March 31, 1970 W. T. FISHER ET AL 3,503,331

CONTROLLED CURRENT FLOW ELECTROSTATIC PRINTING

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FIG. 1.

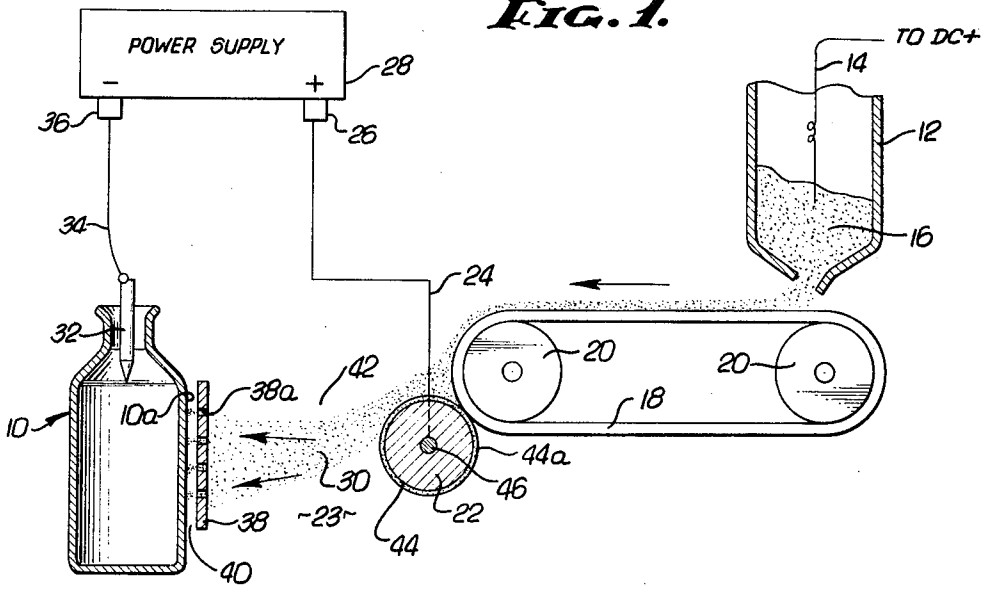


FIG. 3a.

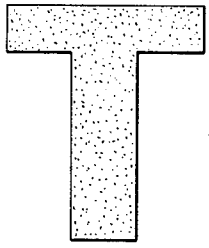


FIG. 2.

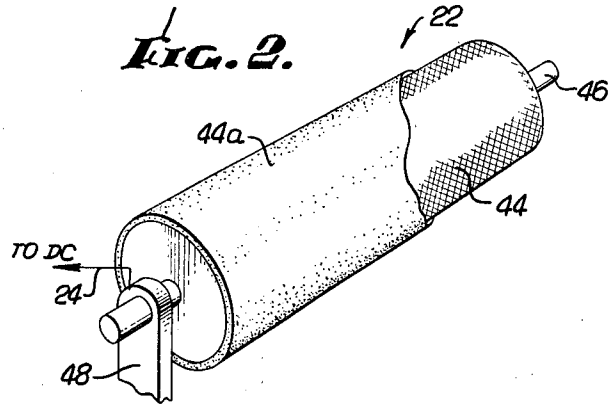
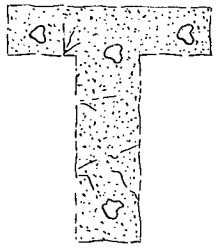


FIG. 3b.



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CONTROLLED CURRENT FLOW ELECTROSTATIC PRINTING

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U.S. Cl. 101—114 13 Claims

ABSTRACT OF THE DISCLOSURE

Excessive flow of current in electrostatic printing, across the gaseous medium through which the particle moving field has been established, is prevented and current flow automatically controlled by the use of a resistive launching electrode which selectively compensates for incipient increases in current flow therethrough, and thus across the field, by decreasing the voltage in the affected portions of the electrode, without lowering the overall field strength, so that printing operations may continue unaffected.

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of our copending application, Ser. No. 479,461, filed Aug. 13, 1965, and a continuation of application, Ser. No. 624,388, filed Mar. 20, 1967, both of which are now abandoned.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention is concerned with improvements in method and apparatus for electrostatically printing or to like purposes depositing electrically charged particles onto a surface and finds application in the coating, labeling and decorating of various surfaces including those of containers such as glass or plastic bottles as well as in the printing of informational and literal indicia on objects ranging from newsprint to comestibles.

