Nov. 23, 1965 C. O. CHILDRESS ETAL 3,218,968

MULTICOLOR ELECTROSTATIC PRINTING

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Fig. 1

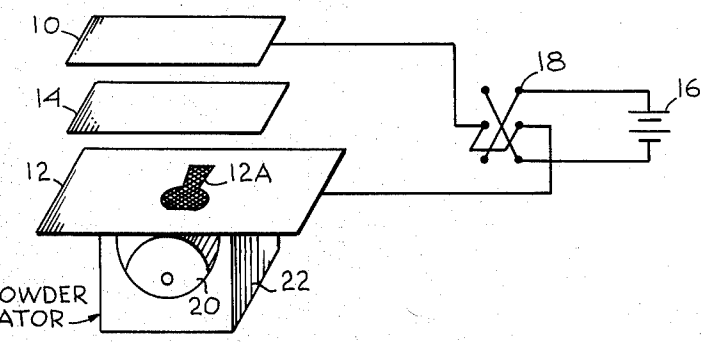
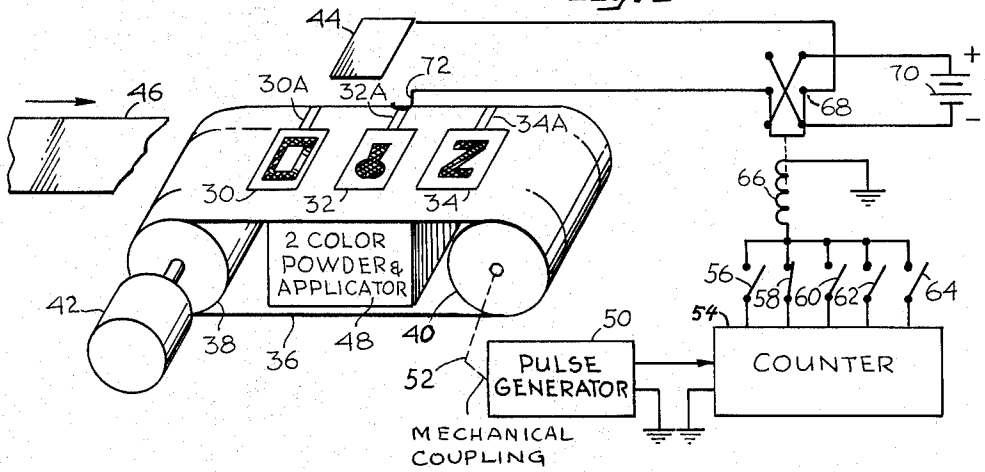


