Jan. 6, 1970 A. CHANEY ET AL 3,487,775

IMAGING SYSTEM

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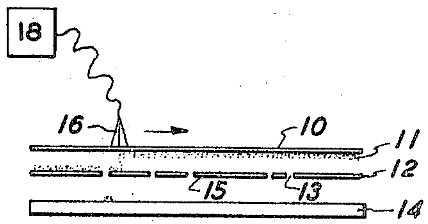

FIG. 1

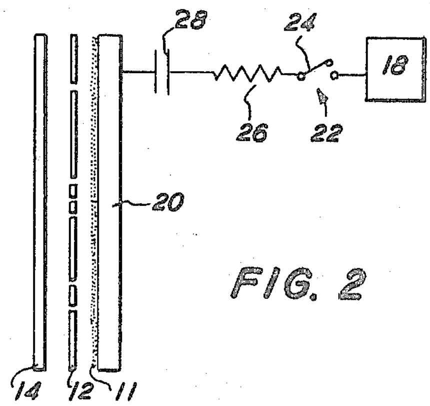

FIG. 2

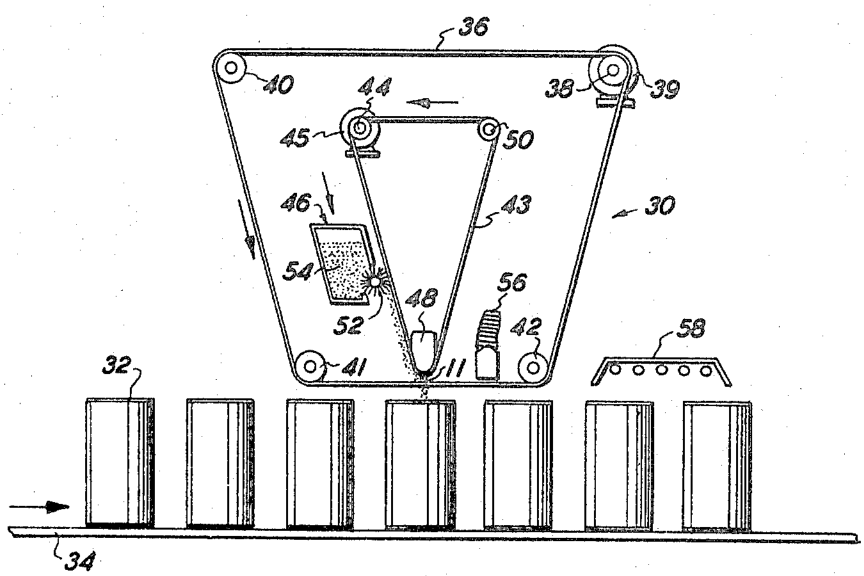

FIG. 3

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IMAGING SYSTEM

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U.S. Cl. 101—114 40 Claims

ABSTRACT OF THE DISCLOSURE

A donor bearing a releasably adhering layer of electro-statically charged marking material spaced apart from a print receiving member with the marking material layer facing the member and an image cut stencil supported between the donor and the member whereupon by applying electrical potential to the donor, the marking material is repelled from the donor and impelled through the stencil and deposited on the print receiving member.

This invention relates to electrostatic printing and more particularly to a printing system which requires neither a formal electric field generating means nor pressure nor contact between the printing element and the print receiving member.

Most commercial printing systems, for example, those employed in the newspaper industry transfer liquid inks from the printing element to the print receiving member by contacting the printing element under considerable pressure with the print receiving member the surfaces of both the element and the member being relatively smooth in order to effect sharp image transfer of the ink. In order to accomplish this transfer at high speeds and subsequently dry the transferred ink on the print receiving member, notoriously complex, precise and bulky equipment has generally been required.

Efforts have been made in the past to develop simpler, pressureless printing systems usually employing electrostatics or electric fields to aid in the transfer of ink, pigmented powders or other marking material from the printing element to the print receiving member.

For example, W. C. Huebner in his U.S. Patents 1,820,194; 2,408,144 and 2,590,321, describes a pressureless printing method wherein a relief plate is directly inked and then disposed a few thousandths of an inch from an electrode backed printing surface whereby ink is transferred from the plate to the surface by the use of electrostatic lines of force rather than by mechanical contact and heavy pressure. Although the printing methods disclosed by Huebner offer advantages over conventional printing techniques, they generally require liquid inks, precise spacings in the nature of thousandths of an inch and a formal backing electrode behind the print receiving member to intensify the electrostatic field. Various embodiments require precise spacing of magnetic means to further confine and intensify the electric field, or complex porous printing elements with extremely fine electrically conductive mesh on the surface thereof again to increase the electric field between the printing element and the print receiving member in order to increase the efficiency and thoroughness of the ink transfer. These structures and the preciseness of their spacings add greatly to the complexity of the Huebner process.