Description of the prior art

Electrostatic printing processes and apparatus are known which employ a launching electrode spaced from a target surface across a dielectric gaseous medium. The target surface is associated with a counter-electrode which forms an electrostatic field with the launching electrode to move electrically charged particles from the launching electrode to the target surface, generally through a stencil, for impingement on the target surface is a predetermined pattern. Printed image density is desirably high and varies directly with field line concentration or field intensity. Therefore field intensity is usually kept at a near maximum for the selected medium. As a result when slight variations in field intensity occur, e.g. because of a locally high concentration of field lines at or about small radius surfaces on the electrode, in the case of an air dielectric, for example, ionization of the air takes place and high current flow is produced along conductive paths so formed in the medium, between points on the electrode and opposing points on the target surface. It is the general practice to fabricate the launching electrode of materials having very high conductivity, i.e. metals. Highly resistive materials, i.e. conductive, nonmetallic materials having less than metal-like conductivity in which current flow increases are usable to increase the voltage drop across the electrode have not been employed to our knowledge.

SUMMARY OF THE INVENTION

The present invention is based on the general concept, among others, that excessive current flow across a dielectric gaseous medium in an electrostatic printing operation can be avoided and current flow controlled by an appropriate local reduction in voltage. This can be accomplished without significant effect on the printing operation. The invention provides apparatus for printing on the surface of an object that comprises printing means for depositing electrically charged particles onto the target surface in a selected pattern and, spaced from the target surface by an intervening dielectric gaseous medium, a resistive electrode charged to a particle repelling potential for so depositing particles. The resistive electrode is connected to a power supply as a source of electric potential and, with a counter-electrode associated with the surface, forms through the dielectric medium an electrostatic field of an intensity appropriate for electrostatic deposition of particles.

The electrode contemplated for use as a launching electrode in the present invention has a volume resistivity at 23° C. above 1×10^8 ohm-centimeters and may be comprised of a low conductivity matrix such as a synthetic organic plastic matrix, e.g. of thermosetting phenolic resin and a relatively more conductive filler selectable from materials such as particulate or fibrous forms of cellulosic, mineral, proteinaceous and synthetic organic materials.

In the method of the present invention, particles are deposited on the surface of the object to be printed by moving the particles away from the launching electrode voltage source and toward the target surface across an intervening gaseous medium, under field intensity conditions tending to produce current conducting paths through the medium, and selectively lowering the voltage at the voltage source terminus of such paths in response to a flow of current there, thereby to proportionately reduce current flow along the paths without significantly affecting the overall field intensity.

A preferred medium in electrostatic printing is air, although under high field intensity conditions it ionizes sufficiently to become current conducting when a sufficient field intensity is reached. In this invention, the voltage on the launching electrode is decreased and, as a consequence, the potential difference or voltage drop across the field is decreased, to a point where excessive current flow cannot occur. Thus the present invention provides, in a printing method which includes establishing an electrostatic field within a gaseous medium and introducing into the field printing particles carrying charges so as to be repelled by the launching electrode voltage source and toward a target surface, a compensation for local increases in field intensity to medium ionizing levels by a corresponding decrease in voltage or increase in the voltage drop across the launching electrode selectively opposite the local field intensity increase, limiting incipient increases in current flow in a manner such that overall field intensity and thus particle flow are substantially undiminished. In other words, current flow produced increased voltage drop across the launching electrode lowers the local surface voltage thereof, decreasing thereby the potential difference across the air gap and reducing current flow.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of a printing apparatus according to the present invention;

FIG. 2 is a perspective view of a resistive launching electrode, illustrating one embodiment of the invention;

FIG. 3*a* is a schematic representation of a perfect letter image formed by the present apparatus; and

FIG. 3*b* is a schematic of a similar letter, poorly formed, owing to use of a highly conductive, metallic launching electrode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1, there is shown a typical improved printing apparatus according to the present invention, particularly printing means for depositing electrically charged particles onto a target surface in a predetermined pattern to print or decorate an open mouth container **10** such as a plastic bottle, having a printable surface **10***a* depicted to include a printing particle supply hopper **12**, having a particle charging wire **14** connected to, e.g. a positive D.C. supply (not shown) for charging printing particles **16**. A conveyor belt **18**, suitably of rubber or cloth is driven continuously beneath the hopper between sheaves **20**. The printing particles are carried on the belt to the launching area. There, a voltage source, launching electrode **22**, to be more fully described, spaced from the surface of **10***a* by an intervening dielectric gaseous medium indicated at **23**, is provided illustratively connected at **24** to the positive terminal **26** of a D.C. power supply **28** so that the particles **16** are repelled by the electrode **22** and therefore, are launched therefrom through the medium. A counter-electrode is provided to define an electrostatic field with electrode **22** such as conductive probe **32** positioned within container **10** at the open mouth or neck thereof. This probe is connected at **34** to illustratively, the negative terminal **36** of the D.C. power supply **28** to receive a charge which ionizes the fluid medium, e.g. air inside the container so that the particles constituting stream **30** are attracted to the thereby created counter-electrode condition and surface **10***a*.