Fig. 2



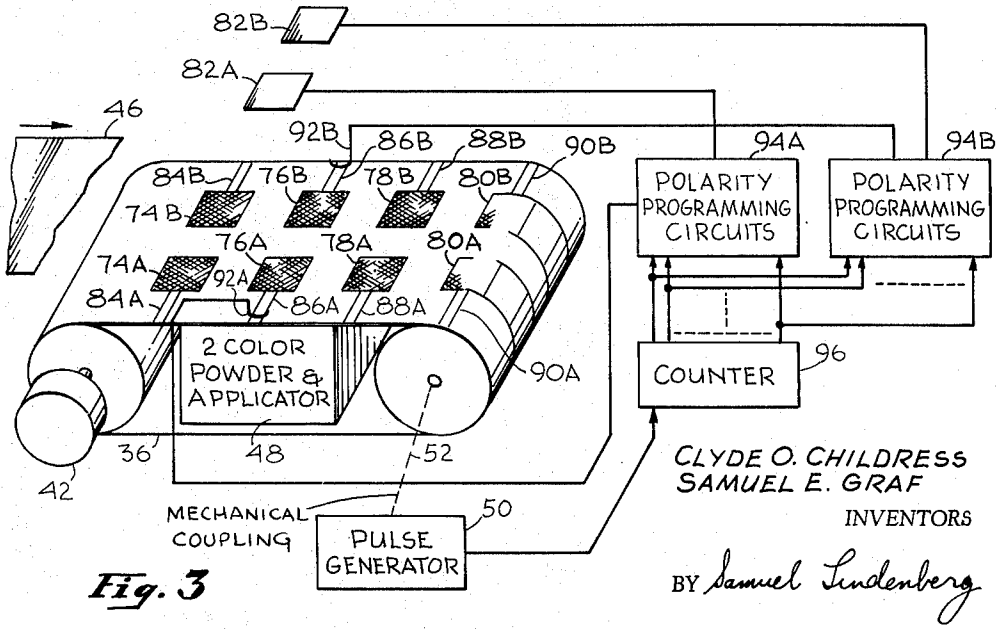


Fig. 3

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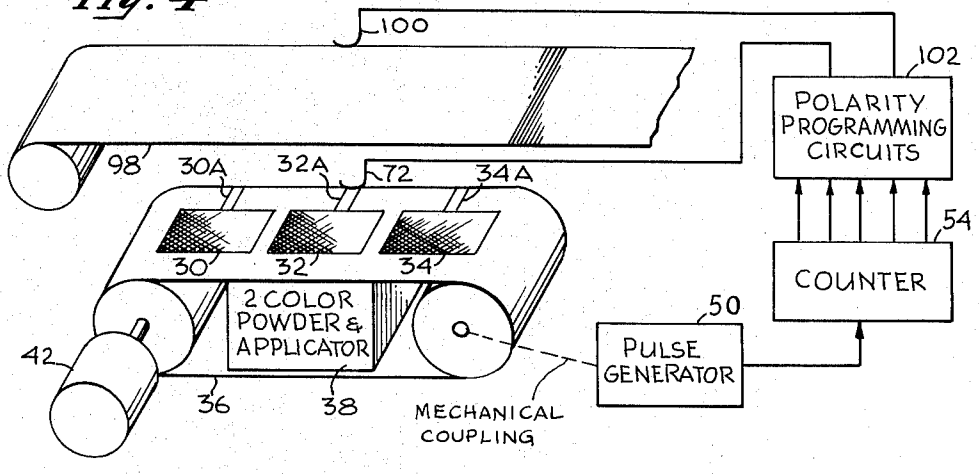
Fig. 4



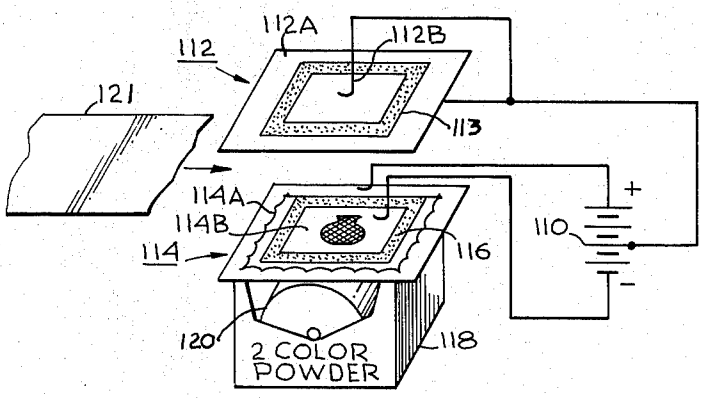
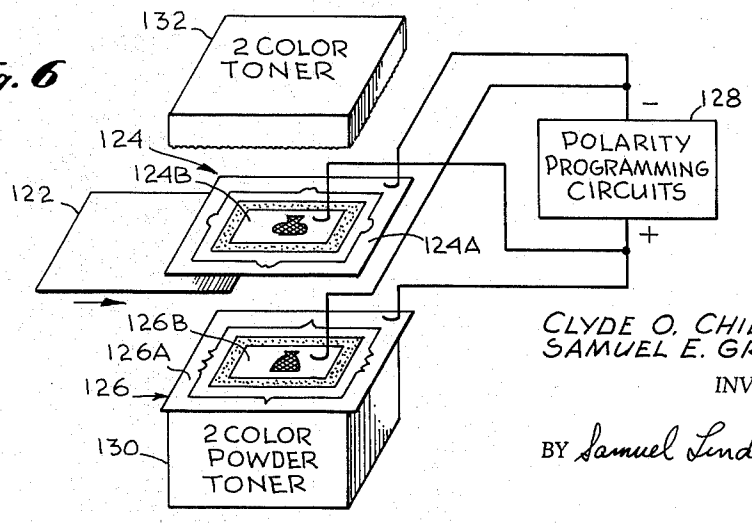


