

[54] APERTURE-CONTROLLED
ELECTROSTATIC PRINTING SYSTEM AND
METHOD EMPLOYING ION PROJECTION

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Related U.S. Application Data

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which is a division of Ser. No. 709,578, March 1,
1968, Pat. No. 3,645,614.

[52] U.S. Cl. 355/17; 355/3
[51] Int. Cl. G03g 17/00
[58] Field of Search 355/3, 17; 96/1

[56] References Cited
UNITED STATES PATENTS

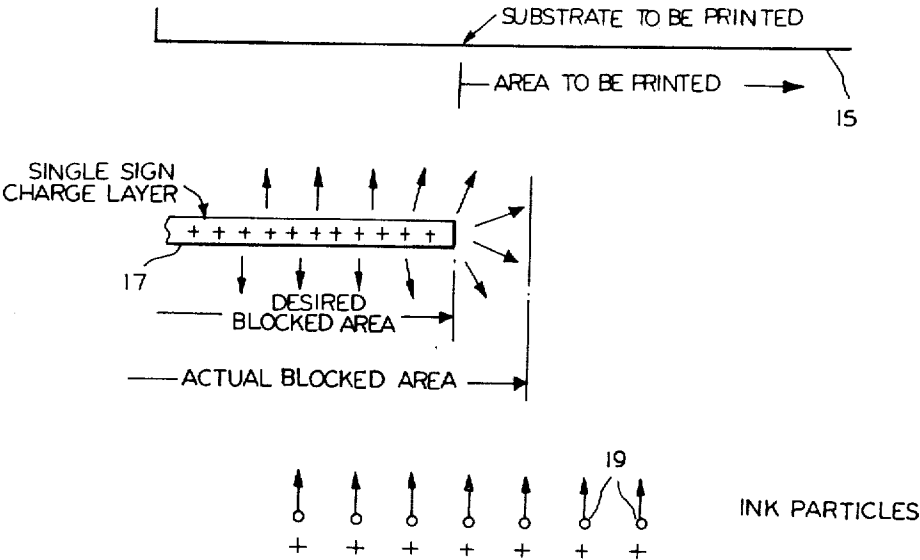
3,339,469 9/1967 McFarlane 355/3

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Attorney, Agent, or Firm—Wilfred G. Caldwell, Esq.

[57] ABSTRACT

Methods and apparatus for electrostatic printing in-
cluding a multi-layer 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 modulating the charge on the insulative layer in
accordance with light received thereby, a Corotron or
other like means for projecting ions through un-
blocked apertures in the screen and through partially
blocked apertures in the screen in fewer numbers to a
substrate for subsequent developing and fixing to pro-
vide both positive and negative reproductions.

