United States Patent

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[54] **ION PROJECTION APERTURE-CONTROLLED ELECTROSTATIC PRINTING SYSTEM**
9 Claims, 9 Drawing Figs.

[52] U.S. Cl. **355/16,** 355/3, 355/16, 96/1
[51] Int. Cl. **G03g 15/00**
[50] Field of Search 355/3, 16, 17

[56] **References Cited**

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2,901,374	8/59	Gundlach	355/16
3,220,831	11/65	McFarlane	355/17
3,220,833	11/1965	McFarlane	355/17
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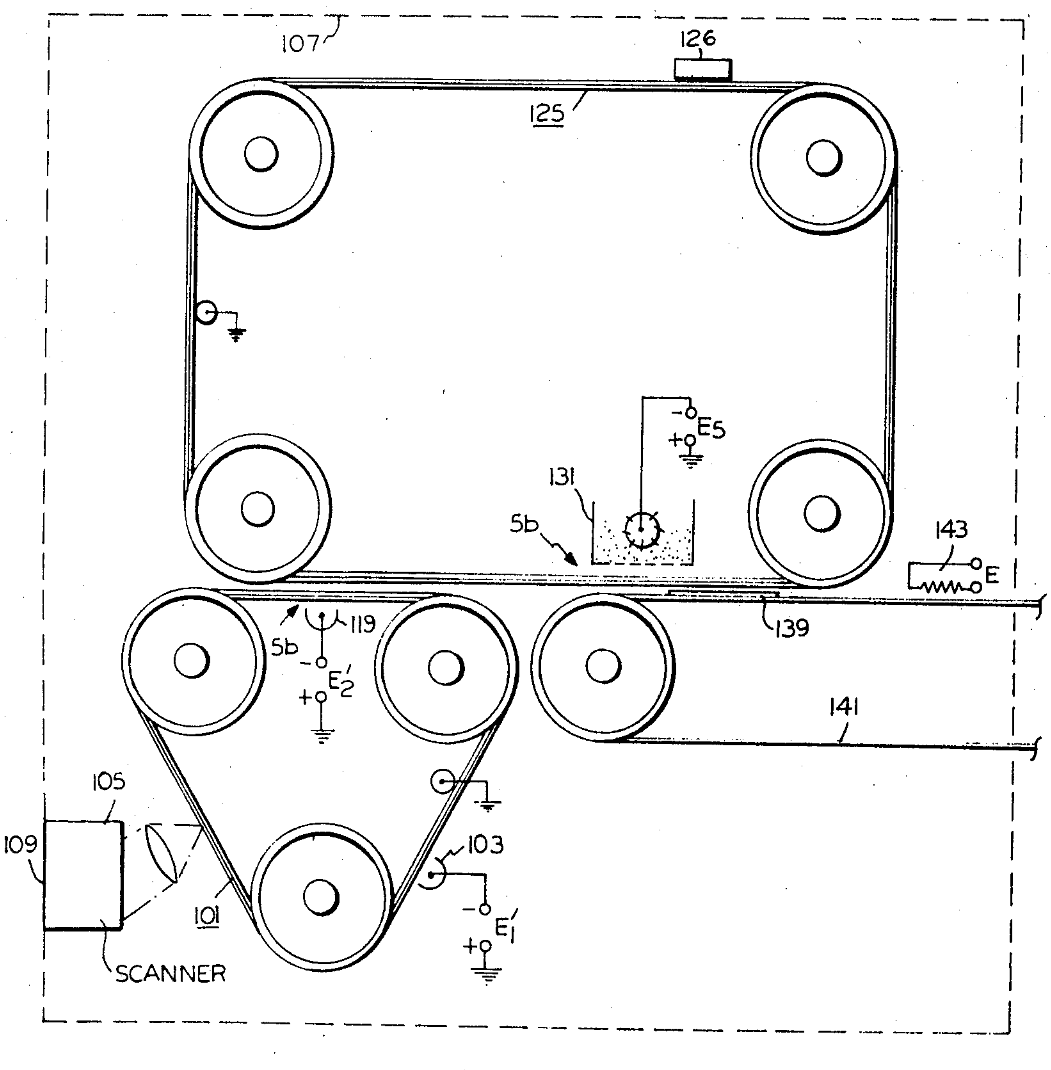
ABSTRACT: Methods and apparatus for electrostatic printing including a multilayer screen having a conductive layer and an insulative layer and having apertures therein, means for deploying opposite electrostatic charges across the insulative layer, an image-projecting system for discharging the insulative layer in accordance with light received thereby, a Corotron or other like means for projecting ions through unblocked apertures in the screen and through partially blocked apertures in the screen in fewer numbers to the insulative layer of a second multilayer screen, and either a Corotron or other like means for projecting ions through the second screen to a substrate for subsequent developing and fixing, or means for projecting charged marking material through the second screen to a substrate for fixing thereon to provide positive reproductions.