Fig. 5

Fig. 6



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United States Patent Office 3,218,968
Patented Nov. 23, 1965

3,218,968

MULTICOLOR ELECTROSTATIC PRINTING

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Filed Dec. 17, 1962, Ser. No. 245,321
3 Claims. (Cl. 101—115)

This invention relates to electrostatic printing and more particularly to improvements therein.

In an application for electrostatic printing filed March 4, 1960, Serial No. 12,714, by Childress et al., which is assigned to a common assignee, there is described an arrangement for electrostatic printing. Such an arrangement requires the establishment of an electric field into which a triboelectric powder bearing the proper charge is introduced. Usually one electrode which establishes such field is a conductive screen all of which is masked except a pattern of apertures which define the area over which it is desired that printing should occur. The electric field is established by applying a potential either to the screen and a conductive backing plate or where the material on which printing is to occur is sufficiently conductive to serve as an electrode in establishing the electric field, then the potential is applied between the screen and the material on which printing is to occur. A triboelectric powder is applied to the perforations in the screen. The powder must be of a type which will assume a charge whereby when it enters the electric field it will be attracted to the opposite electrode.

Where the opposite electrode is the backing plate, then the material to be printed upon is inserted into the field whereupon it intercepts the powder which is introduced into the field, and which maintains the shape of the open aperture in the screen.

Heretofore, if it was desired to print using more than one color then, multiple printing stations had to be used at which the different colored powders are applied in sequence to the material on which printing is to occur. This of course meant a duplication of the equipment just described. Alternative to this, a single printing arrangement may be employed for each one of the different colors. However, this requires a clean up of the colored powder between each use, which is time consuming and a nuisance.

An object of this invention is the provision of a novel arrangement for printing more than one color using electrostatic printing techniques.

Another object of this invention is the provision of an arrangement for printing a plurality of colors with electrostatic techniques which is more rapid than previously known systems.

Yet another object of the present invention is the provision of an arrangement for multi-color printing using electrostatic techniques which is simpler than previous known arrangements.

These and other objects of the invention are achieved by employing, with an electrostatic printing apparatus, a dry ink consisting of a mixture of two differently colored finely ground or powdered resins. These are selected so that the triboelectric inter-actions between the two resins, the brush which is employed for introducing them into the electric field, and the metal screen, all coact

to impart a charge of one sign exclusively to one of the colored resins and a charge of the opposite sign to the other resin. By establishing an electric field whereby the screen has one polarity relative to the powder mixture, one of the powders will pass through the screen apertures and the other is rejected. If the polarity of the screen and the opposite electrode, whether it is back plate or object on which printing is taking place, is reversed, then the other powder component can pass through the screen into the electric field to be deposited on the surface on which printing is to occur, while the first powder is rejected by the electric field.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a diagram of an embodiment of this invention;

FIGURE 2 is a diagram of another embodiment of this invention;

FIGURES 3 through 6 show various other possible arrangements for this invention.

Referring now to FIGURE 1, there may be seen a diagram of an embodiment of this invention in its simplest form. This comprises a conductive backing plate **10**, and a printing element **12**, which may comprise a fine mesh open screen of conductive material or material which is rendered conductive, in the printing areas and the non-printing areas being suitably masked. Here the printing area is represented by the image of a flask **12A**. Spaced from the screen is a sheet of paper **14**, on which the printing is to occur. A source of direct current potential **16** is connected to a double pole double throw reversing switch **18**. The reversing switch is connected to the conductive backing plate **10**, and the screen **12**, in a manner so that, when the switch is in one position the plate and screen are connected to opposite terminals of the potential source **16**, and when the switch is in the other of its two operative positions, the polarity of the connections of the plate and screen to the source of potential **16**, is reversed. As a result of the operation of the switch **18**, an electric field is established between the screen and stencil which has a polarity as determined by the position of the reversing switch.

