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PROCESS AND APPARATUS FOR ELECTROSTATICALLY PRINTING ON HOT SUBSTRATE

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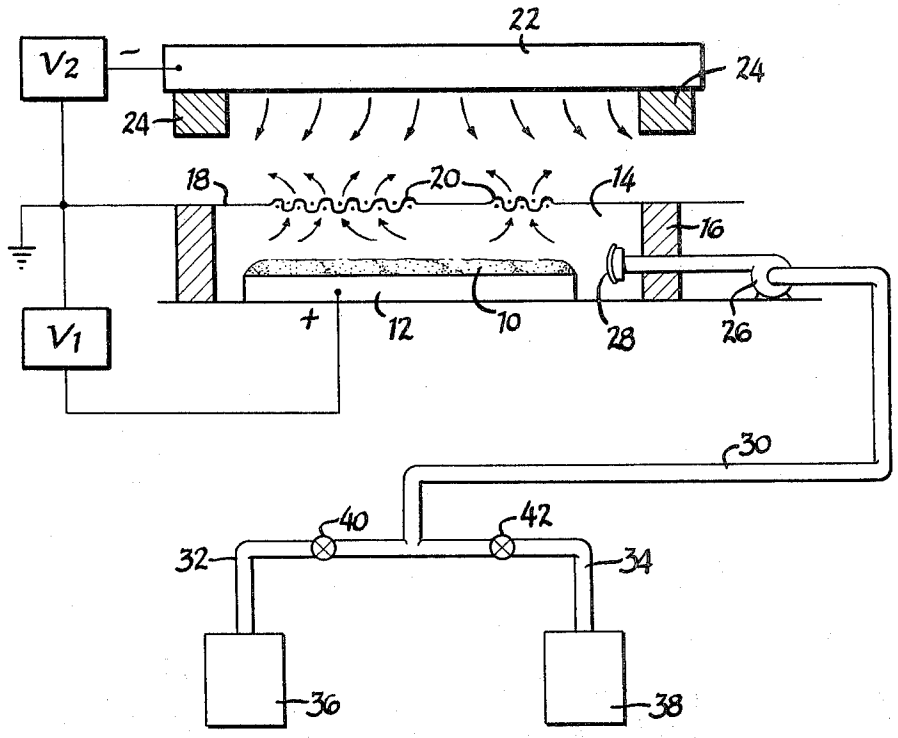

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PROCESS AND APPARATUS FOR ELECTROSTATICALLY PRINTING ON HOT SUBSTRATE

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This invention relates to electrical printing processes and apparatus, and more particularly to processes and apparatus especially adapted to electrically transfer printing powder particles from a supply through image defining apertures in a stencil screen directly to a heated surface, as, for example, to the surface of a glass article still heated to a relatively high temperature by residual heat from the article forming process.

The present invention is especially concerned with problems encountered in the so-called electrostatic printing or decorating of glass articles. In the formation of glass articles such as bottles, for example, the articles are produced in a forming machine and are discharged from the forming machine at a relatively high temperature of the order of 1000° to 1200° F. In conventional practice, the articles are then cooled and conducted to an annealing lehr and reheated to anneal the article. Most previous processes for decorating such articles have required that the article be cooled to a relatively low temperature before it was possible to apply a decoration. In some cases, it was desirable to heat the decorating material after application to the article which suggested the application of the decoration between the forming machine and the annealing lehr. However, this was frequently found to be impractical in cases where the article had to be cooled to a relatively low temperature before the decorating process could be performed. Desirably, cooling beyond a predetermined temperature between the forming machine and annealing lehr should be kept to a minimum because otherwise the article must stay in the lehr for a longer time before it reaches the annealing temperature.

Experience has shown that the so-called electrostatic printing process is peculiarly well adapted to the decorating of glass articles during the period of transit of the article from the forming machine to the annealing lehr. As set forth in more detail in a copending application of Kenneth G. Lusher, Serial No. 242,229, filed December 4, 1962, now abandoned, and assigned to the assignee of the present application, the high temperature of the glass provides several advantages in the electrostatic decorating process.

Further experience with production line methods and apparatus has brought to light several problems peculiar to the printing on surfaces at high temperatures.

In general, decorating processes of the type referred to above are performed by interposing a stencil screen between a bed of printing powder particles and the article surface to be decorated. An electric power source is then connected across the powder supply and article to charge the powder supply and article surface to electric potentials of opposite polarity. In the usual case, the screen is at an intermediate potential, usually at electrical ground. The electrical connections apply a charge to the powder particles and also establish an electric field extending from the supply to the article surface which impels and attracts powder particles from the supply to the article surface. The screen is provided with apertures of the desired shape of the image, and because the field confines the particles to substantially straight line motion, the shape of the apertures in the screen determines the shape of the image on the article.

The screen usually takes the form of a relatively fine mesh steel wire screen which is coated in areas other than

the image aperture to fill the mesh of the screen. Because the screen, supply and article surface are quite close to each other during the process, and the article surface may be at a temperature of 1000° or more, it is quite obvious that the heat radiating from the article surface influences both the screen and supply.

It was found that after several exposures of the screen to heated articles in rapid succession, the wire of the screen became heated to a relatively high temperature. This caused both buckling or expansion of the screen and also undue bridging or clogging of the screen mesh in the aperture openings. Clogging of the screen was caused by powder particles adhering, agglomerating, and melting on the hot wires of the screen.

Further, it was found that the electrical transfer characteristics of the powder rapidly decreased with the number of successive operations.