Within the electrostatic field, thus defined, comprising a multiplicity of field lines determinative of the field intensity, there is placed a printing pattern defining stencil **38** of dielectric material or preferably, conductive material, generally brass or beryllium-copper shim stock which may be entirely electrically unconnected, as shown, or grounded or biased to some value consonant with the field.

The stencil is provided with image-defining apertures **38***a* which permit portions of printing particles stream **30** to pass the stencil and impinge on the container surface. The stencil apertures may be produced mechanically as with a suitable die or with a punch press or chemically or electrochemically or by other suitable means. In the typical arrangement shown in FIG.1, the voltage drop across the medium filled gap **42** will be quite high, e.g. on the order of 20,000 to 100,000 volts or more, provided by potentials of 10,000 to 60,000 volts at the launching electrode and 10,000 to 40,000 volts of opposite polarity at the counter-electrode probe.

For illustrative purposes herein, the launching electrode is considered to be positively charged and the counter-electrode or probe negatively charged; the particles are positively charged. It is to be noted that it is the relationship of the electrode polarities to one another and to the printing particle polarity and not their respective signs that is of significance in the present invention, so while the invention is described herein as having a positively charged launching electrode and to use positively charged printing particles, all signs may be opposite.

While it is contemplated that the stencil **38** may, during printing, have any desired closeness of approach to the container surface **10***a*, it is generally desirable to maintain at **40** sufficient spacing to preclude contact smearing of the deposited particles. The gap **42** between the launching electrode and the stencil can range from zero spacing, where stencil and electrode are integral, to relative wide spacing, typically in the range of 3 to 15 cm, which latter is particularly desirable to promote and

insure dispersion of stream **30** particles for free passage through the stencil openings.

Under the electrostatic field conditions just described, e.g. voltage drops off up to 100,000 volts and more across air or other gaseous medium gaps of approximately 3 to 15 cm., there results a high intensity electrostatic field, one approaching the maximum dielectric strength of the medium, e.g. air. A further intensification of this field, i.e. a greater concentration of field lines, even locally, can overcome the dielectric by extensive ionization of the medium component atoms, and the setting up conductive paths for current flow or even arcing. Uneven launching electrode surfaces, cocked orientation or small radius configurations, e.g. abrupt corners can cause such field intensification and from the locus for current flow path initiation. Continuous high current flow, e.g. of 50 microamperes, or a sparking discharge through the stencil apertures **38***a* causes an electrical disturbance in the image areas, with the resultant loss of image sharpness, fidelity to stencil design or even a pocked image. Thus in FIG. 3*b* the results of continued high current flow during printing is depicted. Nonuniform lettering density, poor reproduction of stencil outline, cratering, and cracks all may occur. With limited current flow, e.g. 0 to 10 μa. letters appear as in FIG. 3*a*.

It is the purpose of the present invention to preclude deleteriously high current flow, although not necessarily to terminate all current flow, thereby to enhance printing image uniformity, image boundary definition, print density and image fidelity to stencil design. It is known in accordance with Ohm's law that as current flow through a resistive body increases, voltage drop across the body increases. Utilizing this principle, it has now been discovered that by employing a resistive launching electrode, current flow through conductive paths in the dielectric medium from local areas of the electrode, which has in the past resulted in poor print results can be minimized. With a resistive electrode, as the current flow increases at a particular locus on the electrode surface, the voltage drop in that area increases directly therewith in accordance with Ohm's law. Thus, when current flow begins to rise, e.g. because of the propinquity of conductive gaseous media, the voltage on the electrode, at areas of incipient excessively high current flow, begins to decrease, automatically to a point where there is insufficient potential difference between the local surface area of the electrode and the counter-electrode or target surface for significant current flow across the conductive path therebetween through the medium. That is, rather than an insignificant variation in voltage drop with increasing current as in a conventional metal launching electrode, with the present, resistive launcher, an adequate voltage drop increase results, to reduce current flow substantially, to acceptable levels.

In FIG. 2, there is shown a typical non-metallic, but conductive electrode body, or resistive launcher, useful in the present invention. The particular shape of the electrode body is not critical, especially in view of the fact that small radius curvature changes such as at the ends of a cylinder are not a problem herein as a potential conductive path terminus unlike such configurations in all-metal electrodes. In the embodiment shown, the launching electrode comprises a cylinder **44** of resistive material mounted for rotation on a conductive spindle **46** which is journaled on support **48**. The cylinder **44**, centrally through spindle **46** is electrically connected at **24** to the positive D.C. source **26**. It is convenient for maximizing particle carrying ability of the electrode exterior to cover the resistive electrode surface with a layer of non-insulative material **44***a* such a mohair, although such covering is not critical to the operation of the electrode of the present invention. Also, the entire electrode body need not be resistive, provided the outer surface is resistive as herein described.

