiguous adjoining areas each composed of a material having an electrical conductivity in the semi-conductive range as this range is normally defined in the art and defined hereinabove. The component or portion of the material of plate **37** immediately below each of said contiguous surface areas is in effect a component having a substantial electrical resistance of a value within the semi-conductive range. That is, each of said components is in effect connected in series between a respective one of said contiguous surface areas and the conductive plate **34**, whereby each component has the equivalent function of a respective one of the resistors **17** of the embodiment shown in FIGURE 1.

The conductive plate **34** of FIGURE 3 is connected by a lead **36** to a double-pole double-throw switch **23** and associated with the latter are a magnetic brush **27** and a direct-current source of electrical potential **32** in the manner described above with respect to the embodiments of FIGURES 1 and 2.

The mode of operation of the embodiment shown in FIGURE 3 is similar to that of the embodiments of FIGURES 1 and 2. The electrophotographic sheet is placed with its rear surface in contact with the upper surface of the semi-conductive plate **37** and the magnetic brush **27** is wiped across the sheet front surface bearing the electrostatic image. When the fibrous mass **33** composed of developer mix adhered to the magnet **26** of the magnetic brush **27** overlaps the edge of the electrophotographic sheet and contacts the upper surface of the semi-conductive plate **37**, a low-resistance short-circuit is prevented by reason of the fact that a portion or component of the material of plate **37** will be in series between the brush **27** and the conductive plate **34**, thereby maintaining the desired bias voltage during the development of the marginal areas of the electrophotographic sheet.

Referring now to FIGURE 4, there is shown a fourth embodiment of the invention comprising a back-up plate **11***c* comprising an insulating block or plate **12** similar to the plate **12** of the embodiment shown in FIGURE 1. Mounted in the plate **12** are a plurality of circular conductive elements **38**. These may be in the form of thin circular discs secured to or imbedded within the upper surface **13** of plate **12**, or they may be in the form of cylindrical plugs extending from the surface **13** down through the plate **12** to a substantial depth therein. The elements **38** may be composed of any highly conductive metal such as copper, bronze or aluminum, and may be in the form of thin foil, or an electrolytic or otherwise coated form of these metals. The conductive elements **38** are illustrated as circular and are preferably of about one-eighth inch in diameter. The center-to-center spacing of adjacent elements **38** is preferably about .180 to .200 inch.

There are provided a plurality of resistors **17**, similar to those described above with respect to the embodiment of FIGURE 1, and each of the resistors **17** is connected by a lead **18** to a respective one of the conductive elements **38**. The opposite end of each of the resistors **17** is connected by a lead **20** to a conductive metal plate **39** which is in turn connected by a lead **40** to the terminal **22** of a double-pole double-throw switch **23** associated with a direct-current source of electrical potential **32** and a magnetic brush **27** in the same manner described above with respect to the first three embodiments of the invention.

The mode of operation of the embodiment of FIGURE 4 will be apparent from the above description of the mode of operation of the embodiment shown in FIGURE 1, the conductive elements **38** being the equivalent and functioning in substantially the same manner as the conductive strips **14**. The conductive plate **39** merely serves as a common lead connecting one end of each of the resistors **17** of FIGURE 4 to the lead **40** which is in turn connected by the switch **23** to one of the terminals **30**, **31** of the direct-current electric potential source **32**.

Referring now to FIGURES 5 and 6, there is shown an arrangement wherein any of the embodiments shown in FIGURES 1 to 4 inclusive may be utilized with a rotary magnetic brush. A longitudinal container or trough **42** is provided with opposite end walls **43**, **44** having openings therein for rotatably mounting a longitudinal shaft **45** formed of steel or any other ferromagnetic material. The shaft is provided with a pair of shoulders or collars **46**, **47** adapted to abut the exterior surfaces of the end walls **43**, **44** so as to limit longitudinal movement of shaft **45**. Mounted on the latter and fixedly secured thereto are a plurality of spaced parallel elliptical discs **48** also composed of a ferromagnetic material.

One end **49** of shaft **45** is rotatably mounted within an opening formed in the leg **50** of an L-shaped element **51** having another leg **52** to which is secured an element **53** of permanently magnetized material, such as "Alnico" or the like. Secured to element **53** is a planar pole piece **54**. The latter is adjacent to a back-up plate **11**, but is spaced therefrom by an air gap indicated at **55**. It will thus be seen that a continuous magnetic circuit is established from element **53** through pole piece **54**, air gap **55**, back-up plate **11**, discs **48**, shaft **45**, and then through L-shaped element **51** to complete the circuit.

A gear **56** is fixedly secured to shaft **45** and is engaged by a pinion **57** secured to the shaft **58** of a conventional electric motor **59**, whereby the latter may drivingly rotate the shaft **45**.

The developer mix comprising toner particles and iron filings is placed within the trough **42** and is caused to adhere to the peripheries of the discs **48**, as indicated at **60**, by means of the magnetic field. The electrophotographic sheet, indicated generally at **61** and comprising a layer of backing paper **62** having a coating of photoconductive material **63** is fed vertically (as viewed in FIGURE 5) between the back-up plate **11** and the elliptical discs **48** while the latter are rotated about the axis of shaft **45** and through the developer mix in the trough **42**. The sheet **61** may be in the form of a continuous web wound in a roll, or a rigid plate, or a single sheet of document size. The rear surface **64** of the electrophotographic sheet **61** contacts the back-up plate **11** and the front surface comprising the photoconductive layer **63** is wiped by the masses **60** of developer mix clinging to the peripheries of the rotating discs **48**.