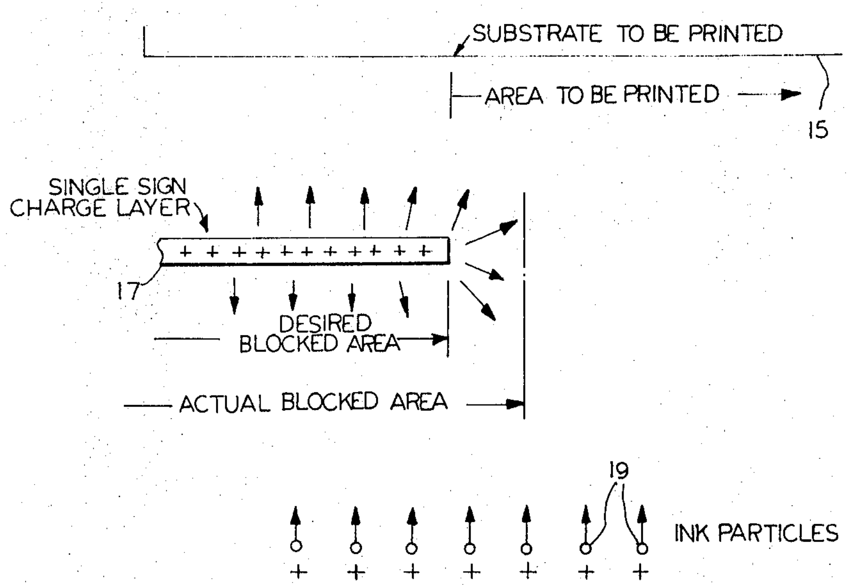


FIG. 1

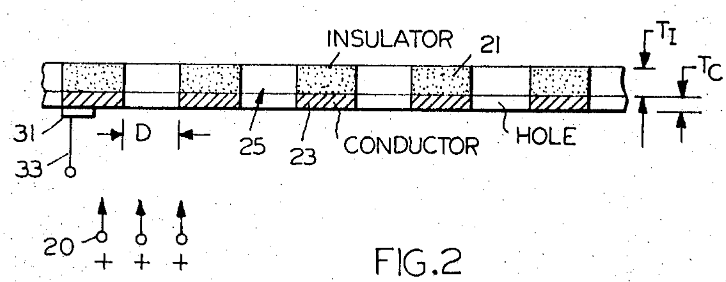


FIG. 2

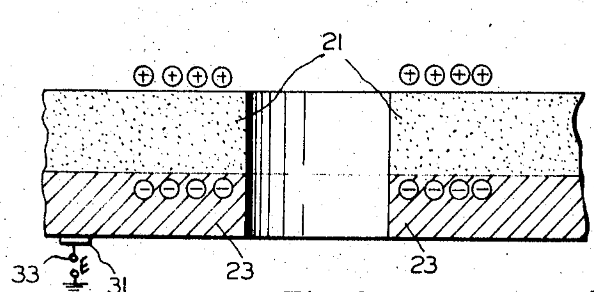


FIG. 3

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