There has also recently been developed, a printing system which eliminates some of the disadavntages of the Huebner systems, This system is disclosed in Childress, et al., Patent 3,081,698 and related Childress Patents 3,202,093 and 3,228,326 and Childress, et al., Patent 3,245,341. These patents described a method of electrostatic printing requiring no contact or pressure

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between the printing element and the print receiving member, which employs an electrically conductive image patterned screen and an electrically conductive electrode spaced from the screen to formally ceate an electric field between the image patterned screen and the conductive electrode whereupon finely divided pigment powder is passed through the screen to be printed onto a print receiving member situated between the screen and the electrode or to print directly on the conductive electrode. This method offers advantages over prior art printing devices, but like Huebner, has serious limitations. For example the Childress system requires that the print receiving member be interposed between a formal rear or backing electrode and an electrically conductive stencil with fine open mesh screening in image areas, in order to satisfactorily deposit powder in image configuration on the print receiving member. The teaching of Childress Patent 3,202,093, is an attempt to alleviate the requirement of an electrically conductive fine mesh screen but discloses as a replacement for the electrically conductive stencil, what appears to be an even more complex system calling for electrically conductive carrier particles mixed with powder marking particles, this combination of materials serving as an electrode when an amount of the combination is supported in a reciprocating printing element which as it reaches the end of the downward stroke, puffs marking particles through a stencil which may be non-conductive.

Also of interest is McNaney Patent 3,071,645, which eliminates some of the disadvantages of the Childress system wherein powder on an electrically insulating member is caused by gravity or by a formal electric field to deposite in image configuration on a recording surface. However, this concept is dependent on the use of light responsive photoconductive insulating materials or image shaped conductors to cause image deposition of the powder and must rely on an undesirable formal backing electrode or gravity forces to deposit toner which limits the flexibility and adaptability of the system.

Thus although improvements have been made to advance the art of electrostatic printing, presently available systems still have many attendant requirements which add to their complexity and cost of construction and operation.

Accordingly, an object of this invention is to provide a printing system which overcomes the above-noted disadvantages.

It is a further object of this invention to provide a pressureless printing system wherein it is not necessary to contact the printing element with the print receiving member.

It is a further object of this invention to provide an electrostatic printing system which does not require the use of an electrically conductive stencil.

It is a still further object of this invention to provide an electrostatic printing system which does not require a formal electrode backing the print receiving member.

It is a still further object of this invention to provide an electrostatic printing system which requires no formal electrical field generating means.

It is a still further object of this invention to provide an electrostatic printing system which does not require the use of photoconductive insulating materials or image shaped conductive materials.

The foregoing objects and others are accomplished in accordance with this invention by providing a donor bearing on one side thereof a uniform releasably adhering layer of electrostatically charged marking material, the donor spaced apart from a print-receiving member with the marking material layer facing said member. An image cut stencil is supported therebetween, whereby an electrical voltage preferably of the same polarity as the charge residing on the marking material is applied to the donor to repel marking material from the donor and impel it through the stencil and deposit it on the print receiving member to form a loosely adhering marking material image thereon. This loose image may be subsequently fixed, caused to permanently adhere to the print receiving member, by a variety of means well known in the art.

For a better understanding of the invention as well as other objects and further features thereof, reference is made to the following detailed disclosure of this invention taken in conjunction with the accompanying drawings wherein:

FIG. 1 is a partially schematic, sectional, side view of one embodiment of the printing system of this invention;

FIG. 2 is a partially schematic, sectional, side view of another embodiment of the printing system of this invention;

FIG. 3 is a partially schematic side view representation of yet another embodiment of the printing system of this invention shown to be adapted for automatic, continuous type operation.

Referring now to FIG. 1 there is shown donor **10** in the form of a sheet of material with a uniform layer of marking material **11** on the underside of the donor which is superposed above stencil **12** which is in turn superposed above print receiving member **14**. Electrode **16**, in the form of an electrically conductive brush, is shown to be moving from left to right above and in contact with the top surface of the donor, repelling marking material **11** from the bottom surface of the donor as the electrode makes its traverse. Electrode **16** is electrically connected to high voltage power source **18**, preferably a D.C. source.

Donor **10** may comprise any material, electrically conductive or nonconductive, which is capable of accepting and releasably holding on at least one side thereof a uniform layer of marking material at least part of which is capable of being repelled from the donor when a voltage is applied to the opposite side of the donor.

For example, ordinary office-stock bond paper is found to be entirely satisfactory as a donor for use herein although onionskin papers which are generally thinner than ordinary copy paper are found to transfer marking material at lower voltages presumably because of their thinner cross section.