In the event that the embodiment of the invention shown in FIGURE 1 is employed in the type of apparatus shown in FIGURES 5 and 6, the back-up plate **11** will comprise a plurality of conductive strips **14** imbedded in the surface of an insulating block **12** and in contact with the rear surface **64** of sheet **61**. Each of the conductive strips **14** is connected by a lead **18** to a respective one of a plurality of resistors **17** (only one being shown in FIGURE 5 for simplicity in illustration). The opposite end of each resistor **17** is connected by a common lead **21** to the terminal **65** of the arm **66** of a potentiometer indicated generally at **67**. The latter is connected to a double-pole double-throw switch **23** and electric potential source **32** arranged as heretofore described. One terminal **68** of switch **23** is connected by a lead **69** to ground and shaft **45** is also grounded by a lead **70** to complete the circuit for the bias potential.

As the sheet **61** is moved with respect to the back-up plate **11** and the rotating discs **48**, the toner particles will be deposited on the charged areas of the latter as indicated at **71**, thereby forming a visible image. It will be understood that the rotary magnetic brush apparatus of FIGURES 5 and 6 may be employed with the inventive embodiments of FIGURES 2, 3 or 4 by substituting the

back-up plate **11***a*, **11***b* or **11***c* respectively for the back-up plate **11** shown in FIGURES 5 and 6.

The unidirectional field established between the magnetic brush and the back-up plate, as a result of the application of the bias potential, will add to or subtract from the electric field due to the latent electrostatic image, depending upon the polarity of the applied bias potential. When the two electric fields are properly additive, the physical image formed by the deposited toner powder has a very high contrast characteristic and a minimum amount of spurious deposit. If it is desired to reduce the contrast, the potentiometer **67** may be adjusted to reduce the voltage of the applied bias potential. If it is desired to produce a reverse image during the development step, the switch **23** may be reversed to cause the electric field of the applied bias potential to buck or oppose the electric field of the latent electrostatic image.

Although the application of a bias potential to obtain these advantages and modes of operation during development of the intermediate areas of the electrophotographic sheet, was known prior to the present invention, the novel apparatus and method disclosed and claimed herein enable the bias potential to be maintained at the desired voltage during development of the marginal areas of the electrophotographic sheet.

The specific embodiments described in the above specification and illustrated in the accompanying drawings are merely illustrative of several forms which the invention may take in practice, and there will readily occur to those skilled in the art numerous modifications within the scope of the invention as delineated by the appended claims which are to be construed as broadly as possible in view of the prior art.

I claim:

1. An apparatus for developing an electrophotographic sheet having a previously applied latent electrostatic image on the front surface thereof, said apparatus comprising means adapted to contact the rear surface of said sheet, said means comprising a plurality of contiguous areas each composed of a material having an electrical conductivity of a value at least in the semi-conductive range, and a plurality of spaced conductive elements disposed in spaced electrically insulated relation to each other and positioned adjacent said means adapted to contact the rear surface of said sheet, a magnetic brush adapted to contact the front surface of said sheet, a source of electrical potential having a pair of terminals of opposite polarity, means connecting said magnetic brush to one of said terminals, and means connecting said areas to the other of said terminals, said last-recited means having a substantial electrical resistance of a value no greater than that of the semi-conductive range.

2. An apparatus as recited in claim 1 wherein said means having a substantial electrical resistance comprises a plurality of resistors, each of said resistors being connected to a respective one of said conductive elements, each of said resistors being in series between its respective conductive element and said other terminal.

3. An apparatus as recited in claim 1 wherein said last-recited means comprises a plurality of components each having a substantial electrical resistance of a value no greater than that of the semi-conductive range, each of said components being connected to a respective one of said areas, each of said components being in series between its respective area and said other terminal.

4. An apparatus as recited in claim 1 wherein said means adapted to contact the rear surface of said sheet comprises a plate composed of electrically insulating material, each of said contiguous areas comprising a metallic conductive element, said conductive elements being secured to the surface of said plate and being in spaced contiguous relation to each other.

5. An apparatus as recited in claim 4 wherein said means having a substantial electrical resistance comprises a plurality of resistors each connected in series with a respective one of said conductive elements.

6. An apparatus as recited in claim 1 and comprising a receptacle for containing a mixture of toner particles and iron filings, means mounting said magnetic brush for rotation in contact with said mixture, said means adapted to contact the rear surface of said sheet being spaced from said magnetic brush whereby the electro-photographic sheet may pass through the space therebetween, and drive means for rotating said brush to cause the latter to convey said mixture from the receptacle to said front surface of the sheet.

7. An apparatus as recited in claim 6 wherein said means adapted to contact the rear surface of said sheet comprises a plate composed of electrically insulating material, each of said contiguous areas comprising a metallic conductive element, said conductive elements being secured to the surface of said plate and being in spaced contiguous insulated relation to each other.

8. An apparatus as recited in claim 7 wherein said means having a substantial electrical resistance comprises a plurality of resistors, each of said resistors being connected to a respective one of said conductive elements, each of said resistors being in series between its respective conductive element and said other terminal of said source of electrical potential.

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