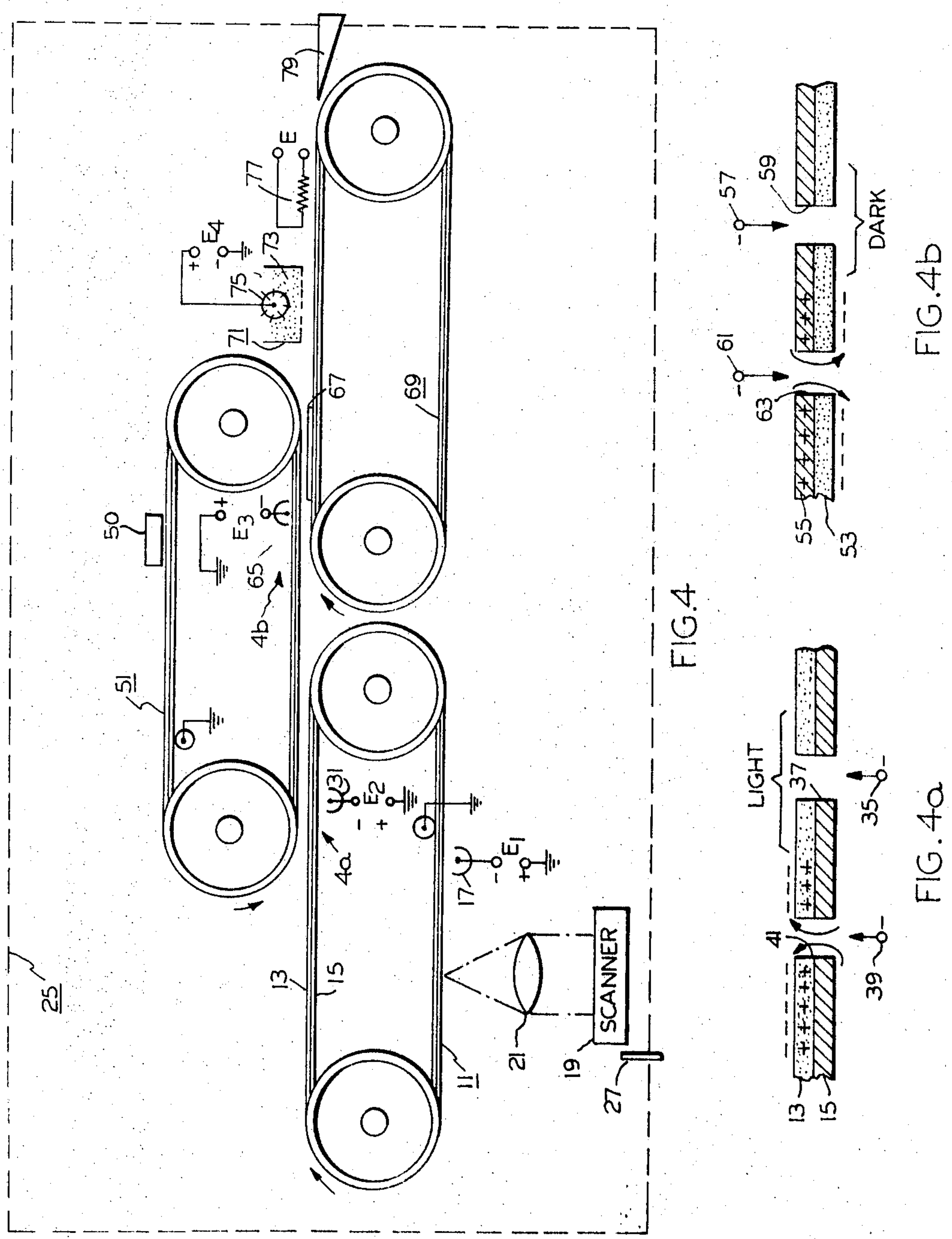

FIG.4

FIG.4a

FIG.4b

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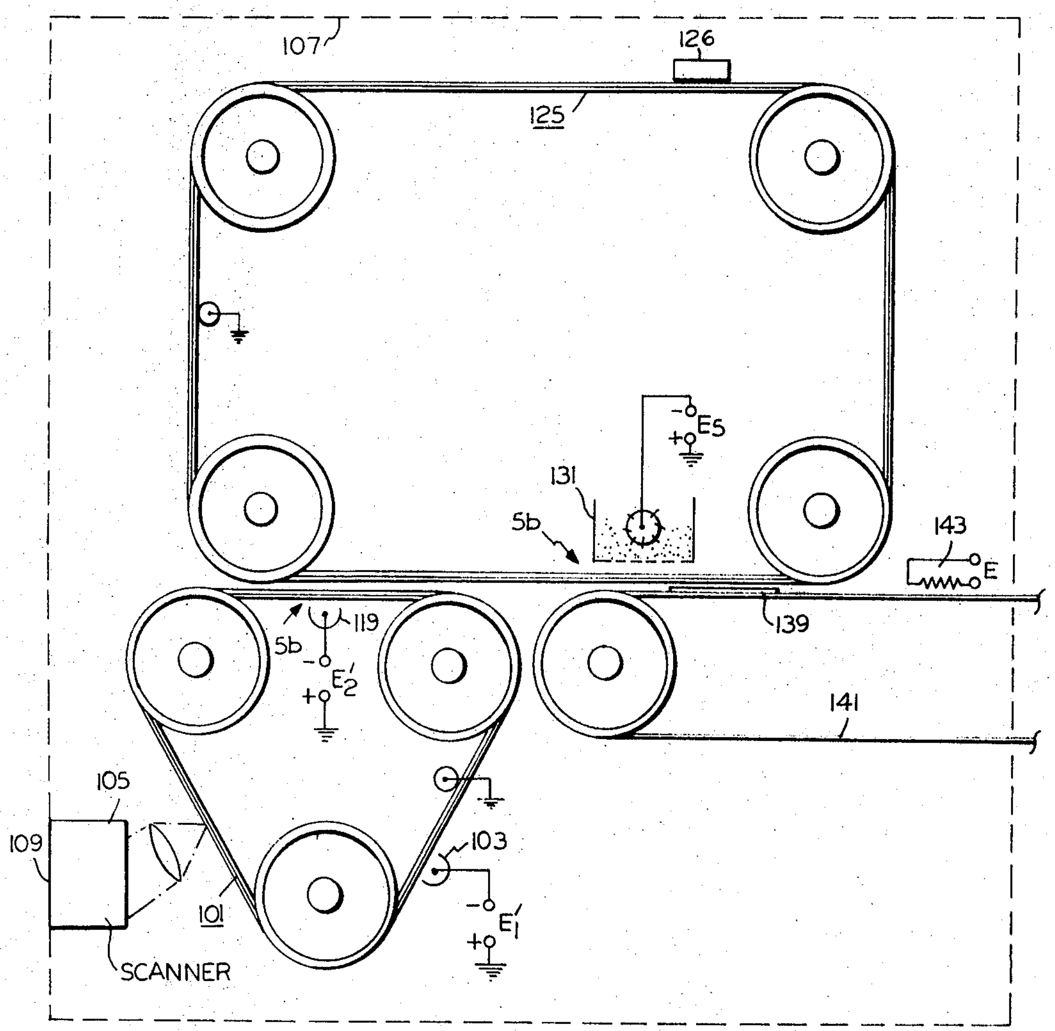