Among the materials useful in fabricating the cylinder body **44** there may be mentioned organic plastic materials, preferably combinations of a relatively less conductive matrix and a relatively more conductive filler. Among desirable matrix materials are such materials as are thermosetting in character, e.g. melamine- and phenolformaldehyde resins of the resole or novolac type. For controlling the resistivity properties of electrode bodies formed from such matrix materials, relatively more conductive fillers including natural and synthetic fibrous materials may be inccrporated therein. Among the naturally occurring fillers there may be mentioned cellulosic, mineral, and proteinaceous fibers such as silk, sisal, wool, cotton, hemp, jute, carbon, metal and asbestos fibers. Pulverulent and/or fibrous materials of natural or synthetic origin also may be used as fillers including silicates, ground cellulosic products such as wood flour and sawdust, as well as macerated fibers and fabric and the like. Among specific materials useful for fabrication of the launching electrode body, there may be mentioned the following specific combinations: cellulose nitrate and melamine-formaldehyde resins with appropriate fillers such as macerated fabric filler or phenolformaldehyde resins with, e.g. asbestos or wood flour fillers and vinyl butyral resins as well as shellac with or without extenders or fillers.

In summary, the present invention provides a solution to the problem of undue current flow during electrostatic depositing of particles on objects having conductive or non-conductive surfaces. Such flow is destructive of image uniformity and fidelity and is reducible to negligibility by employing a resistive launching electrode member which, as current flow increases therein, directly decrease the voltage at affected surface areas, to levels below those necessary for printed-image-affecting amounts of current to traverse the dielectric medium through which the electorstatic field is established.

We claim:

1. Apparatus for printing on the surface of an object that comprises printing means for depositing electrically charged particles onto said surface in a predetermined pattern, said printing means including an electrode spaced from said surface by an intervening dielectric gaseous medium and charged to a particle repelling potential to define an electrostatic field with said surface and to repel particles from said electrode toward said surface, and stencil means defining said pattern and being spaced from said surface and said electrode within said electrostatic field, said electrode comprising a relatively conductive member at least partly surrounded by a relatively resistive material, said relatively resistive material causing a reduction in said particle repelling potential of said electrode at localized portions of said electrode in response to current flow in said relatively resistive material such that said particle repelling potential varies at different portions of said electrode and arcing is prevented while the printing field is maintained.

2. Apparatus according to claim **1** in which said electrode has a volume resistivity at 23° C. above 1 x 10^8 ohm-centimeters.

3. Apparatus according to claim **1** in which said object is a bottle and said printing means also includes a counter-electrode maintained within the bottle.

4. Apparatus according to claim **3** including also a voltage supply to maintain a voltage differential between electrode and counter-electrode between 20,000 and 100,000 volts, in which said bottle surface and said stencil are between 3 and 15 centimeters apart and said gaseous medium is air.

5. Apparatus for printing on the surface of an object that comprises printing means for depositing electrically charged particles onto said surface in a predetermined pattern said means including an electrode spaced from said surface by an intervening dielectric gaseous medium said electrode being formed of a relatively less conductive matrix containing a relatively more conductive filler and having a volume resistivity at 23° C., above 1 x 10^8 ohm-centimeters.

6. Apparatus according to claim **5** in which said matrix comprises synthetic organic plastic.

7. Apparatus according to claim **6** in which said filler is selected from cellulosic, mineral, proteinaceous, and synthetic organic materials having a higher conductivity than said matrix.

8. Apparatus according to claim **7** in which said matrix is a thermosetting phenolic resin and said filler is a cellulosic material.

9. Method of eliminating arcing in electrostatic printing on the surface of an object that includes moving printing particles away from a resistive launching electrode toward and through a spaced stencil defining a printing pattern and toward said surface across an intervening gaseous medium by an electrostatic printing field extending between said electrode and the object surface and locally reducing the potential of said resistive launching electrode in response to increased current flow in said resistive launching electrode so that said potential varies at different areas to prevent arcing, while the printing field is maintained.

10. Method according to claim **9** in which said printing field extends between **3** and **15** centimeters and maintaining a potential difference between 20,000 and 100,000 volts across said field for printing.

11. Method according to claim **9** including also maintaining a counter-electrode behind said object surface to define with said launching electrode said electrostatic printing field.

12. Method according to claim **11** in which said object is a bottle and including also forming said counter-electrode by ionizing air within said bottle.

13. Method according to claim **9** including also charging as electrode having a differentially conductive matrix and filler composition and a volume resistivity at 23° C., above 1 x 10^8 ohm-centimeters to a particle launching potential and introducing oppositely charged printing particles into said field between said electrode and said object surface for movement to said surface for printing thereon.

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U.S. Cl. X.R.

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