In accordance with the teachings in the previously mentioned application to Childress et al., a pigment powder of a suitable type and color is applied to the open mesh region **12A** of the stencil screen, and under the influence of the electric field the powder is drawn toward the conductive backing plate. However, it is intercepted by the paper **14** to which it adheres in the shape of the open mesh region **12A** of the screen **12**. The paper can then be withdrawn from between the screen and backplate and the pigment may be fixed thereon by the application of heat, or by spraying a transparent fixative over the powder image.

The manner of introducing the pigment powder into the electric field may be for example, by employing a brush, here designated as a rotating brush **20** of natural animal hair or of a suitable synthetic fiber, which in rotating passes through suitable toner powder particles which are held in the container **22**. The powder particles may con-

sist of a mixture of two differently colored finely ground resins. These are selected so that the triboelectric interactions between the two resins, the brush and the metal screen impart a charge of one sign exclusively to one of the colored resins and a charge of the opposite sign to the other resin. An illustration of suitable powders to form a mixture of the type described may comprise a red toner, sold by the Switzer Company of Cleveland, Ohio, under the commercial designation of Rocket A–13 Red Toner, sold by Radiant Color Corp., of Oakland, California, a blue toner, under the commercial designation Velva-Glo Blue R–103. As illustrated, an embodiment of the invention which was constructed and operated, the paper **14** was substantially in contact with a metal backplate and was spaced away from the screen by a distance on the order of .025 inch. An electrical potential, on the order of 1000 volts, was applied between the screen and the plate. A brush of natural animal hair or of a suitable synthetic fiber was employed to pick up the powder from the container **22** and brush it against the screen printing element. When the field between the screen and the backplate was established, with the screen positive and the plate negative, by the switch **18**, the blue toner component of the mixture entered the field and was printed out onto the interposed paper. The red component of the mixture was rejected by the field and remained with the brush or adhered to the screen.

When the polarity of the screen and the plate was reversed, with the screen negative and the backplate positive, effectuated by operating the switch **18**, the red toner particles entered into the field and were printed onto the interposed paper. The blue particles were rejected by the field and remained with the brush or the screen.

Another powder suitable for utilization with the present invention is found described and shown in Patent No. 2,890,968.

While the mixing of particles of any two materials of different compositions will produce charges in those materials of opposite polarity relative to each other; this is not sufficient to produce the desired behavior in the present invention. Many pairs of materials which acquire opposite charges relative to each other, and which show opposite polarity response when used alone in the same printing apparatus, nevertheless when combined, print as an undifferentiated or poorly differentiated mixture. While this behavior is not fully understood, it is believed that the material comprising a mixture that will successfully perform the polarity differentiated color printing of this invention must not only acquire opposite charges relative to each other, but must react oppositely to the combined triboelectric effects of the materials comprising the powder feed and applicator mechanism and the image stencil element. They must also be immune to charge reversal caused by contact with the potential of the conductive screen, and must acquire charges that are not only opposite but relatively equal to prevent their mutual attraction from binding them together in such a manner that the particles of the sign with the lesser charge attach to the particles with the opposite and greater charge and thus transfer together as units whose net charge and consequent behavior corresponds to that of the material which has the greater charge.

Reference is now made to FIGURE 2 wherein there may be seen an arrangement of an embodiment of the invention for employing the concept described above in an automatic fashion. Screen printing stencils **30, 32, 34,** and others, not shown, are mounted in a belt arrangement **36**. This endless belt is rotatably moved by means of two rollers **38, 40,** driven by a motor **42**. The belt **36,** holding the stencil screens, is mounted over the two rollers to be rotatably driven as the rollers are rotated.