FIG. 5

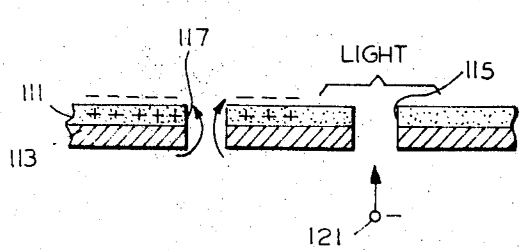

FIG. 5a

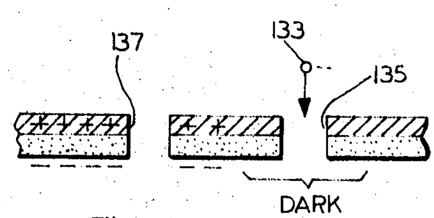

FIG. 5b

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ION PROJECTION APERTURE-CONTROLLED ELECTROSTATIC PRINTING SYSTEM

This invention relates to an aperture-controlled electrostatic printing process and method which employs a multilayer screen comprising at least a conductive layer and a superimposed insulative layer to enable the deployment of opposite electrostatic charges on the screen across the insulative layer. The double layer charges are modified in accordance with an image to produce blocking and nonblocking fields controlling the apertures in accordance with the image to be reproduced. The conductive screen layer is maintained at a potential (sometimes ground), and a propulsion field is provided for directing ions toward and through the screen. The ions pass through the screen where the apertures are not blocked by the fringing fields; they also pass through apertures which are partially blocked, but in fewer numbers. This process uses the fringing field pattern of the apertures which modulates the flow of ions through the screen to an insulative receiving medium, via preferably an air gap, for subsequent developing and fixing thereon, if necessary, by a conventional technique, such as for example, a liquid or a solid toner, an aerosol cloud, a magnetic brush, or the like.

In a second embodiment, the same type multilayer screen is charged and exposed and thereafter employed as a stencil through which ions are projected to a second multilayer screen; however, charged marking material is projected through the second screen onto print-receiving material, such as ordinary paper or the like, and is thereafter fixed as before.

The insulative layer of the screen may comprise a photoconductor which is merely charged or discharged in accordance with a light pattern, or it may comprise an insulator other than of the photoconductive type which may be electrically charged. Alternatively, if the selected insulator screen has a low dielectric strength, a thin undercoating of a high dielectric strength material, not necessarily photoconductive, is employed between the photoconductive layer and the conductive layer. Similarly, a thin overcoating of high resistivity material may be employed to provide a charged carrier for photoconductors with poor surface resistivity. When employing photoelectric materials that cannot be deposited in heavy layers, the insulating layer may be comprised of any good insulating material which will accept the sensitive material as a thin deposit. Thus, a thin layer photosensitive material may be coated over the screen comprised of an insulative layer and a conductive layer.

Other materials which may be used as the insulator layers are photoemissive material, polyester films, epoxy, photoresists, fused quartz, or combinations thereof. In addition, the conductor backing itself may be deposited on the insulator, or a separate insulator layer not taking part directly in the electrostatic process may be used to support both the conductor and insulator layers.

The receiving medium may comprise paper or other materials, preferably coated, in the first embodiment, with a very thin layer of plastic or other flexible insulative material, such as polystyrene, polyvinyl chloride, cellulose acetate, such thin layer coated paper being commercially available at the present time.