19 Claims, 10 Drawing Figures



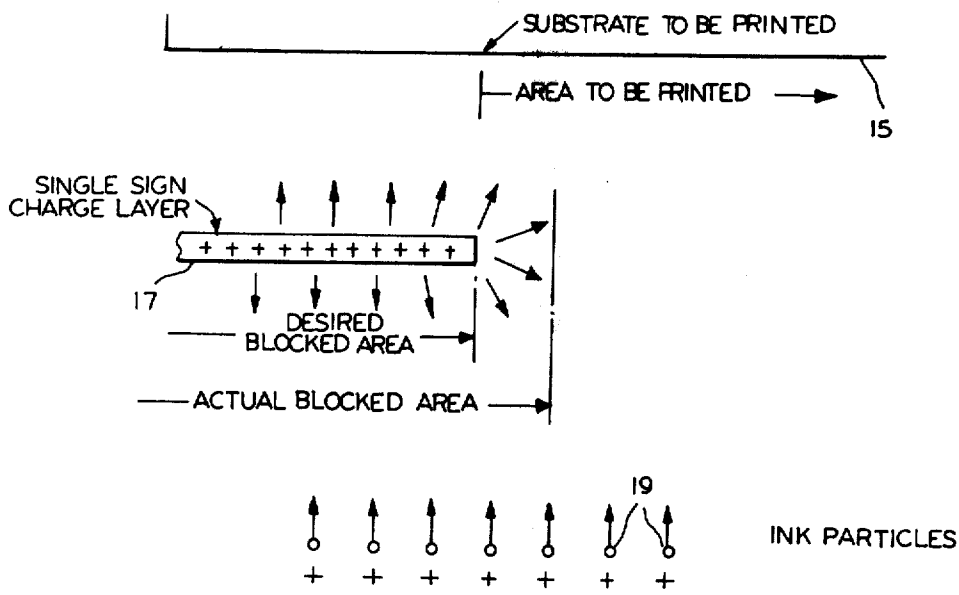


FIG. 1

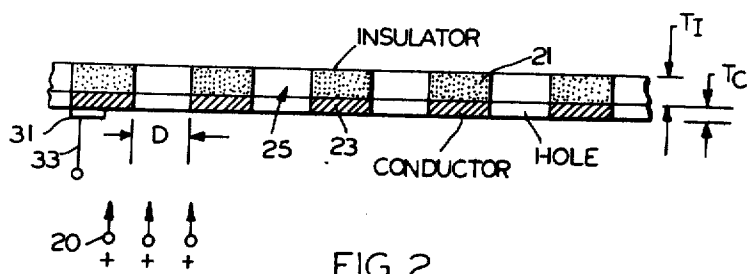


FIG. 2

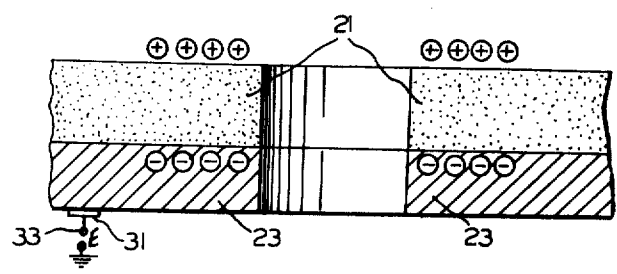


FIG. 3

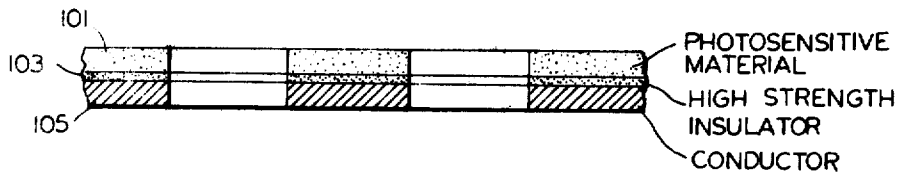


FIG. 4a