Mylar or Cronar electrically insulating polyester films available from the E. I. du Pont de Nemours & Co. are also found to be suitable donor materials for use herein and offer a mechanical strength advantage over ordinary paper. For example, Mylar and Cronar films ranging in thickness from about 25 microns to about 250 microns are found to provide sufficient mechanical strength for many printing cycles in the embodiment of FIG. 1 and in endless belt **43** configuration as shown in FIG. 3 while still being sufficiently thin to permit ready repelling of marking material from the donor surface upon application of a voltage to the opposite side of the donor.

Metal donors are also suitable for use herein. For example, aluminum sheets of about 25 microns in thickness are found to be excellent donors because of their excellent mechanical strength and their ability to accept, hold and repel marking material. For electrically conductive donors, for example, most metals, donor thickness may vary over a very wide range without significantly effecting the donor's ability to repel marking material. For electrically nonconductive materials, it is found that the thinner films are preferred. For example, for donor materials of electrical resistivity greater than about 10^8 ohm-centimeters, a donor thickness generally less than about 75 microns is found to be preferred in order to ensure that marking material will be readily repeled from the donor upon the application of a voltage thereto.

Marking material may conveniently be deposited onto the donor in a uniformly distributed, releasably adhering layer of marking material by a wide variety of techniques including running the donor through a quantity of marking material; wiping the marking material on the donor; cascading a two-component developer comprising a marking material over the donor, for example, see Walkup et al. Patent 2,638,416; Walkup Patent 2,618,551 and Wise Patent 2,618,552; or applying the marking material by varoius brushing techniques examples of which are described in copending application Ser. No. 453,640, filed May 6, 1965. Also, powder cloud development for example see Carlson Patent 2,217,776; a combination of cascade and cloud development, for example, see copending applications Ser. No. 421,297, filed Dec. 28, 1964 and Ser. No. 452,098, filed Apr. 30, 1965, and other means are available for coating the donor with a uniform, releasably adhering layer of marking material of sufficient density to produce quality prints by this invention.

It is found that most methods of applying marking material to the donor impart sufficient triboelectrically generated electrostatic charges to the marking material to cause the material to releasably adhere to the donor and be repelled from the donor in sufficient quantity upon application of a voltage to print by the process hereof. However, to impart additional charge to the marking material on a loaded donor or to refresh a loaded donor which, for example, has been stored for a sufficient time to permit dissipation of most of the electrostatic charges which may be desirable to cause greater or more forceful repelling of marking material from the donor, independent means are known in the art to impart additional electrostatic charges to the marking material. These same means may be used to precharge an electrically insulating donor to increase its capacity to accept and releasably retain marking material.

The most convenient of these independent charging means is termed corona charging and generally employs a high voltage applied to a fine wire to create charged particles emanating from the wire which travel to the marking material particles or the donor, as the case may be, causing the subject to become charged. For example, corona discharge devices of the general description and generally operated as described in Vyverberg Patent 2,836,725 and Walkup Patent 2,777,957 are found to be excellent and convenient corona devices for use herein. However, many other suitable corona charging devices are known in the art.

Stencil **12** comprises open printing areas **13** in image configuration and nonprinting areas **15** which are suitably masked or blocked to prevent passage therethrough of marking material. Open areas may be of any dimension large enough to permit marking material to pass therethrough and do not have to but may comprise a fine mesh electrically conductive open screen. Various methods of stencil manufacture call for a screen even in open areas to support, bridge and anchor independent elements of design such as the centers of letters D, O and Q to the blocked out, nonprinting areas of the stencil, and these stencils are entirely satisfactory for use herein.

The stencil may be manufactured of almost any electrically conductive or nonconductive material not being limited to conductive materials as in some prior art systems, thus permitting a wider range of stencil materials and methods for making stencils.

Suitable stencils for use herein may be manufactured by almost any method including simple punch out or cut out techniques or by more sophisticated techniques, for example, the "Silk Screen Process" illustratively described in chapter 8 at page 357 of the work Photomechanics and Printing by Mertle and Monsen (1957) available from the Mertle Publishing Co.; the method described in Childress Patent 3,081,698 beginning column 2, line 60; the method of Brennan et al. Patents 2,213,237, 2,338,091 and 2,395,448, and many other techniques well known in the stencil making art.

Marking material **11** may be any pigmented material of a size sufficiently small to pass through stencil open areas 13 or through the openings of fine mesh screening found in stencil open areas as a result of certain stencil making techniques, and which possess the electrical capability of carrying an electrostatic charge and responding to an application of voltage to donor 10.

Because it is desirable to fix or permanently fuse the marking material when deposited in image configuration on the print receiving member 14, it is found to be preferred herein as in prior art electrophotographic imaging systems for example as described in Carlson Patent 2,297,691 to employ as a marking material a pigmented resin material called "toner" which is either thermally softenable or softenable by application of solvents, vapors or the like to cause the deposited loose powder image to fuse into or onto the print receiving member thereby rendering the produced image indefinitely useable under ordinary conditions.