The present invention improves over the known stencil-type inventions, such as disclosed in U.S. Pat. No. 3,061,068 to C. O. Childress et al. issued Mar. 16, 1963, and entitled Electrostatic Printing System, for the reason that the screen employed in this patent must be in the form of a permanent stencil having openings where printing is desired and through which charged particles pass to the print-receiving material. These stencils, however, are not useful for producing more than one shape of image without resorting to stencil-forming processes to change the image. Such stencil-forming processes may be similar to the production of a silk screen image.

In the present invention, the screen is instantly reuseable and there is no physical stencil required.

The present invention differs from the inventions disclosed in U.S. Pat. No. 3,220,831 to Samuel McFarlane issued Nov. 30, 1965, entitled Electrostatic Printing Method and Apparatus Using Developer Power Projection Means, and also U.S. Pat. No. 3,220,833 to Samuel McFarlane issued Nov. 30, 1965, entitled Electrostatic Printing Method in that the McFarlane inventions employ electrostatic latent images which are powdered and the powder image is projected across an air gap from a photoconductive needle tip carrier in the former patent or from a photoconductive coated screen carrier in the latter patent.

The present invention actually electrostatically modulates the apertures of the screen through the provision of the double layer charge, which is modified in accordance with the image, to control the flow of ions through the screen to the print-receiving material where a charge pattern is built up in accordance with the image to be reproduced, such that development of the charge pattern results in production of a visible image. Alternatively, powder may be projected through the electrostatic stencil directly onto ordinary paper.

In the composite screen structure of the present invention, the conductive layer at fixed potential or ground performs two functions. In the first place, it enables the double layer charge to be established across the insulative layer, thereby developing the fringing or blocking fields within the apertures of the screen, which fields are subsequently modulated in accordance with the image pattern. In the preferred embodiment, it enables the maintenance of the blocking fields during projection of the ions; the charges of the ions which do not pass through the grid are simple dissipated due to the electrical potential maintained at the conductive layer.

The conductive layer may also be used to establish an electrical field between the screen and receiving material, if this is desired. The magnitude of this field can be used to control the fraction of emitted charge (number of ions) which reach the receiving medium.

Thus, the invention may comprise a composite screen mounted for endless movement and having at least an insulative layer and a conductive layer with coinciding mesh. The composite screen is uniformly charged. An imaging station is provided for exposing the charged screen. When a photoconductor is employed as the insulative layer of the screen, such a material is an insulator in the dark and becomes conductive upon light impingement. It can be charged by ions sprayed from an electrode, and a light image is then used to discharge those areas on which light impinges.

The discharged areas then permit ions from a further source to pass to a second multilayer screen to charge it in the discharged areas. Then either ions or charged inking materials pass through the uncharged areas of the second multilayer screen to produce positive printing directly on ordinary paper or positive printing is produced on nonconductive paper, following powdering of the charge pattern when ions are employed.

Of the photoconductive materials, it is known that selenium is preferentially sensitized with a positive charge and zinc oxide with a negative charge. Some materials, however, such as a mixture of cadmium sulfide and zinc sulfide may be sensitized with either a positive or a negative charge; it is from this group of materials that the insulative layer of the screen is preferably selected.

With the foregoing in mind, it is among the objects of the invention to provide an aperture-controlled electrostatic printing process and method using ion projection or ion-and-printing particle projection through modulated screens onto ordinary or nonconductive paper or other substrate across an air gap.

It is a further object of the invention to provide such reproduction simulating halftone printing with varying degrees of gray-to-black printing or sequential color reproduction.

A further object of the invention is the provision of the coordination including the novel arrangement of a multilayer screen susceptible to image modulation for controlling the passage of ions therethrough and a further multilayer screen to serve as an electrostatic stencil for ions or inking materials.

Another important object of the invention is the provision of reproduction methods and apparatus wherein no charged marking material is propelled against or through any of the components.

It is a further object of the invention to provide a method wherein a double layer charging of a screen may be employed for subsequent modulation or to provide blocking fields to ions in the apertures of blank areas of the image being reproduced for producing an electrostatic stencil for printing.

Yet another object is the provision of positive printing free of holidays and with good edge effects.

The invention will be better understood from a reading of the following detailed description thereof, when taken in conjunction with the drawing wherein:

FIG. 1 is a prior art arrangement to depict single charge stencil type blocking of charged toner particles with fringe effects;

FIG. 2 is a view in section of a preferred embodiment of the screen of the present invention;

FIG. 3 is an enlarged view of a portion of FIG. 2;

FIG. 4 shows a first embodiment of the invention employing ion projection to make an electrostatic stencil, in turn, used for building up an ion charge pattern, for subsequent developing and fixing;

FIG. 4*a* is a detailed view of a portion of the first multilayer screen, taken at point 4*a*;

FIG. 4*b* shows a similar detailed view of the second conveyor, taken at point 4*b;*

FIG. 5 is a schematic arrangement of apparatus for carrying out the second embodiment of the invention wherein the electrostatic stencil is produced and used for powder particle projection onto ordinary paper;

FIG. 5*a* is a detailed view of a portion of the first conveyor, taken at 5*a;* and

FIG. 5*b* shows a portion of the second conveyor or electrostatic stencil, taken at point 5*b*.