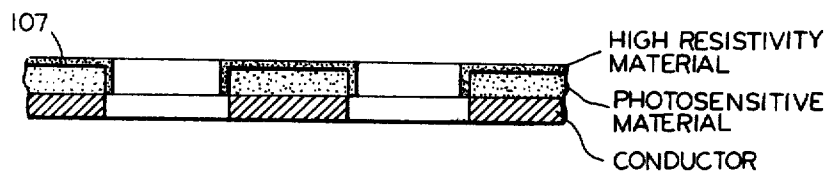


FIG. 4b

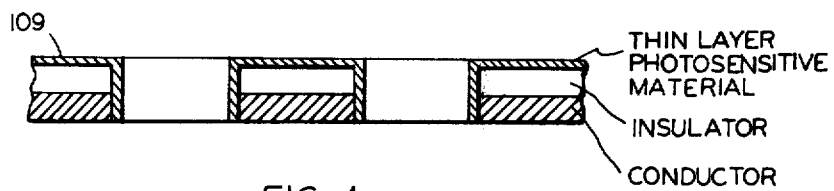


FIG. 4c

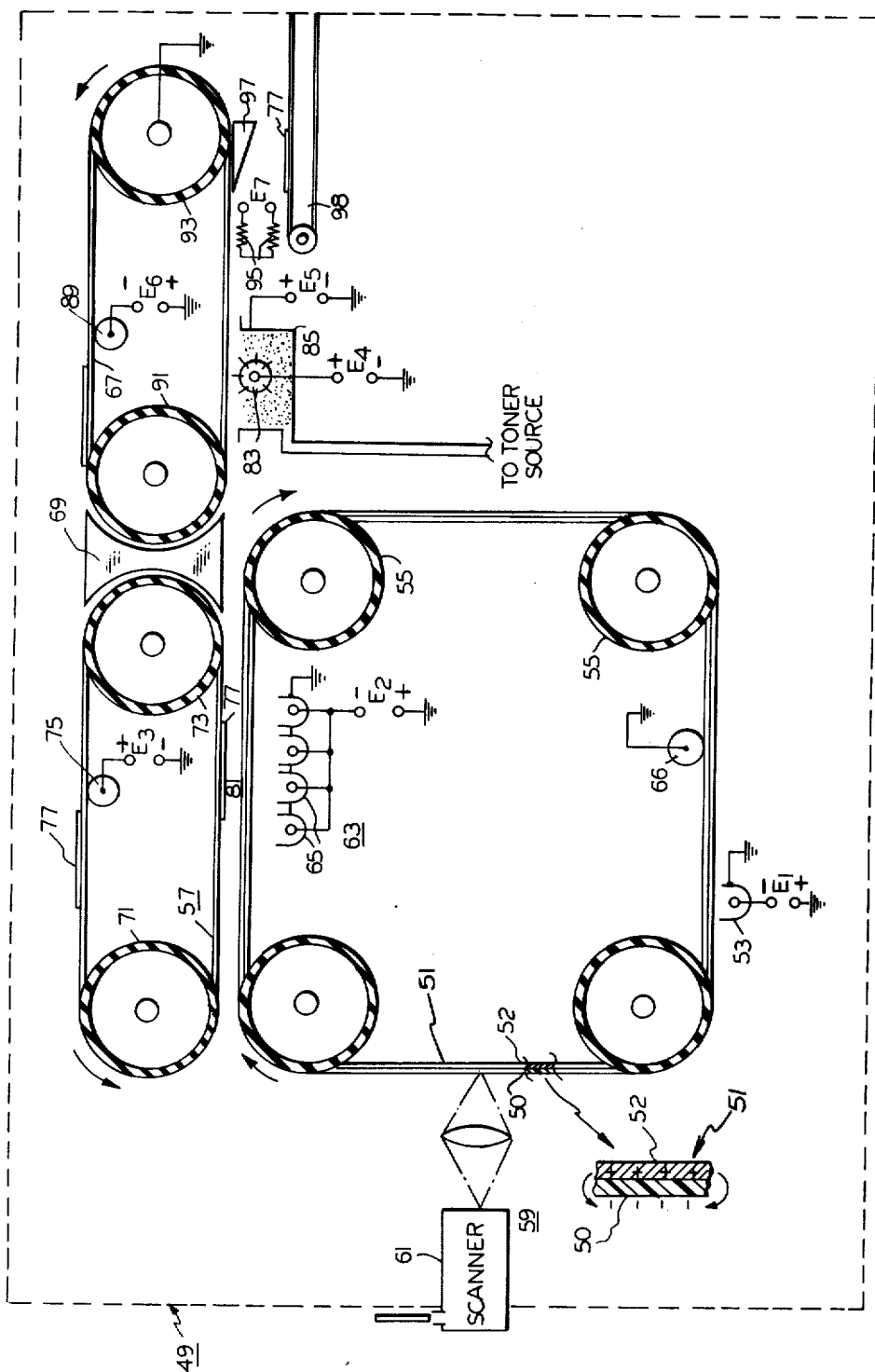


FIG. 5

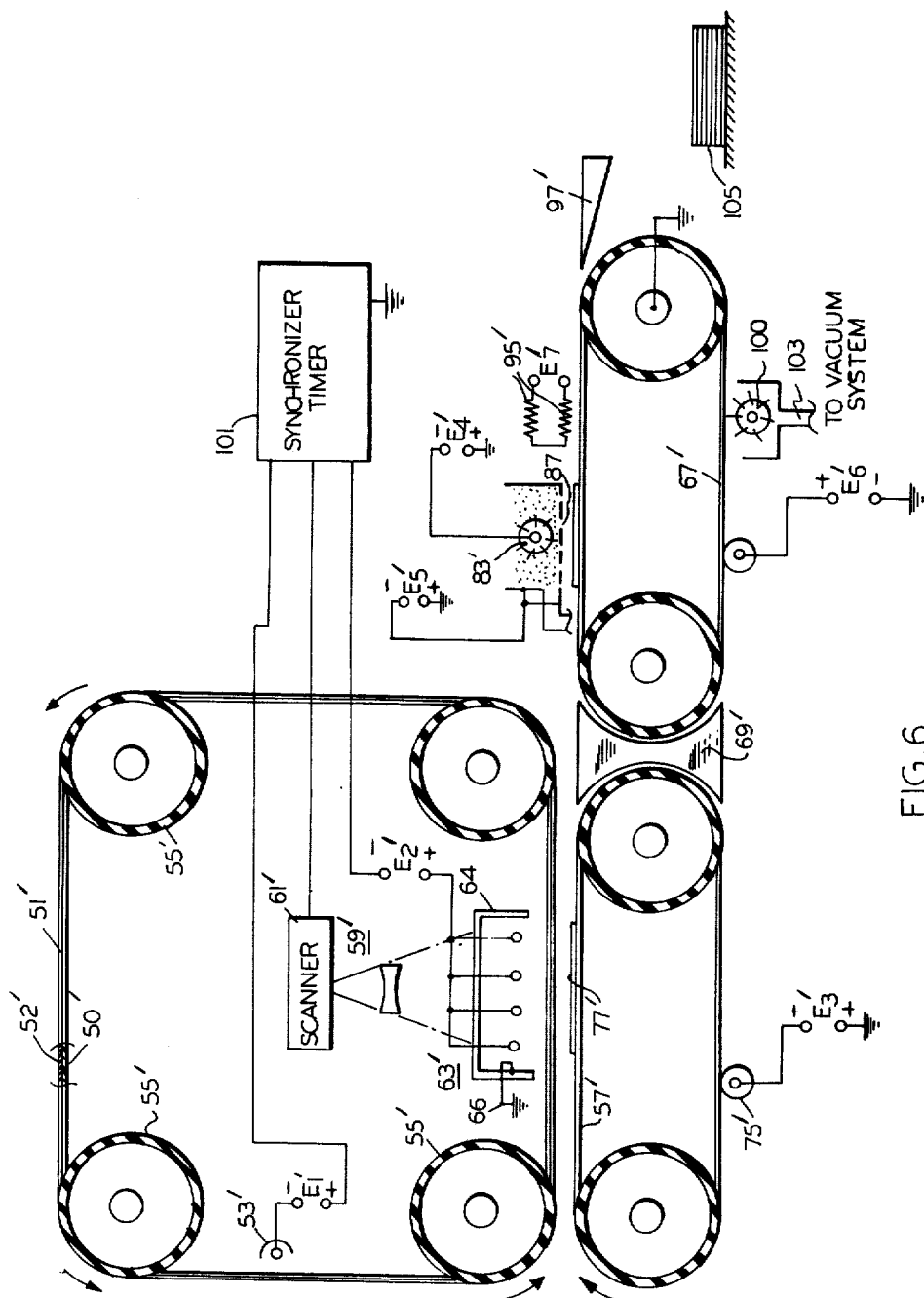


FIG. 6

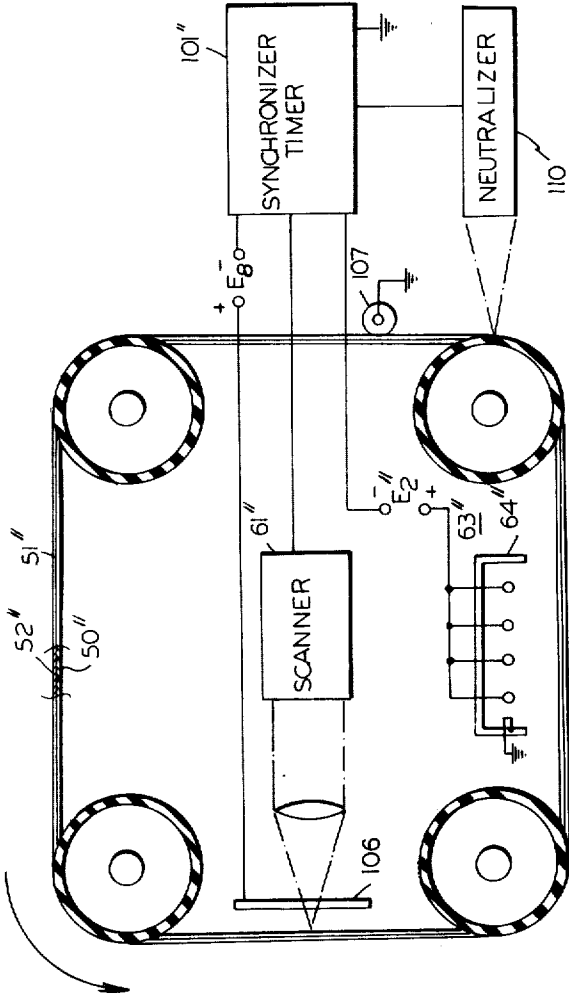


FIG. 6a.