For example, a toner with an average particle size of between about 5 and 15 microns comprising a styrene-butyl methacrylate copolymer, polyvinyl butyral and carbon black prepared as disclosed in Example I of Insalaco Patent 3,079,342 is found to be a preferred toner for use herein because it loads on most donor materials and is readily repelled from a donor to form a heavily pigmented loose powder image on the print receiving member which is readily fixed by ordinary heat fusing.

Any suitable toner or other marking material may be used herein. Typical materials are described in the balance of the aforementioned Insalaco Patent as well as in Carlson Reissue Patent 25,136, Copley Patent 2,659,670, Landrigan Patent 2,753,308, Insalaco Patent 2,891,011 and others.

Marking material particles of, for example, 50 microns and larger are also usable herein but it is found that for these particle sizes resolution of the final image begins to suffer since edges are not as clearly defined as when smaller particle marking material is used.

Print receiving member 14 for simplicity has been illustrated as a flat member which may be, for example, a piece of paper, glass, metal, cardboard or plastic. It is important to note that an important advantage of the inventive system herein, is its capability to print on almost any print receiving member whether it is electrically insulating or conductive. Also important is that the invention employs no backing electrode, which allows various filled or sealed containers such as cardboard boxes and bottles to be printed upon since there is no need for a formal backing electrode to be positioned adjacent the backside of the print receiving member which would of course necessitate that it be placed inside the container or bottle which in most packaging operations would clearly have to be done before the container is filled. Textile fabrics and food products, even fruit, may be printed without pressure or contact and without applying a potential to the fruit which is required by some prior art systems. Thus is avoided the possibility of bruising or damaging the fruit or other fragile merchandise.

Some prior art printing systems require the container to be printed upon at a very early stage of the container filling operation, specifically before the container is filled. This requirement, of course, severely limits the operational sequence of a combination container filling-container printing operation and subjects the printed containers to further filling and processing operations such as the customary heat processing steps applied to canned goods which may degrade the quality of the printing put on the containers at such an early stage. The printing system of this invention which does not require a formal rear or backing electrode permits printing to be accomplished at the very end of the filling and processing operation to permit the deposited image to be in its most presentable form when the container is ultimately received by the consumer. In addition, the printing system of this invention opens up a wide variety of new printing applications which were heretofore impossible or unduly burdensome by any other prior art printing method. For example, printing on walls or glass doors or windows, for example, for showcase purposes where often it is impossible or at best extremely cumbersome to position a backing electrode adjacent the backside of the wall or other vertical surface is possible by the invention system herein by simply placing the donor and stencil contiguous to and everywhere substantially equidistant from the print receiving member and repelling the marking material onto the print receiving member. The entire printing operation takes place on and all the printing apparatus is situated on the print receiving side of the print receiving member.

In operation, it has been found preferred to position the donor, for example by the use of shims, a distance not greater than about 1/8 inch from the stencil during the printing operation. Of course for these greater spacings image definition is found to suffer as compared to closer spacings between the donor and the stencil. It has been found practical and suitable in certain embodiments of this invention to actually lay the donor in contact with the top surface of the stencil and then pulse marking material through the stencil. For "in contact" work electrically insulating screen materials are preferred in order to lessen the danger of arcing which is found to only negligibly effect image quality but may corrode the edges of the open printing area screen portions of some stencils.

It will be appreciated that a portable voltage applicator and a composite donor-stencil device shape to fit the contour of various curved or other non planar print receiving members, for example, fruit, may be readily constructed.

The distance between stencil 12 and print receiving member 14 also depends inter alia upon the desired sharpness of the resulting image. For spacings greater than about 1/4 of an inch, spreading of the image with resultant lowering of image resolution is found to be appreciable. Actual contact of the stencil with the print receiving member is possible and fine quality, high resolution prints are possible thereby, although care must be taken in removing the stencil as to not smudge the loose powder image deposited on the print receiving member. Practically, this capability of printing with the stencil from 0 inch to greater than about 1/4 inch above a surface allows the inventive system hereof to print on corrugated paper or bottles or other print receiving members with rough surfaces or raised patterns.