In FIG. 1 there is shown a prior art arrangement for stencil blocking utilizing a single sign charge layer only to show the limitations of this approach. The substrate **15** to be printed is positioned behind the stencil **17** which is positively charged, and the charged ink particles or toner material **19** are similarly charged and projected toward the substrate.

Electrostatic printing is normally achieved by the propulsion of the charged ink particles **19** through the fixed stencil **17** by means of an electric field. The blocked portions of the stencil **17** prevent passage of certain of the ink particles **19**, thus forming the image that is printed. This use of mechanical blocking requires that the stencils be prepared by mechanical or photochemical means; these are slow processes, requiring several hours for the completion of a screen stencil.

Greater usefulness of the electrostatic printing process is achieved if the stencils could be substituted for and the substitute prepared within seconds and if the image could be erased and the screen reused.

As is well known, the presence of a concentration of charges will create surrounding fields such that the charges of like sign are repelled from the charged area. It is clear that if an image is formed of a coplanar uniformly charged layer and the sign of the charges used to form the image is the same as the charge on the toner particles, the toner will be repelled from the charged areas, thus producing the blocking required to use the image as a stencil. Since this blocking of the passage of the charged toner or equivalent is accomplished by the field surrounding the charge layer, these fields are called "blocking fields."

A one-sign charge layer, however, will not satisfy the requirements of a blocking field, since the field of such a system extends in all directions from the charges. Thus, toner particles will be repelled not only from the surface of the charge layer (the desired blocking effect), but also from the edges of the charge layer which exist at the image boundaries (FIG. 1). For printing to occur, particles must pass through the uncharged areas (indicated in FIG. 1 as "Area to Be Printed"). The lateral repulsion field existing at the edge of the layer increases the blocking area, diffuses the edges of the printed image, and prevents passage of ink through small gaps in the charge layer.

The present invention overcomes the problems described above while permitting the desired charge layer blocking in the nonprinting areas of the image.

The screen used to carry the charges and the disposition of charges on the screen so as to perform the blocking action relative to ions **20**, thus forming an electric charge pattern, are illustrated in FIG. 2. The screen is constructed of conventional insulator material **21** layered with a conductor **23**; the holes **25** through which the ions pass extend in coincidence through both layers of the screen.

Electrical connection is made to the conductor layers **23** of the screen by tab **31** and lead **33** so that the potential of the backing members can be maintained at, for example, ground or other desired potential during charging, exposure, and ion or powder projection.

The insulator portion is charged so as to acquire a "double layer" of charges (as indicated in FIG. 3) in which one face of the insulator **21** contains charges of one polarity, while the other surface contains an equal amount of charges of opposite polarity. (The charge layer which is formed on the insulator surface in contact with the conductor appears on the surface of the conductor **23** as shown in FIG. 3). Thus, the net charge on the screen is zero; therefore, no field exists from these charges at a distance of more than few screen thicknesses away from the charged double layer. The motion of ion particles which have passed through the screen at uncharged areas is therefore not affected by the charged areas of the screen.

Charging of the form indicated in FIG. 3 is made possible by the presence of the conductor layer. A charge source, such as a corona wand, Corotrons, or radioactive strip, is used to spray ions on the surface of the insulator; the conductor portion of the screen is maintained at a fixed potential (or ground) during this process so that any charge which deposits on the insulator surface will attract an equal and opposite charge to the junction between the insulator and the conductor, thus creating the required double layer.

Blocking of ions in the charged areas is performed by the fringing fields which exist within the holes of the screen. The basic fringing field is oriented so as to prevent ions from passing through a hole. The electrical field lines within the apertures are such that the positively charged ions **20** will be deflected to one or the other sides of an aperture and are collected and the charge dissipated by the conductor **23**.

If the ions **20** are positive, then the double layer charges are arranged so that the particles approach the screen's negatively charged side; conversely, negative ions must be directed toward the positively charged surface. The same principles obtain with charged marking material.

The weakest fringing field exist along the center of the hole, and the magnitude of this field depends on both the charge magnitude (strength of the field inside the insulator) and the thickness-to-diameter ratio (T_I/D) for the screen to aperture. Since the fringing field increases in strength as the insulator thickness increases, it is clear that for effective blocking a large ratio of T_I/D as well as high charge level is desirable. The amount of fringing field required to block the ions depends on the strength of the field used to propel the ions from the source to the printing substrate, i.e., the relative Corotron potential level, spacing and any additional propelling fields. If the ions had no inertia, blocking would occur if the combination of fringing field and the propulsion field, which act in opposition, produce a net zero field or repulsive field at any point along the centerline of the hole. Ion inertia effects, however, will carry the ion through the hole unless the combined fields within the hole exert a net repelling force. Of course, the powder particles have greater inertia and, accordingly, repulsive electric fields of greater magnitude may be required.