Spaced from the belt arrangement of the screens is the backing plate **44**. The web **46,** on which writing is to take place, is positioned between the backing plate **44** and the belt stencil screen arrangements. In order to preserve clarity in the invention however, it is here fragmented. It will be understood however, that in the normal course of writing, the web **46** is interposed between the backing plate **44** and the stencil screen belt **36**. The figures or pattern of openings in the stencil screen may be complementary in the sense that for example, the stencil screen **32** may have the central pattern desired to be printed and the stencil screen **30** may have the frame around the central pattern. It is desired to print the central pattern in one color and the frame in the second color. A two color pigment powder and applicator **48,** of the type described in connection with FIGURE 1, is positioned so that the pigment powders are applied to the stencil screen which is in the writing position opposite the backing plate **44**.

As the rollers **38, 40,** rotate, they actuate an electromechanical pulse generator **50**. This can constitute any known arrangement for generating pulses when driven by means of a shaft **52**. This can be for example, a wheel having magnets in the periphery which pass by a pickup coil as the wheel rotates to induce voltages in the pickup coil. These may be subsequently amplified and shaped for application to a cyclic counter **54,** to advance the count thereof. Each output of the counter **54,** is connected to a separate switch respectively **56, 58, 60, 62, 64.** These switches are individually settable to be open or closed as desired, in order to program the polarity of the potential to be applied between the stencil screens on the belt **36** and the back plate **44**. All of these switches in turn are connected to a relay coil **66,** which has a pair of double pole double throw contacts **68**. The contacts **68** have a normally closed position, wherein they connect the positive terminal of a source of operating potential **70** to a contact brush **72** and the negative source of operating potential is connected to the backing plate **44**. When the relay **66** is operated by reason of one of these switches **56** through **64** being closed, and by reason of the counter **54** having the count condition which can apply its output through the closed switch to the relay **66,** then the double pole double throw contact **68** reverses the polarity of the voltage being applied to the backplate **44** and contact brush **72**.

The contact brush **72** makes contact with conductive extension tabs for example, **32A,** which connect to each one of the stencils **30, 32, 34,** on the belt. Accordingly, the brush **72** and contact tab **32A,** serve not only to connect operating potential to the screen, but also to apply the potential only when the screen is located at the proper writing position, with respect to the backplate **44**. Proper powder transfer occurs only upon the application of potential between screen and backplate. This is triggered and maintained when, and over the interval brush **72** and tab **32A** are in contact with each other.

With the arrangement described thus far, it is possible to program the polarity of the field which is to be established between the screen and the backing plate, whereby the color of the powder which is deposited upon the web **46,** is selected. Therefore, if for example, as shown in FIGURE 2, the stencil **32** contains the central pattern of the figures desired to be printed, and the counter is placed in its first count condition, the switch **56** being open, the relay **66** is not energized and therefore, the central pattern is printed upon the web **46** with a colored powder which has a negative triboelectric charge. As the belt **36** continues to rotate, the stencil **30** is brought into position. This stencil contains openings which define a border pattern. Just before the stencil reaches the printing position the pulse generator **50** applies its second pulse to the counter **54**. The second switch **58** is closed and therefore relay **66** is operated. This enables the relay contacts **68** to reverse the polarity of the voltages applied between the stencil **30** and the backplate **44**. Accordingly, the other colored powder will pass through the openings in the stencil and be deposited upon the web **46**. A two color figure has now been produced. The web ad-

vances to enable the next pattern to be printed. The program for the polarity to be applied between screen and backing plate is established by means of a counter **54**, the switches **56**, and the relay **66**.