Electrode 16 may be of any suitable electrode material and configuration but is illustratively shown to be in brush form which has been found to be preferred for use in the embodiment illustrated in FIG. 1 for reasons given below and because of its capability when moved in gentle sliding contact with the back of donor 10 to uniformly repel marking material from the donor through the stencil, without significantly abrading or wearing the surface of the donor thus allowing for many repetitive uses of a single donor. Two examples of a preferred brush configuration are an aluminum brush electrode formed by finely slitting a 2 mil sheet of aluminum and a brush electrode comprising parallel and closely adjacent strands of steel piano wire of a diameter ranging for example between about 1 and 10 mils. The piano wire brush may be readily formed by closely winding a length of wire around an elongate core member such as a metal pipe, each winding positioned ahead of, but immediately adjacent the next preceding winding until a desired brush length is attained. Then the wire is secured to the elongate core member for example by solder or a resinous material along a line extending the length of the core, whereupon the windings of wire are severed along a line on the opposite side of the core from the line of securing material extending the length of the core whereupon the natural springiness of the wire causes it to spring from the core to form two wire comb structures emanating in opposite directions from the line of securing material. The piano wire comb because of its springiness ensures intimate contact wih even irregularly shaped donor members and each wire terminates in a sharp edge to enhance charge concentration at the wire ends which contact the donor.

Voltages generally in the range of from about 3,000 volts to about 10,000 volts are found to be suitable for use herein with 5,000 volts being a commonly used and preferred voltage. It is to be noted that voltages higher than about 10,000 volts may be used herein but corona discharges with the accompanying ozone odor and increased arcing danger are found to be undesirable attendant factors when operating in this voltage range. The polarity of the voltage applied to electrode **16** preferably should be the same as the polarity of the electrostatic charges residing on the marking material on the donor in order to maximize the amount of material repelled by a given voltage applied to the donor. It will be understood that either positive or negative voltages and electrostatic charges may be utilized herein.

The rate of traverse of electrode **16** across the donor **10** may vary over a wide range depending inter alia on the type and thickness of the donor. For example, for an onionskin paper donor a rate of traverse of a preferred brush electrode configuration described above of between about 2 and 100 inches per second is found to be entirely satisfactory to repel marking material from the donor. More than one traverse may be made, for example a high potential brush electrode may be stroked back and forth across the back of the donor as many times as necessary to give the desired resultant print density. Also a single donor may be used to make a number of prints depending on the desired resultant print density and the amount of marking material loaded on the donor.

Alternatively, a corona charging device for example of the type as previously herein described may be used as a voltage applicator to repel toner by traversing the device across and adjacent the back of the donor.

For a flat donor surface a sharp edged structure such as a razor blade serves as a preferred electrode configuration since the sharp edge concentrates charge at the electrode's line of contact with the back of the donor.

Referring now to FIG. 2 there is illustrated another embodiment of the invention with member **20** illustratively comprising an electrically conductive member to serve as both an electrode and as a donor. Member **20** is connected to electrical circuitry **22** comprising high voltage, preferably D.C. power source **18**, switch **24**, resistance **26** and capacitor **28**. In operation when switch **24** is closed, capacitor **28** builds up a potential anywhere in the preferred voltage range of between about 3,000 to 10,000 volts whereupon the capacitor discharges applying a voltage to member **20** to repel marking material from the surface of member **20** through the stencil **12** to the print receiving member. The voltage may be applied in a variety of other ways to repel marking material from member **20** an alternative method being to momentarily touch one point on the member with an electrode biased between about 3,000 to 10,000 volts. Also, brush corona charging devices or other traversing electrodes may be used as in FIG. 1 to repel marking material from member **20** in which case the member may be constructed of electrically conductive or insulating material. Additionally, an electrically insulating donor may be employed with an electrically conductive backing to serve as the electrode when for example connected to electrical circuitry **22** or when momentarily touched to a high voltage source.

It will be noted that print receiving member **14**, stencil **12** and member **20** are positioned vertically, for example, as to print on the side of a carton or on a store window front. It is found that printing in this position produces the same quality prints produced when marking material is repelled in the direction of gravitational lines of force, for example, as illustrated in FIG. 1. Quality prints also result when marking material is repelled opposite to the direction of gravitational lines of force.

For donors positioned as illustrated in FIGS. 1 and 2, wherein gravitational forces tend to move marking material from positions of original placement on the donor it may be found helpful, especially where heavy, very dense layers of marking material are applied to the donor to mechanically shake or tap or otherwise remove for example by a doctor blade, excess marking material from the donor before printing.

It might be expected that the loose marking material images would adhere better to print receiving members positioned as in FIG. 1 where gravity forces aid in holding the position of the loose image until fixing but it is found that in printing on almost any vertical surface, for example, as shown in FIG. 2 a sufficient amount of loose marking material is transferred to and adheres with sufficient tenacity to the print receiving member to form upon fixing an image of commercially acceptable density. For example, a vertical plate glass window may be printed on by this invention. In addition, various print receiving members may be precharged preferably to a polarity opposite to the polarity of charge residing on the marking material on the donor to enhance the ability of the print receiving member to receive and hold a marking material image.