The preferred technique is the utilization of a photoconductive material as the insulator layer of the screen for either type printing. Such a material, which is an insulator in the dark and becomes conductive in the light, can be charged as described above, e.g., with a corona wand, and a light image used to discharge those areas to be printed.

In FIG. 4 there is shown a first conveyor **11** of the double layer type. It comprises an insulative, or preferably photoconductive, screen layer **13** and a conductive screen layer **15**.

A detailed showing of a portion of the conveyor is shown in FIG. 4*a*, wherein it is seen that the corona source or Corotron **17** projects negative ions onto the insulative layer **13**, which ions cause the double charge to appear across the insulator **13**. The source E_1 is a direct current source of conventional nature, and the proximity of the discharge wire of the corona source to the conveyor **11** determines the preferred potential, which may be in the range of 3,000 to 5,000 volts or higher.

The charged conveyor moves to the scanner station wherein a conventional scanner **19** is provided to project image light via lens **21** onto the conveyor **11**. This may be done in line-by-line fashion or image-by-image fashion, particularly for intermittent movement. The charge on the conveyor **11** is not dissipated until the light shines on the photoconductor **13** to lower its resistence, the unit being within light-tight housing **25** provided with an access for the original of the image **27** to be reproduced in known fashion. Where the light impinges, however, the charge is dissipated, as is also represented in FIG. 4*a* by the bracket bearing the legend "Light."

The conveyor **11** is then moved past further Corotron or corona source **31** which sprays negative ions, generated by source E_2, toward the now exposed (image) areas. As can be seen in FIG. 4, the ions, such as **35**, move through the exposed apertures, such as **37**, but the ions **39** in the regions of the unexposed apertures **41** are blocked due to the fringing field in these unexposed apertures; therefore, the second conveyor **51**, which may be identical to conveyor **11**, receives a double layer charge in the regions of light exposure. This is represented in FIG. 4*b* wherein the insulator **53** is sprayed with negative ions and the conductive screen layer **55** permits the double layer to be produced. Thus, in FIG. 4*b* the negative ions, such as **57**, will pass through apertures, such as **59**, in the uncharged regions and the ions, such as **61**, are blocked in the charged regions, such as aperture **63**. Particle is herein defined as either ions or powdered marking material, as will be apparent from the description of FIG. 5.

The negative ion source **65**, which is at a DC potential E_3, may correspond to the negative ion sources **17** and **3**. Alternatively, the sources **31** and **65** may comprise banks of Corotrons at potentials up to 8,000 volts DC for spraying entire images at once. A conventional anti static or erasure station **50** is disposed adjacent conveyor **51** in order to remove the charge therefrom and permit continuous operation of the system.

The negative ions, such as **57**, passing through the uncharged regions (apertures **59**) produce a charge pattern on print-receiving material **67** carried by an ordinary conveyor **69**. The print-receiving material **67** preferably has a thin insulative coating in order that the charge pattern will not dissipate. The paper **67** is then conveyed under a conventional powdering source **71**, which includes the charged marking material **73**, charged by revolving brush **75** connected to the positive source E_4. Thereafter, the printing material **73** adhering to the charging pattern on paper **67** is fixed by heat source **77** and then removed from the light-tight housing **75** by wedge **79**.

The conveyors **11**, **51**, and **69** may be at potentials other than ground to aid in propelling the ions across the air gaps or the powder to the substrate. Such arrangements are described in copending U.S. Pat. application, Ser. No. entitled "Aperture-Controlled Electrostatic Printing System and Method Employing Ion Projection," invention by Samuel B. McFarlane, Jr., Joseph Burdige, and Norman E. Alexander.

In FIG. 5, the preferred embodiment of the invention is depicted wherein the ion stencil principle is employed with powder projection across an air gap to reproduce on ordinary paper. The first conveyor **101** is charged by ion projection from Corotron **103**, powered by source E_1'. The scanner **105** exposes conveyor **101** within the light-tight housing **107**. Scanner **105** may have a door or slot **109** through which the original to be reproduced is inserted.

In FIG. 5*a*, the charged and exposed conveyor **101** is shown in detail as comprising photoconductor **111** and conductive backing **113**. Where the photoconductor **111** is exposed is indicated by the legend "Light." Here the fringing fields have been eliminated, as at aperture **115**. In the dark regions (indicated by aperture **117**), however, the blocking fields remain.