While FIGURE 2 shows an arrangement for printing, using a mixture of two pigment powders, each having opposite polarity triboelectric properties, it is possible to simultaneously print with the scheme shown in FIGURE 3, more than one image. In order to operate in this manner, the belt **36**, must carry more than one stencil screen respectively **74A**, **74B**, **76A**, **76B**, **78A**, **78B**, **80A**, **80B**, in a direction transverse to the direction of rotation. Two of these stencils are shown by way of example, although the scheme shown can be extended to include any desired number. The web **46**, upon which printing is to occur, as described before, is shown fragmented in order to enable a better presentation in the drawing. A backing plate respectively **82A**, **82B**, is provided for each one of the screens at the writing position. Each one of the screens **74A** through **80A**, and **74B** through **80B**, has its own associated conductive tab respectively **84A**, **84B**, **86A**, **86B**, **88A**, **88B**, **90A**, **90B**, which extend from the stencil screen toward the edge of the belt to a location where the respective A and B tabs can respectively contact brushes **92A**, **92B**.

Each one of the brushes **92A**, **92B**, is respectively connected to a separate polarity programing circuit respectively **93A**, **94B**. Each one of the polarity programing circuits constitutes a separate array of settable switches, one switch in each array being connected to the same output of a common cyclic counter **96**. Furthermore, each one of the polarity program circuits also includes, besides a set of switches **56** through **64**, such as is shown in FIGURE 2, a relay **66**, **68**, connected to a source of potential **70**. Thus, the structure of the polarity programing circuits respectively **94A**, **94B**, are identical with that shown and described in FIGURE 2 for the purpose of programing the polarity of the respective potentials being applied between the backplate **82A** and whichever one of the A stencil screens attains the writing position, and between the backplate **82B** and whichever one of the B stencil screens reaches the writing position. Proper powder transfer is triggered and maintained when and over the interval of contact of brushes **92A**, **92B** with the respective tabs **84A** through **90A**, **84B** through **90B**.

It should be apparent, that the operation of the structure shown in FIGURE 3 should be identical with the operation of the structure shown in FIGURE 2, except that two patterns are written on the web **46** simultaneously instead of one as before. The color of the pattern that is deposited upon the web is determined by the relative polarity of the backplate and screen stencil at the writing position.

It was shown in the previously mentioned patent application by Childress and Kabell, that if the material upon which printing is to occur is sufficiently conductive to establish an electric field when a potential is applied thereto, then the backplate can be dispensed with and the material itself can serve as one of the electrodes in the electric field. Accordingly, in FIGURE 4, a web **98**, representative of material upon which electrostatic printing is to occur, is made of conductive material. Accordingly, contact is made directly thereto by means of a brush **100**, which is connected to a polarity programing circuit **102**. The structure represented by the rectangle **102**, is the same as is shown in FIGURE 2, comprising switches **56**, through **64**, and the reversible relay **66**, **68**, and the source of potential **70**. The remaining structure shown in FIGURE 4 is given the same reference numerals as are applied in FIGURE 2, since their functions are substantially identical.

As each one of the screen stencils **30**, **32**, **34**, reaches the printing position, its conductive tab respectively **30A**, **32A**, **34A**, contacts the brush **72** and thus an electric field is established between the screen stencil at the printing position and the conductive web **98**, and more specifically with the portion of the conductive web which is opposite the screen stencil at the time. The setting of the switches in the polarity programing circuits determines the polarity established between screen and web and therefore the color of the triboelectric powder which is attracted toward the web which therefore is printed out in the pattern established by the opened aperture portion of the screen. The operation of the embodiment of the invention, shown in FIGURE 4, accordingly is substantially identical with the operation of the embodiment of the invention shown in FIGURE 2, except that the web **46** and the conductive backing plate **44** have their functions combined in the material **98** upon which it is desired to print.

It was shown in FIGURE 3 that it is possible to simultaneously print from two screen stencils using a single counter which instructs two polarity programing circuits. This nmber, shown by way of illustration, is not to be construed as a limitation, since it is possible, of course, to drive more than two. FIGURE 5 shows an arrangement for printing simultaneously with two colors using the principles of the invention which have been described. A center tapped power supply **110** has the center tap connected to the conductive backing plate **112** (or to the material upon which printing is desired if such material can serve as an electrode in establishing the electric field). The backing plate can be a single conductive sheet, or to eliminate possible effects of a fringing field caused by the split construction of the screen **114**, can consist of two conductive sections **112A**, **112B** separated by an insulating section **113**. Connection is made to both sections **112A**, **112B** from the center tap of the power supply **110**.