Referring now to FIG. 3 there is seen in side view an automated printing system according to the invention adapted for printing on the tops of containers **32** being advanced by conveyor **34**. Apparatus **30** comprises endless stencil **36** being advanced in a counter-clockwise direction by drive roller **38** powered by motor **39** around guide and tensioning rollers **40**, **41** and **42** such that the rate of advancement of the stencil is about equal to the rate of advancement of the containers on conveyor **34**. Within the outline of endless stencil **36** is shown endless donor belt **43** advanced by drive roller **44** powered by motor **45** in a counter-clockwise direction sequentially past marking material application **46**, electrode **48** and guide and tensioning roller **50**. The rate of advancement of the donor need not be identical to the rate of advancement of the stencil **36** or of the conveyor **34** but will depend upon the type of marking material being used, the voltage applied by electrode **48**, the density of the marking material applied by applicator **46** and the required density of images to be printed upon the top surface of containers **32**. Of course the direction of advancement of the donor need not be the same as for stencil **36**.

Marking material applicator **46** comprises rotating brush **52** and marking material supply **54**, brush **52** picking up marking material from the supply and distributing a quantity of the material to the outside surface of donor **43**.

Electrode **48** need not be of any special configuration. Said electrode may be of any suitable material and preferably of metal, the particular preferred cross section shown as a narrow edge contacting the donor, tangent diverting sides leading to a more rounded top portion, being designed to permit the concentration of electrostatic charge along the narrow edge which engages the donor **43**.

In operation the top surfaces of containers **32** are continuously advanced for example at a rate of 300 feet per minute beneath electrode **48** whereat marking material **11** is repelled from endless donor belt **43** which is continuously advanced around the narrow edge of the electrode. Marking material is impelled through open image areas of endless stencil **36** advancing at about the same rate as the containers, the image cut portions of the stencil being in register with print receiving portions of the containers. Many means exist for precisely spacing containers in order to maintain register between image cut portions of the advancing stencil and print receiving portions of the containers. In addition periodically momentarily accelerating or decelerating either the conveyor **34** or the stencil **36** may be employed to re-

register a system where the rate of advancement of the conveyor and the stencil are not precisely equal. Of course the width of the stencil **36**, donor **43**, and the length of electrode **48**, brush **52**, and rollers attendant to the stencil and the donor will be dependent on the maximum dimension in a direction normal to the view shown in FIG. 3 of the particular image to be printed and in most printing embodiments all of these dimensions will be about equal. Generally the same operating parameters found to be preferred for the embodiment illustrated in FIG. 1 are suitable for the embodiment illustrated in FIG. 3.

Optionally, vacuum cleaning device for example of the type described in Walkup et al. Patent 2,832,977 or other suitable cleaning mechanisms may be employed to clean marking material from stencil **36** after the printing operation. The marking material garnered by this cleaning operation may be conserved and resupplied back to marking material supply **54** by conventional means not shown.

After having received a loose marking material image, each container is advanced to pass under fixing apparatus **58** illustratively shown to be a resistance heat fixing means for example of the type as described in Eichler Patent 2,965,868. Of course, many other fixing systems are known in the art which are suitable herein including solvent vapor, flash lamp fusing and others.

It will be apparent to those skilled in the art that because of the simplicity and inherent flexibility of the invention described herein many variations may be made to the various embodiments of the printing system of this invention to adapt the invention to the many printing application which exist therefor.

For example, two embodiments of the inventive system hereof may be positioned to print on opposite sides of a container or on two different sides of any print receiving member such as paper or cardboard. In this manner, utilizing apparatus similar to that shown in FIG. 3 multiple copies of, for example, newspaper pages may be printed on both sides. It will be seen that if a continuous roll of paper is used as the print receiving member registering of stencil image areas with print receiving portions of the paper is no longer required. The rates of advancement of the stencil and paper may vary slightly so long as image quality is not unduly blurred. Ordinarily it is preferred to keep these rates of advancement as nearly identical as possible.

Color printing is possible herewith since marking materials for use herein may be made up of various colored pigments besides carbon black which is often used to give a black or dark marking material for imaging on a white or other light colored print receiving member.

As many different colors as desired may be printed, for example, as in the case of silkscreen printing, by employing a different screen for each color, one following the other in sequence and each in turn properly positioned and registered to deliver the colored marking material to the proper spot in relation to the other colors. With four screens each having the image corresponding to an individual color, four-color printing can be accomplished. One screen after another is positioned above the print receiving member and each color is printed individually.

Another variation is that a plurality of printing cycles may be used to deposit a plurality of loose marking particle images in register on a single print receiving member to thereby increase the density of the image. As referenced to automatic apparatus, for example, as illustrated in FIG. 3 this result may be attained by providing a plurality of electrodes **48** in a row each preceded by a marking material applicator **46**.