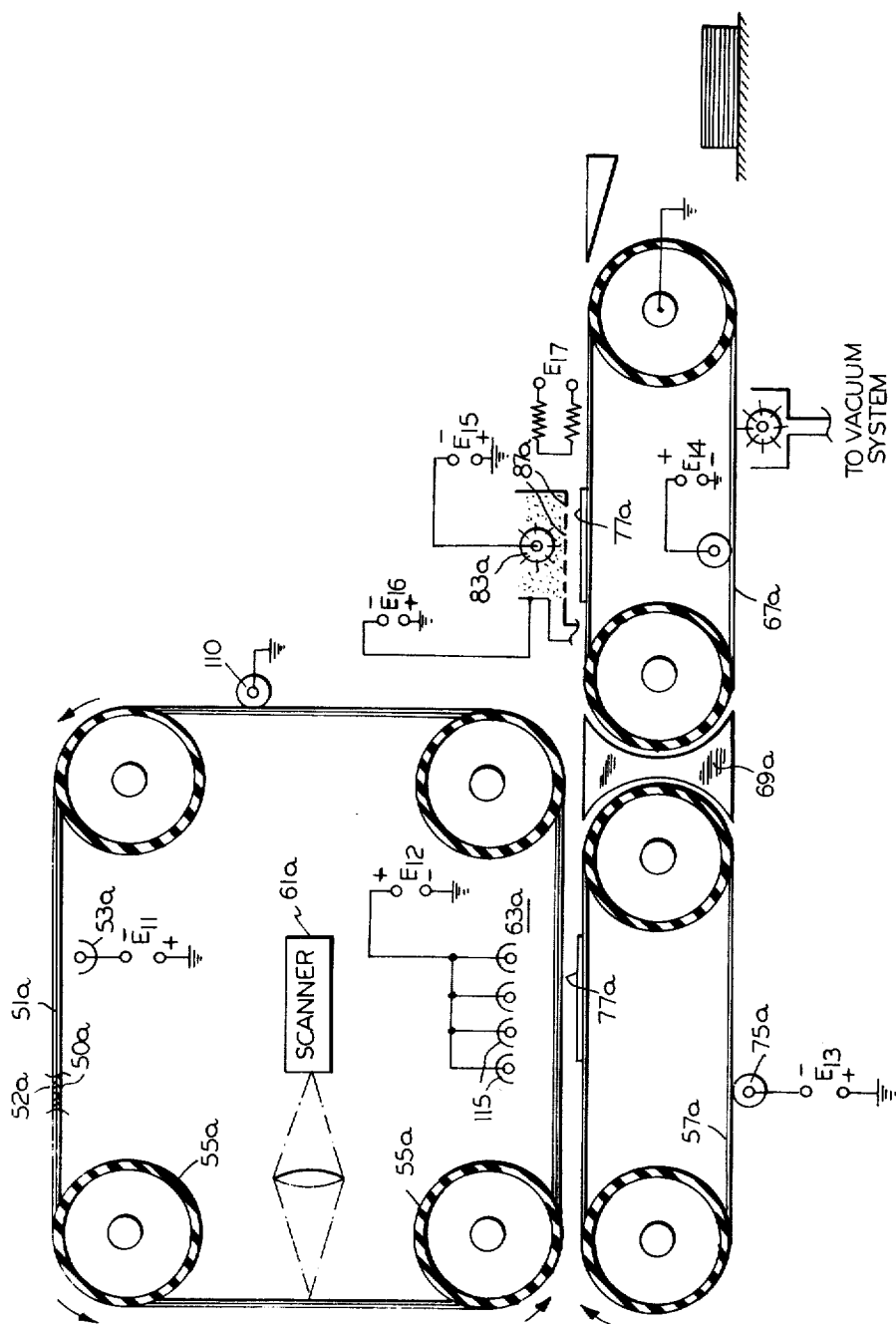


FIG. 7

APERTURE-CONTROLLED ELECTROSTATIC PRINTING SYSTEM AND METHOD EMPLOYING ION PROJECTION

This is a continuation of application Ser. No. 167,011 filed July 28, 1971 which is a Divisional of U.S. Pat. No. 709,578 filed March 1, 1968 now U.S. Pat. No. 3,645,614 issued Feb. 29, 1972.

This invention relates to an aperture-controlled electrostatic printing process and method which employs a multi-layer screen comprising at least a conductive layer and a superimposed 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 non-blocking 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.

The insulative layer of the screen may comprise a photoconductor which is merely charged or discharge 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 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 process may be similar to the production of a silk-screen image.

In the present invention, the screen is instantly reusable; there is no physical stencil required; and no problems of any buildup of toner particles on the screen are encountered.

The present invention differs from the inventions disclosed in U.S. Pat. 3,220,831 to Samuel McFarlane issued Nov. 30, 1965, and entitled Electrostatic Printing Method and Apparatus Using Developer Powder Projection Means, and also U.S. Pat. 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 power 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.

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 simply 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 to be printed. The light image is reproduced in negative form because printing occurs where the image light impinges on the screen and the discharge has been diminished or reduced to zero. For positive printing, the screen may be charged

by an applied (internal) field during exposure to the light images. Illuminated areas of the screen photoconductive layer become conductive and under the influence of the applied field cause a charge separation similar to the double layer charge previously mentioned. After the charge separation is formed, the illumination is removed, causing all parts of the screen photosensitive layer to become insulative. Then the charging field is removed; the portions of the field which were illuminated remain charged and thus block the passage of the ions during the pattern buildup on the viewing material.