Thus, when the conveyor reaches Corotron or ion source **119**, powered by DC source E_2', the negative ions emitted, such as **121** (FIG. 5*a*), can only pass through the exposed apertures, indicated at **115**.

In the manner hereinbefore explained, the second conveyor **125** is sprayed with negative ions across the air gap wherein the ions can only pass in conformity with the light regions of the original image. Thus, conveyor **125** becomes an electrostatic stencil for the powder or marking material source **131**. The powder is charged negatively by source E_5 and a particular powder particle **133** is shown passing through aperture **135** corresponding to the dark region of the original image, which aperture has been unblocked. Aperture **137** is blocked in the light region and so prevents powder passage to the ordinary paper **139** carried by ordinary conveyor **141**. Heat fixing means **143** is depicted, and the conveyor exits from housing **107** with the image reproduced thereon.

A conventional antistatic or erasure station **126** is disposed adjacent conveyor **125** in order to remove the charge therefrom and permit continuous operation of the system, and a vacuum system (not shown) may be utilized with station **126** to clean marking material from conveyor **125**.

In the various embodiments, the ions and charged printing particles employed and the polarities of the voltage sources are determined by the materials used, but one principle obtains; namely, that the fringing fields block when they are oriented in the direction to oppose the ions. Thus, if positive ions or powder are projected toward the screen from the inside, a fringing field would oppose such ions if its direction were from outside the screen toward the inside thereof. With this principle in mind, the photoconductor can either be inside or outside the screen and the source of ions and powder accordingly disposed.

In general, the voltage magnitudes are not critical, and the voltage sources (which may all be derived from a common power supply) are preferably made adjustable to compensate for humidity and environmental conditions. The sources should not, however, be adjusted to a sufficiently high magnitude as to project the particles or ions through the blocking areas. This condition is readily obtainable and remains substantially constant, because projection through the unblocked apertures can be attained at much lower potentials which will not propel particles through the fringing or blocking fields.

Since further modifications of the invention within the principles herein taught may readily occur to those skilled in the art, it is intended that the invention be limited only by the appended claims wherein:

What I claim is:

1. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along predetermined paths, said screen means each comprising an insulative screen layer and a conductive screen layer; means for electrically charging the insulative layer of the first screen means with substantially equal and opposite charges; means for modifying the charges of the first screen means in accordance with an image to be reproduced; means for directing charged particles toward the first screen means in the regions of modified charges to permit selective passage of particles to a second screen means across a gap; means for projecting charged particles from a further source through the second screen means; and print-receiving means for intercepting the last-mentioned particles and developing the image.

2. The apparatus of claim 1 wherein the means for directing charged particles and the means for projecting charged particles comprise ion sources.

3. The apparatus of claim 1 wherein the means for directing charged particles comprises an ion source and the means for projecting charged particles comprises a source of marking material.

4. The apparatus of claim 1 wherein the means for modifying the charges of the first screen means in accordance with an image comprises image light projection means which permit the dissipation of the charges in the areas of light impingement; and the means for directing charged particles toward the first screen means are oriented relative to the screen means to project charged particles of opposite sign to the charges on the side of the screen means adjacent thereto.

5. The apparatus of claim 1 wherein the means for modifying the charges of the first screen means in accordance with an image comprises image light projection means which permit the dissipation of the charges in the areas of light impingement; and the means for directing charged particles from a further source are polarized to project charged particles of opposite sign to the charges on the side of the second screen means adjacent thereto.

6. The apparatus of claim 1 wherein the means for charging comprises a source of negative ions disposed adjacent to the insulative screen layer; the means for directing charged particles comprises a source of negative ions disposed adjacent to the conductive screen layer; and the means for projecting charged particles from a further source comprises a source of negative ions disposed adjacent to the conductive layer of the second screen means.

7. The apparatus of claim 1 wherein the means for charging comprises a source of negative ions disposed adjacent to the insulative screen layer; the means for directing charged particles comprises a source of negative ions disposed adjacent to the conductive screen layer; and the means for projecting charged particles from a further source comprises a source of inking material charged negatively and disposed adjacent to the conductive layer of the second screen means.

8. The apparatus of claim 1 wherein the first and second screen means are oriented to dispose their respective insulative layers to define the air gap between said first and second screen means.

9. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along predetermined paths, said screen means each comprising an insulative screen layer and a conductive screen layer; means for electrically charging the insulative layer of the first conveyor with substantially equal and opposite charges; means for modifying the charges of the first screen means in accordance with an image to be reproduced; means for directing ions toward the first screen means in the regions of modified charges to permit selective passage of ions to a second screen means across an air gap; means for projecting particles from a further source through the second screen means onto print-receiving means across a further air gap; and means for developing the print-receving means.