It will be understood that various other changes in the details, materials, steps and arrangements of parts, which have been herein described and illustrated in order to explain the nature of the invention will occur to and may be made by those skilled in the art, upon a reading of this disclosure and such changes are intended to be included within the principle and scope of this invention.

What is claimed is:

1. The electrostatic printing method comprising the steps of:

(a) providing a donor member, bearing on one side thereof a uniform layer of releasably adhering electrostatically charged marking material;

(b) providing a print receiving member adjacent to and facing but in spaced apart relationship with the marking material bearing surface of said donor member, said print receiving member not adjacent a backing electrode, and thus not electrically affected by an adjacent backing electrode;

(c) providing an unbiased image cut stencil having open area printing portions and blocked area nonprinting portions between said donor member and said print receiving member; and

(d) applying a voltage to the donor member to impel marking material from the donor driving said material through open area printing portions of the stencil to deposit said material on the print receiving member in image configuration, without an adjacent backing electrode backing said print receiving member, wherein the term backing electrode shall mean either a biased or grounded conductor electrically connected to a potential source or ground, respectively.

2. The electrostatic printing method of claim **1** wherein said donor member is in contact with said stencil.

3. The electrostatic printing method of claim **1** wherein said print receiving member and said stencil are essentially planar and are substantially equidistant from each other in the region where marking material is being repelled through the stencil to deposit on the print receiving member.

4. The electrostatic printing method of claim **1** wherein said donor member, said stencil and said print receiving member are essentially planar and wherein the minimum direct distance between any portion of the donor member and said stencil is not more than about ⅛ of an inch and the minimum direct distance between any portion of the print receiving member and said stencil is not more than about ¼ of an inch.

5. The electrostatic printing method of claim **1** wherein, in the region where marking material is being repelled through the stencil to deposit on the print receiving member, the minimum direct distance between said donor member and said stencil is not more than about ⅛ of an inch and the minimum direct distance between said stencil and said print receiving member is not more than about ¼ of an inch.

6. The electrostatic printing method of claim **1** wherein said voltage is between about 3,000 and 10,000 volts.

7. The electrostatic printing method of claim **1** including the additional step of fixing the marking material image on the print receiving member.

8. The electrostatic printing method of claim **1** wherein said donor is electrically conductive and wherein said voltage is applied to said donor by momentarily contacting said donor to a voltage source.

9. The electrostatic printing method of claim **8** wherein at least the initial potential applied to said donor by said voltage source is between about 3,000 and about 10,000 volts.

10. The electrostatic printing method of claim **1** wherein the electrostatic charge on the marking material and the voltage applied to the donor member are of the same polarity.

11. The electrostatic printing method of claim **10** wherein said voltage is between about 3,000 and 10,000 volts.

12. The electrostatic printing method of claim 11 wherein said marking material is a finely divided powder of particle size less than about 50 microns.

13. The electrostatic printing method of claim 12 wherein said finely divided powder is a pigmented resin.

14. The electrostatic printing method of claim 1 wherein said voltage is applied to the donor by traversing a biased electrode across and contiguous to the side of said donor member of opposite said marking material layered side.

15. The electrostatic printing method of claim 14 wherein said biased electrode is a corona charging device.

16. The electrostatic printing method of claim 14 wherein said biased electrode is an electrically conductive brush.

17. The electrostatic printing method of claim 16 wherein said electrically conductive brush is biased to between about 3,000 and 10,000 volts and is traversed in contact with the side of said donor member opposite said marking material layered side.

18. An electrostatic printing apparatus comprising:

(a) an unbiased image cut stencil comprising open area printing portions and blocked area non-printing portions;

(b) a donor member mounted in superposed relation to said stencil wherein said donor carries on the donor side facing said stencil a uniform layer of releasably adhering electrostatically charged marking material, said donor member substantially coextensive with at least the open area printing portions of said stencil;

(c) an electrode contiguous to the side of said donor member opposite said marking material layered side;

(d) means to provide an electrical bias to said electrode; and

(e) means to position a print receiving member so that it is substantialy coextensive with at least the open area printing portions of said image cut stencil on the side thereof opposite said donor member, said print receiving member not adjacent a backing electrode, and thus not electrically affected by an adjacent backing electrode; marking material being repelled from said donor by said biased electrode and impelled through open area, printing portions of said stencil to deposit in image configuration on said print receiving member, without an adjacent backing electrode backing said print receiving member, wherein the term backing electrode shall mean either a biased or grounded conductor electrically connected to a potential source or ground, respectively.

19. An electrostatic printing apparatus according to claim 18 wherein, in said region of substantial coextensivity, the stencil is not more than about ⅛ of an inch from the layer of marking material.

20. An electrostatic printing apparatus according to claim 18 wherein the electrical bias aplied to said electrode is between about 3,000 and 10,000 volts.