The ions from the latter source neutralize the oppositely charged ions where they exist on the screen, but pass through where they have been neutralized or diminished by the light exposure. Timing is critical in this approach, because the exposure should be limited in time so that it only takes off the charges where the light impinges.

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

In the case of negative printing as in microfilm exposures, the modulated apertures of the screen, depicting the image area, move into an ion propulsion field where ions are projected toward the screen and pass through the screen in accordance with the modulation to continue across an air gap, due to the propulsion field, to flexible plastic coated print receiving paper. The charge pattern created by the ions on the nonconductive paper is then developed with, for example, charged ink particles. A heat fixing station fixes the ink, where necessary, because this process may employ powdered inks, as well as aerosol sprays or liquid droplets.

With the foregoing in mind, it is among the objects of the invention to provide an aperture-controlled electrostatic printing process and method which enable printing through a modulated screen onto nonconductive paper or other substrate, across an air gap.

It is a further object of the invention to provide such reproduction simulating half-tone 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 multi-layer screen susceptible to image modulation for controlling the passage of ions therethrough.

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, thereby avoiding such overall problems as clogging of apertures, transport to and through the screen, and removal of excess or unused marking material.

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.

Yet another object is the provision of positive or negative 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. 4a is a view, in cross section, of a portion of a screen showing the use of low dielectric strength photosensitive material in conjunction with high dielectric strength insulative material placed between the photosensitive layer and the conductive layer;

FIG. 4b is a similar view showing the use of high resistivity material as the charge carrier overlying photosensitive material with poor surface resistivity;

FIG. 4c is another view employing a conductive layer, a good insulative layer, and a thin layer of photosensitive material deposited over the insulator and within the apertures;

FIG. 5 is a schematic arrangement of an apparatus which uniformly charges the screen, exposes, projects ions through the modulated apertures, and develops and fixes the charge pattern on the print receiving material;

FIG. 6 shows a similar apparatus but wherein scanning or modulation may be effected almost simultaneously with, but just prior to, projections of the ions for positive printing;

FIG. 6a illustrates apparatus for another method of positive printing wherein the applied field of the screen is modified in accordance with the double charge principle; and

FIG. 7 shows a further apparatus suitable for sequential charging, exposing, projecting of ions, developing and fusing similar to the apparatus of FIG. 5 but using differing polarities therefrom.

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 coplanar uniformly charged layers 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 fields of such a system extend 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 in the 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 layer 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 projection.

The insulator portion is charged so as to acquire a "double layer" of charge (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 charge 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 a 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 disseminated 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 weakest fringing field exists 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/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/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.

Since no charged marking materials are projected toward or through the screen, it is unnecessary to be concerned over the collection of such marking material on the screen. In addition, the need for providing metering and distributing devices is obviated.

To obtain printing, the charge image on the screen in at least one embodiment must be the negative of the desired print, i.e., printing will occur where no charge or reduced charge exists. A number of techniques may be used to create the charge image.

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. Thus, the light image would be reproduced in negative form.

The preferred embodiment of the invention relates to positive printing, and particularly to FIGS. 6 and 6a. In FIG. 6 the screen is charged by an ion source and discharged by the image prior to or substantially simultaneously with the projection of ions of opposite sign of the charging ion source therethrough where discharge and partially discharged.

Otherwise, and even more preferable, as for suitable conventional materials, the screen may be charged by an applied field during exposure to the light image and ions of the opposite sign projected therethrough where discharged by the light image, as in FIG. 6a, to produce positive images.

Effective field blocking of ions requires a combination of high charge level and suitable insulator thickness. The range of photosensitive materials which may be used for the insulator layer can be extended by special screen configurations. If the desired insulator material 101 (FIG. 4a) has low dielectric strength, thus limiting the degree of charge separation it can support, a thin undercoating 103 of a high dielectric strength, but not necessarily photoconductive, material can be used to separate the photosensitive layer from high field regions near the edge of the holes. The conductor 105 is affixed to the undercoating 103.

Similarly, a thin overcoating 107 (FIG. 4b) of high resistivity material can be used to provide a charge carrier for photoconductors with poor surface resistivity.

For photoelectric materials, that cannot be deposited in the layers appropriate to this process, the insulating layer may be formed of any good insulating material which will accept the sensitive material as thin deposit 109 (FIG. 4c). The entire screen, including portions of the conductive layer, may be coated.

It is computed that the form of the field within the hole is such that, if a hole is only partially charged, i.e., has not developed sufficient charge to block, the effects of the charge is to limit the aperture of the hole. Partially charged holes are created by reduced exposure during discharge, as would occur in gray areas of the image. Thus, gray areas reproduce with reduced apparent aperture, forming a half-tone reproduction of a continuous-tone source.

In FIG. 5 a light-type box is generally shown in dotted outline at 49, housing the equipment for reproduction using the ion principle herein disclosed. The main conveyor comprises screen 51 made in accordance with one or more of the embodiments described herein. A double layer charge may be produced by Corotron or corona source 55 which is at an adjustable potential E_1 to spray the photoconductor side 50 of screen 51 with negative ions, thereby effecting a uniform charge on photoconductor 50 relative to conductor layer 52. The screen 51 is conveyed in endless fashion through conventional components, such as the insulated drive drums or sprockets 55, and the motion may be intermittent or synchronized with the paper conveyor 57.