The stencil screen **114** consists of two conductive portions respectively **114A** and **114B**, which are separated from one another by an insulating portion **116**. The conductive portion **114B** is connected to the negative terminal of the center tap source of potential and the conductive portion **114A** is connected to the positive terminal of the center tap source of potential. The two sections **112A**, **112B**, are preferably disposed opposite the portions **114A**, **114B**.

The powder in the container **118** is applied over the entire screen by an applicator brush **120**, which is moved in a manner to pick up this powder and apply it to the screen. The web **121** is positioned between the backplate and the screen **114**.

The conductive backing plate **112** is negative with respect to the outer portion, **114A**, of the screen **114** and therefore powder particles having positive triboelectric charges will be drawn through the screen apertures in the outer portion to be deposited upon the web **121**. The conductive backing plate is positive with respect to the central portion, **114B**, of the stencil screen **114** and therefore, those powder particles which have a charge such as to be attracted toward the relatively positive conductive backing plate will be drawn through the apertures at the center of the screen toward the web **121**. From the foregoing it should be apparent that one can print simultaneously with different colors using a screen with apertures placed on different areas thereof, which are insulated from one another. These different areas of course, must be biased at different polarities relative to the opposite electrode used for establishing the electric field.

FIGURE 6 shows an arrangement for electrostatic printing on opposite sides of a web **122**, using two polarity screens respectively **124**, **126**, which are positioned on opposite sides of the web. Each of the two screens has an outer conductive section, respectively **124A**, **126A**, and an inner conductive screen section respectively **124B**, **126B**. These are contacted by brushes which connect by leads to a polarity programing circuit **128**. The polarity programing circuit may be of the type described previously, which consists of a relay, switches and a counter for establishing desired voltage relationships between op-

posite screens **124**, **126**, as well as between the inner and outer conductive sections of the screens themselves. The two color powder containers **130**, **132**, are positioned in the manner previously described, to apply to the respective stencil screens triboelectric powder particles having mutually opposite polarity charges.

An electric field is established between the screen section **124B** and the screen section **126B** and the web which is interposed therebetween will be printed on both sides with a powder pattern having the configuration of the open or unmasked portions of the screen. There will be a different colored powder deposited on opposite sides of the paper. Similarly, printing will occur through the open portions of the screens **124A** and **126A** with opposite color toner powders.

The mechanisms imparting charge to the powder particles is not fully understood. Even the triboelectric charging which occurs when a single resin powder is rubbed on another material, is not fully comprehended (e.g. questions remain regarding the charge distribution through the bulk of a resin particle). It is known however, that if two dissimilar resins, a brush fiber material, a metal screen and a mask are involved in the charging system the triboelectric interactions become very complex. The basic reaction however, appears to be between the two powdered resins. This is borne out by the fact that, when each of the powdered resins is used separately for electrostatic printing, it will print with either polarity although generally better at one or the other polarity, depending upon the triboelectric relationship of the brush fiber material to the toner. Further evidence that the primary reaction occurs between the two resin toners is afforded by the fact that, the two resins will print selectively when no brush is used for pushing the resin toner particles through a screen but instead they are deposited upon a vibration agitated screen directly from a grounded metal container and an electric field of one or the other relative polarity is established. However, the fact remains that the two powders triboelectrically react with one another so as to acquire charges of the opposite sign, whereby they may be printed selectively as a function of a polarity of a field created between the charged printing element and a conductive backing plate, which may be the material on which the printing is to occur if it is conductive. In the latter connection it is to be understood that, when the term conductive is applied to either a screen, backing plate or material on which printing is to occur, it is meant that such screen, backing plate or material is sufficiently conductive to act as an electrode for the purpose of establishing an electric field by means of which printing in accordance with the teachings of this invention can occur.