21. An electrostatic printing apparatus according to claim 18 wherein said electrode is substantially coextensive with at least the portions of said donor coextensive with the open area printing portions of said stencil.

22. An electrostatic printing apparatus according to claim 21 wherein said print receiving member and said stencil are essentially planar and are substantially equidistant from each other in the region where marking material is being repelled through the stencil to deposit on the print receiving member.

23. An electrostatic printing apparatus according to claim 21 wherein, in said region of substantial coextensivity, the stencil is not more than about ⅛ of an inch from the layer of marking material.

24. An electrostatic printing apparatus according to claim 23 wherein, in said region of substantial coextensivity, the stencil is not more than about ¼ of an inch from said print receiving member.

25. An electrostatic printing apparatus according to claim 24 wherein said electrode is in contact with the side of said donor member opposite said marking material layered side.

26. An electrostatic printing apparatus according to claim 21 wherein said electrode is in contact with the side of said donor member opposite said marking material layered side.

27. An electrostatic printing apparatus according to claim 26 wherein said donor member is in contact with said stencil.

28. An electrostatic printing apparatus comprising:

(a) an unbiased image cut stencil comprising open area printing portions and blocked area non-printing portions;

(b) an electrode donor member mounted in superposed relation to said stencil wherein said electrode donor carries on its side facing said stencil a uniform layer of releasably adhering electrostatically charged marking material, said electrode donor member substantially coextensive with at least the open area printing portions of said stencil;

(c) means to provide an electrical bias to said electrode donor; and

(d) means to position a print receiving member so that it is substantially coextensive with at least the open area printing portions of said image cut stencil on the side thereof opposite said electrode donor member, said print receiving member not adjacent a backing electrode, and thus not electrically affected by an adjacent backing electrode; marking material being repelled from said donor by said biased electrode donor member and impelled through open area printing portions of said stencil to deposit in image configuration on said print receiving member, without an adjacent backing electrode backing said print receiving member, wherein the term backing electrode shall mean either a biased or grounded conductor electrically connected to a potential source or ground, respectively.

29. An electrostatic printing apparatus according to claim 28 wherein said electrode donor member is in contact with said stencil.

30. An electrostatic printing apparatus according to claim 28 wherein said print receiving member and said stencil are essentially planar and are substantially equidistant from each other in the region where marking material is being repelled through the stencil to deposit on the print receiving member.

31. An electrostatic printing apparatus according to claim 28 wherein the electrical bias applied to said electrode donor member is between about 3,000 and 10,000 volts.

32. An electrostatic printing apparatus according to claim 28 wherein, in said region of substantial coextensivity, the stencil is not more than about ⅛ of an inch from the layer of marking material.

33. An electrostatic printing apparatus according to claim 32 wherein, in said region of substantial coextensivity, the stencil is not more than about ¼ of an inch from said print receiving member.

34. An electrostatic printing apparatus comprising:

(a) an advancing web donor member bearing on one side thereof a uniform layer of releasably adhering electrostatically charged marking material;

(b) an elongate electrode having its axis substantially paralell to said donor and being at least coextensive in length with the width of said donor, said electrode being contiguous to the side of said donor member opposite said marking material layered side;

(c) means to provide an electrical bias to said elongate electrode to repel marking material from said donor in a printing zone;

(d) an advancing unbiased web image cut stencil comprising open area printing portions and blocked area non-printing portions, said stencil being substantially equidistant from said donor member in said printing zone; and

(e) a print receiving member, in the printing zone, advanced at about the same rate and in about the same direction as said stencil and being substantially equidistant from said stencil in the printing zone, said print receiving member not adjacent a backing electrode and thus not electrically affected by an adjacent backing electrode; making material being repelled from said donor by said biased elongate electrode and impelled through open area, printing portions of said stencil to deposit in image convguration on said print receiving member, without an adjacent backing electrode backing said print receiving member, wherein the term backing electrode shall mean either a biased or grounded conductor electrically connected to a potential source or ground, respectively.

35. An electrostatic printing apparatus according to claim **34** wherein said biased elongate electrode is a corona charging device.

36. Apparatus according to claim **34** wherein, in the printing zone, said stencil is not more than about ⅛ of an inch from said donor and said print receiving member is not more than about ¼ of an inch from said stencil.

37. An electrostatic printing apparatus according to

claim **36** wherein at least one of said web donor member and said web image cut stencil is an endless belt.

38. An electrostatic printing apparatus according to claim **36** wherein said biased elongate electrode is in contact with the side of said donor member opposite said marking material layered side.

39. An electrostatic printing apparatus according to claim **34** wherein the electrical bias applied to the electrode is between about 3,000 and 10,000 volts.

40. An electrostatic printing apparatus according to claim **39** wherein the electrical bias applied to said electrode is of the same polarity as the electrostatic charge on the marking material.

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