The uniformly double charged screen 51 moves to the image station 59 where a conventional scanner 61 or image projecting arrangement shines light in accordance with the image to discharge screen 51 in such a way as to modulate the apertures thereof, some apertures being discharged completely, some partially, and some not at all, in accordance with the image to be reproduced.

The electrostatic latent image in the form of modulated screen apertures is then conveyed to the ion projections source 63, which may comprise a bank of Corotrons 65 disposed quite closely to the interior, i.e., conductive layer of screen 51. The bank of Corotrons 65 projects negative ions toward the grounded, as by roller 66, or positively charged side (the conductive layer) to permit the ions to pass through screen 51 in accordance with the potential distribution across the modulated apertures. Here again conventionally available controls may be employed for intermittently or continuously discharging the bank of Corotrons 65.

It will be seen that the voltage E_2 is of such polarity as to cause negative ions to be propelled toward and through the screen, thus providing an opposite charge relationship, i.e., positive charges on the side of screen toward which the negative ions are projected. The voltage source E_2 may be of the order of 8,000 volts d.c.

The schematic arrangement of FIGS. 5, 6, and 7 may be built generally using components selected from the apparatus and control circuitry of U.S. Ser. No. 565,284 in the name of Samuel B. McFarlane, Jr. filed July 14, 1966, and entitled Method and Apparatus of Electrostatic Color Reproduction or the U.S. application Ser. No. 673,499 entitled Modulated Aperture Control for Electrostatic Printing to Gerald Pressman, and assigned to the same assignee as the subject invention. Exposure and printing are preferably carried out with the conveyor intermittently stopped, although exposure may be accomplished in line-by-line fashion on a continuous

basis and printing done as above described. Similarly, sequential color reproduction may be achieved with the present invention in accordance with the apparatus disclosed herein identified and as in the McFarlane application.

In the apparatus of FIGS. 5, 6 and 7, all fields depicted are preferably direct (d.c.) potential fields, and all may be derived from a common power supply.

The arrangement of FIG. 5 is preferably as shown, with the isolated paper or print receiving material carriers, shown as conveyors 57 and 67, electrically isolated as by a polystyrene or plastic spacer 69, which enables the conveyors 57 and 67 to be at different potentials. In conveyor 57 the drums 71 and 73 are preferably insulated, and a positive potential from source E_3 , e.g., adjustable from 0 to 3,000 volts, is mesh or other conductive material. The paper or other print receiving material 77 may be caused to adhere to the conveyor 57 by vacuum or edge holding means, not shown, or it may be disposed beneath conveyor 51, as shown in FIGS. 6 and 7.

With the source E_3 applying a positive potential to the carrier or conveyor 57, it will be seen that the field projecting the negative ions in accordance with voltage source E_2 is enhanced and the source is preferably adjustable for setting in accordance with the environment, i.e., humidity and other factors which affect potential distribution across the gap 81.

Once the charge pattern is produced on the print receiving material 77 with its non-conductive coating, the material or paper 77 is transferred to conveyor 67 where charged marking powder is caused to be attracted thereto due to the revolving brush 83 and conventional powder charging source E_4 . Since the pattern is comprised of negative charges, the powder is positively charged by source E_4 for better adherence. Also, the power holder compartment 85 may include a screen or mesh 87 across its top through which the powder particles are projected. This screen may be maintained at a positive potential by a source E_5 to further enhance the projection or powdering field. Also, source E_6 connected to roller 89 may establish a negative potential level for conveyor 67, supported by insulated sprockets or drums 91 and 93 in order further to improve the powdering action. The potential of these latter sources is not critical and may be adjustable in the range of 500 to 1,000 volts.

In this embodiment fixing is carried out by conventional means with heater source E_7 supplying heating coils or resistors 95 to fix the resin binder of whatever printing material is employed. A wedge 97 serves to drop the printed sheets 77 onto a further conveyor 98 for exit from the light tight housing 49. Fixing may be accomplished also by means of a liquid toner, a bead cascade, an aerosol cloud, a magnetic brush, or the like.

In FIG. 6, there is disclosed an embodiment wherein exposure and ion projection may take place simultaneously or substantially at the same time or flash exposure may occur some timer prior to ion projection if material such as cadmium sulfide and zinc sulfide are used as the photoconductor layer. In this embodiment, the photoconductor layer 50' comprises the inner side of conveyor 51' with the metal or conductive screen layer 52' being exposed exteriorly of conveyor 51'. A corona source 53' of negative ions from voltage source E_1' is supplied to the photoconductor 50' of

conveyor 51', also mounted on insulated drums or wheels 55'. The negatively charged carrier 51' is exposed by scanner 61' at image station 59' by way of the Nesa glass compartment 64, or other transparent conductive material, which has its inner surface grounded at 66. The bank of Corotrons 63' are in this embodiment connected to the positive side of source E_2' .

Positive ions are projected toward the negatively charged conductor layer 50' and pass where permitted to the paper or print receiving material 77' carried on conveyor 57' which is at a negative potential due to source E_3' connected via roller 75'. Here again the operation may be intermittent or continuous, depending upon the type scanner 61' employed at image station 59' and the synchronization of conveyors 51' and 57'.

Powdering is effected by rotating brush 83' now connected to negative source E_4' with screen 87 also being connected to negative source E_3' .

Fixing is also effected in conventional manner by resistors 95' and source E_7' .

The second conveyor 67' is maintained at a positive potential level by E_6' and a vacuum cleaning system comprising brush 100 and exhaust conduit 103 is provided to clean the powder marking material from conveyor 67'. The wedge 97' is provided to stack the print receiving material in the stack 105. The usual light-tight housing is provided (not shown) as is shown in FIG. 5.