There has accordingly been described and shown herein a novel, useful and unique printing method and means which does not require pressure to be applied to the surfaces on which printing is to occur, and which in a simple and inexpensive manner affords multicolor printing from a powder mixture by properly selecting the polarities of the voltages applied. While the figures of the drawing show flat stencil screens, in connection with flat backing plates and writing materials, this is not to be construed as a limitation upon the invention since, where required, because of the configuration of the material upon which printing is to occur, the screen as well as the backing plate may be curved in order to conform to the curved surface on which it is desired to print. For example, if it is wished to print on a curved glass bottle, or on the curved surface of fruit, or on the curved surface of wood or ceramic material, in order to keep a substantially uniform spacing, which is desirable but not essential, between the screen and the material upon which printing is to occur, the screen may be curved. Therefore, it is intended that the drawings herein are shown by way of illustration of the inventive concept and not as a limitation thereof.

Further, the invention is to be limited only by the spirit and scope of the claims herein.

We claim:

1. An electrostatic printing system for printing with a mixture of at least two powders having different physical properties and having relatively opposite polarity triboelectric properties, said system comprising means for establishing an electric field including two opposite electrodes, one of said opposite electrodes comprising a screen having two apertured portions therein in a pattern defining the desired printing patterns, said two apertured portions being conductive and being separated from one another by an insulating region, means for applying said powder mixture to the two apertured regions of said screen, the apertures in said screen being larger than particles of said powder, a source of operating potential having two opposite polarity output terminals, means for connecting one of said two terminals to one of said apertured regions and the other of said two terminals to said opposite electrode, whereby only one of said two powders can pass through said apertures into said electric field to be carried thereby away from said screen to said other of said opposite electrodes, and means for connecting said one of said two terminals to said opposite electrode and the other of said two terminals to said other apertured region of said screen whereby only the other of said two powders can pass through said other apertured region of said screen into said electric field to be carried thereby away from said screen to said other of said opposite electrodes.

2. An electrostatic printing system for printing with a powder mixture including at least two powders having different physical properties and having opposite polarity triboelectric properties, said system comprising a pair of oppositely spaced electrodes one of said electrodes being a screen having two conductive regions spaced apart by an insulating region, each of said conductive regions including a plurality of apertures in a pattern desired to be printed, each of said apertures being larger than the particles of said powder mixture, means for applying a first potential to the first conductive region of said screen, means for applying a second potential having a polarity opposite to that of said first potential to the second conductive region of said screen, means for applying a third potential intermediate said first and second potential to said other electrode whereby a first electric field is established between said first conductive region and said other electrode, and a second electric field is established between said second conductive region and said other electrode, and means for applying said powder mixture to said first and second regions of said screen whereby only one of said powders will pass through one of said regions into said electric field to be carried by said first electric field away from said screen to said other of said pair of electrodes and only the other of said powders will pass through the apertures in the other of said regions into said electric field to be carried by said second electric field away from said screen to said other of said pair of electrodes.

3. A system for electrostatic printing with a powder mixture including at least two powders having different physical properties and having relatively opposite polarity triboelectric properties, said system comprising means establishing a printing station including a plurality of screens each of which has a conductive region therein including apertures in a pattern defining the desired form of said printing, the particles of powder in said powder mixture being smaller than the apertures of said screen, electrode means, means for moving each one of said plurality of screens in sequence to a position spaced opposite said electrode means to thereby establish said printing position, means for applying said powder mixture to said screen when in said printing position, a source of potental, means for predetermining with what polarity connection is made from said source of potential to said electrode means and a screen at said printing position,

means for producing a signal when each of said screens reaches said printing position, means for applying said signal to said means for predetermining for establishing a connection to said electrode means and the screen which is at said printing position to establish an electric field therebetween with a relative polarity to permit only a desired one of said powders to pass through the apertures of said screen into said electric field to be moved thereby away from said screen toward said electrode means.

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