In operation, positive printing is achieved by flashing the image from scanner 61', either image by image or line by line, only long enough to discharge the negative charges in the areas to be printed, thus eliminating or diminishing the fringe fields in the image light regions relative to the dark regions.

A timer, shown as synchronizer timer 101, which may comprise a commercially available counter, such as manufactured by Eagle Signal Division of E. W. Bliss Co., is provided to flash the scanner 61' and to apply the voltage source such as E_1' and E_2' in proper sequence. Since the photocopy unit is in a light-tight housing, it is not necessary that the scanner 61' flash the image through the location of the Nesa glass 64', but only that it flash the image onto the negatively charged conveyor 51' subsequent to energization of Corotron 53'.

The light discharges the regions where it impinges, thereby eliminating the fringing fields at the apertures illuminated. Then the bank of Corotrons 63' projects positive ions toward the screen and they pass in the illuminated areas to the paper 77' to cause the charge pattern buildup in accordance with the original scan. This may be achieved in line by line fashion, but is illustrated in image by image reproduction; for this arrangement an intermittent drive (not shown) is provided, also under the control of synchronizer timer 101.

The other positive printing method and apparatus is shown in FIG. 6a, which would also incorporate the conveyors 57' and 67' and associated powdering and cleaning equipment, as shown in FIG. 6. In FIG. 6a the photoconductive screen is also on the inside, as shown at 50'' of the screen 51'' with the metal screen 52'' facing outwardly. The scanner 61'' focuses the image onto the photoconductive side 50'' of the screen 51'' via transparent electrode 106 which is at the potential E_8 , in this case shown as a positive potential, and conductor layer 52'' is grounded at 107. The magnitude of source E_8 may be selected from a wide range because

the only purpose of this source is to establish an applied or internal field which can be ruptured by image light spots impinging on the photoconductor to permit a double layer charge buildup. This charge buildup is trapped by removal of source E_8 because of the dark housing interior, and accordingly the charge pattern is then conveyed to the bank of Corotrons 63'' conveniently disposed in Nesa glass housing 64''.

Depending upon the materials employed and particularly the type junction between layers 50'' and 52'', a positive or negative charge can be built up on photoconductor 50'' where exposed to the light. If zinc oxide is employed as the photoconductor material, the charge will be negative and with, for example, selenium as a photoconductor material, it will be positive.

In either event, the principle obtains that the charge pattern produced by the flash of light removes fringing fields only where the light impinged, because the photoconductor becomes conductive to leak off the charges.

For example, assume that the materials of the screen are such that the positive transparent electrode 106 induces a charge separation with the negative charge disposed on the inside of screen 51, i.e., on the photoconductor, and the positive charges are on the opposite side. Then the fringing fields will be oriented in the direction from outside the apertures to the inside, or outside the conveyor 51 to the interior thereof. The light spots remove these charges such that positive ions from source E_2'' supplied by Corotron bank 63'' will pass through the areas that were unblocked by the light, but will be diverted by the fringing fields in the dark regions. Thus, a charge pattern will be laid down on the paper, such as shown in FIG. 6 at 77', which is subsequently developed and fixed.

The synchronizer timer may operate the neutralizer 110 continuously or intermittently as desired. The purpose of neutralizer 110 is simply to remove charges from conveyor 51'' and it may merely consist of a known radiation source. Next, synchronizer timer 101 turns on the field from source E_8 and then flashes scanner 61'' just long enough to remove the charges where the light impinges. Thereafter, synchronizer timer 101'' energizes the Corotrons 63'' from source E_2 to project the ions.

In FIG 7, there is disclosed a further embodiment of the invention wherein the scanner 61a is disposed within the confines of the conveyor 51a which has a configuration to locate the photoconductor 50a interiorly and the conductor layer 52a exteriorly, the latter being grounded at 110. The belt or screen 51a is charged negatively by corona wire or Corotron 53a from source E_{11} and the photoconductive layer 50a is exposed by scanner 61a being conveyed by insulated sprockets or drums 55a. The Corotron bank 63a is maintained at a positive potential E_{12} with the shields grounded at 115. The paper conveyor 57a is maintained at a negative potential by roller contactor 75a from source E_{13} whereby the paper 77a is caused to develop a positive charge pattern in accordance with the image. Isolated conveyor 67a, separated by insulator 69a, is maintained at a positive potential by E_{14} and the powder brush 83a is at a negative potential due to source E_{15} with screen 87a also being at a negative potential via source E_{16} . Otherwise the system is the same as that described in FIG. 6.

In the various embodiments, the ions 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 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 accordingly disposed.

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 is claimed is:

1. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along a predetermined path, said screen means comprising an insulative screen layer and a conductive screen layer; means for electrically charging the insulative layer with substantially equal and opposite charges; means for modifying the charges in accordance with an image to be reproduced; means for directing ions toward the screen means; means for locating print receiving material across an air gap in the direction of projection of the ions to receive a charge pattern in the form of said image; and means for developing the image.

2. The apparatus of claim 1 wherein the means for electrically charging the insulative layer comprises a source of ions.

3. The apparatus of claim 1 wherein the means for electrically charging the insulative layer comprises an electrode adjacent to the screen means and a connection to the conductive layer whereat a source of electric power is adapted to be connected between the connection and the electrode.

4. The apparatus of claim 3 further comprising synchronizer timer means for connecting and disconnecting the electric power source.

5. An aperture-controlled electrostatic printing system comprising in combination a multi-layer screen comprising at least a screen insulator layer overlying a screen conductor layer; means for electrostatically charging the insulator layer to provide a double charge layer; means for modifying the charges of the insulator layer in accordance with the image to be reproduced; means for directing ions through the multi-layer screen in accordance with the modified charge; means for locating a print receiving medium oppositely of the insulator layer relative to the accordance for directing ions, to receive the ions as a charge pattern; and means for developing the charge pattern to produce the image on the print-receiving substrate.

6. A system for image reproduction through the use of modulated apertures comprising in combination a multi-layer screen comprising at least a conductor screen and an insulator screen overlying the conductor screen and affixed thereto with the apertures coinciding; image means; means for double charging the insulator screen in accordance with the image means; means for directing ions toward the screen for passage therethrough in accordance with said charging; and means for intercepting the ions passing through the screen on print-receiving material.

7. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along a predetermined path, said screen means comprising an insulative screen layer and a conductive screen layer; a source of ions of a first polarity for charging the insulative screen layer; an imaging station for shining light in accordance with an image to be reproduced onto the charged insulative screen layer; a source of ions of a polarity opposite said first polarity for projecting ions through the screen means where permitted by the diminished or absence of charges thereon; a conveyor for presenting print receiving material oppositely of said last-mentioned source of ions and across an air gap therefrom whereby a charge pattern is laid down on the print receiving material; means for developing the charge pattern; and means for fixing the developer in the form of the pattern.

8. The apparatus of claim 7 further comprising a source of potential connected to the print receiving conveyor of polarity opposite to that of said last-mentioned source of ions to enhance the projection.

9. The apparatus of claim 8 further comprising powder charging means including a source of potential of opposite polarity to the charge laid down as the charge pattern to enhance developing.

10. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along a predetermined path, said screen means comprising an insulative screen layer and a conductive screen layer; a source of ions of a first polarity for charging the insulative screen layer; an imaging station for flashing light in accordance with an image to be reproduced onto the charged insulative screen layer; a source of ions of a polarity opposite to said first polarity disposed at the imaging station for projecting ions through the screen means where permitted by the diminished or absence of charges thereon; said source of ions comprising a voltage source of a polarity to produce ions of opposite charge to said first polarity; synchronizer timer means for controlling the imaging station to flash the light and for connecting said source of voltage to project the opposite polarity ions; conveyor means for presenting print receiving material oppositely of said last-mentioned source of ions and across an air gap therefrom whereby a charge pattern is laid down on the print receiving material; means for developing the charge pattern; and means for fixing said developer on the print-receiving material.

11. Apparatus for electrostatic reproducing comprising in combination composite screen means supported for movement along a predetermined path, said screen means comprising an insulative screen layer and a conductive screen layer, an electrode disposed near the screen means, means for applying an electric potential between said electrode and the conductive layer of said screen means for charging the insulative screen layer; image means for shining light on the insulative layer during the application of the charging means to discharge areas where light impinges; means for projecting ions toward the screen means to pass therethrough in the regions discharged; means for presenting print receiving material to the ions passing through the screen means to produce a charge pattern thereon; means for developing said charge pattern; and synchronizer timer means for controlling the application of said charging electric means and the shining of the image

light during the application of the charging electric means.

12. The apparatus of claim 11 further comprising neutralizer means for neutralizing any charges on the screen means.

13. The method of electrostatic printing comprising the steps of applying an electric field to a combination screen having an electrically active photosensitive apertured insulative layer and a conductive layer with coinciding apertures and then exposing the insulative layer to a light image to produce a charge separation across the insulative layer in accordance with the image by maintaining the potential of the conductive layer fixed; removing the light image and then the field to trap the charge separation; disposing dielectric print receiving material adjacent to the screen; directing ions through the screen in accordance with the image to produce a charge pattern on the print receiving material; and developing the charge pattern.

14. The method of electrostatic printing comprising the steps of charging an insulating screen having an apertured insulative layer and a coinciding apertured conductive layer with a uniform double layer of charges comprising charges of opposite polarity on either side of the insulative layer to establish blocking fields in the apertures of the screen; modifying the double layer of charges in accordance with an image to be reproduced to electrically unblock apertures thereof in accordance with the image; directing ions toward the screen to pass therethrough in accordance with the unblocked apertures; intercepting the ions which pass through the screen on dielectric print receiving material to form a charge pattern; and developing the charge pattern to produce printing.

15. In electrostatic printing wherein a multi-layer screen having an electrically active photosensitive apertured insulative layer and a coinciding apertured conductive layer is used, the steps of electrically charging the insulative layer while maintaining the conductive

layer at a fixed potential to establish fringing fields in the screen apertures; modifying the charge on the insulating layer by shining light in accordance with an image to be reproduced thereon to at least partly eliminate fringing fields where the light impinged; projecting ions at the modified charged area of the screen to permit ion passage through the apertures in the regions where the charge and fringing fields are modified or eliminated; intercepting the ions which pass through the screen on dielectric print receiving material to produce a charge pattern; and developing the charge pattern to reproduce the image.

16. The method of claim 15 further comprising the steps of flashing the image light on the screen, and directing the ions toward the screen after the flashing.

17. The method of claim 15 wherein the image light is flashed on the screen simultaneously with the direction of ions toward the screen.

18. The method of electrostatic printing using a screen having at least an apertured photoconductive layer overlaying a conductive layer having coinciding apertures comprising the steps of: establishing a uniform potential level at the conductive layer; establishing a double layer charge separation across the insulator layer in accordance with an image comprising charges of opposite polarity on either side of the insulator layer to create fringing fields in the apertures as a result of the double layer charge separation; projecting ions through the charges screen under control of the fringing fields in accordance with the image; intercepting the ions which have passed through the screen on a dielectric print receiving medium; and developing the intercepted ions for printing the image.

19. The method of claim 18 comprising the further step of determining the charge of the ions to be employed by selecting it for opposition by the fringing fields whereby the fringing fields block ion passage in proportion to light intensity establishing them.

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