It is a primary object of the present invention to provide processes and apparatus for electrically applying printing powder particles to the surface of heated articles wherein adverse effects produced by the high temperatures of the articles are minimized.

It is a further object of the invention to provide methods and apparatus for achieving the foregoing object which further improve or enable variation of electrical properties and characteristics upon which the particle transfer is dependent.

Other objects and features of the invention will become apparent by reference to the following specification and to the drawing.

In the drawing:

The single figure is a schematic diagram of an exemplary process and apparatus embodying the invention.

In the drawing, there is disclosed an apparatus wherein a supply or bed of printing powder particles **10** is supported upon the surface of an electrically conductive plate **12**. Bed **10** and plate **12** are physically located at the interior of a chamber **14** which is defined by a suitable side wall construction designated generally **16**. The upper wall of chamber **14** is defined by a stencil screen **18** which rests upon or is secured to the top of the wall **16** and is provided with a series of suitably shaped image defining apertures as at **20**.

Screen **16** takes the form of a relatively fine mesh steel wire screen which is normally coated with a suitable coating which completely fills the openings in the screen mesh. Image defining apertures **20** are provided by removing the coating from selected areas above the screen. Suitable screens and methods for preparing such screens are disclosed in United States Patent No. 3,100,150.

The surface of an article to be decorated is illustrated schematically at **22** and suitable supporting structure such as a frame **24** is provided so that the article surface can be located in the desired spaced registry with screen **18** during the decorating operation.

Suitable sources of electric power schematically indicated at V1 and V2 are electrically connected to plate **12**, screen **18** and article **22**, as illustrated in the drawing. Further details of suitable electrical connections, etc., and potential magnitudes are set forth in detail in a copending application of William E. Johnson, Serial No. 393,817, filed August 31, 1964, and assigned to the assignee of this application.

A suitable blower **26** is connected to discharge gaseous fluid into the interior of chamber **14** and is provided a diffuser **28** on its outlet, so that gaseous fluid discharged into the interior of chamber **14** does not disturb the powder in bed **10**. The intake line **30** of blower **26** is connected by branch lines **32** and **34** to a supply **36** of water saturated air at ambient temperature and a water-free liquid nitrogen supply **38** from which cold nitrogen

vapor is withdrawn. Suitable regulating valves **40** and **42** are located in the branch conduits to proportion the mixture withdrawn by blower **26**.

Alternatively, supplies **36** and **38** may take the form of containers in which the gas or liquid is maintained under pressure. In this case blower **26** would be replaced by a regulating or throttle valve.

It has been found, after experimentation, that best results are achieved by diffusing into chamber **14** a mixture of approximately equal volumes of saturated room temperature air and dry nitrogen vapor from a supply of water-free liquid nitrogen. The mixture is diffused into chamber **14** at a rate such that a pressure differential of between one-half and five pounds per square inch exists between the interior of chamber **14** and the ambient air pressure outside. This pressure differential is sufficient to set up a gentle flow of gas through the image apertures of screen **18** as indicated by arrows in the drawing, this flows of gaseous fluid further serving to assist in deflecting the radiant flow of heat from the article surface.

The pressure differential is selected in accordance with the mesh size of screen **18** and the area of the image apertures—i.e. effectively the area of the opening through the screen from chamber **14**. For a #200 mesh screen with an image area of about 2 square inches, a pressure differential of 2 pounds per square inch is satisfactory.

Because of the relatively low temperature of the nitrogen vapor from the liquid nitrogen supply, a cooling action is achieved which minimizes the adverse effects of radiant heat from the article surface upon the wire mesh stencil screen, which may for convenience be termed a mechanical effect, as well as the effects of an undue amount of heat upon the electrical characteristics of the printing process.

In a typical practice of a printing operation in accordance with the invention, the article **22** which is being decorated might take the form of a flat sided glass flask or bottle which at the time of printing would be at a temperature of approximately 1200° F. Bottles being decorated are held stationary in the position of article **22** in the drawings for approximately 100 milliseconds and are advanced to the decorating position at a rate of 40 bottles per minute—i.e. one bottle is decorated each one and one-half seconds. The total distance from the surface being decorated—the lower surface of article **22** and the upper surface of powder bed **10** is one quarter of an inch, while the distance between the article surface being decorated and screen **18** is approximately .007 inch. Screen **18** is a #200 mesh stainless steel screen, prepared according to United States Patent 3,100,150.

A suitable glass frit composition for decorating hot glass bottles under the above circumstances has the following composition of ingredients in terms of percentage by weight.

	Percent
PbO	46
Pigment (selected from TiO_2 cadmium selenide, cobalt)	10
SiO_2	25–32
B_2O_3	3–5
RO (this includes ZrO_2, Fe_2O_3, Al_2O_3, BaO, ZnO, CaO, NaO, and K_2O grouped as RO)	7–16

The glass frit described above is in the form of an extremely fine particle sized powder, the particle size ranges preferably being between one and ten microns, although particle sizes up to 50 microns can be successfully transferred under the conditions described above.

In order for the particles to be transferred, it is necessary that the particles be capable of being electrically charged. The above composition is essentially of a nonconductive character and the possibility of electrically charging the particles is primarily dependent upon the moisture content of the powder supply. The moisture content is most conveniently considered as a relatively thin layer of moisture on each of the individual particles.

When the moisture content of the powder supply is within the range of .05 percent to .3 percent by weight, the individual particles can be electrically charged and satisfactorily transferred from powder bed **10** to the article surface. If the moisture content of the powder supply falls below .05 percent, the electrical characteristics of the powder become such that it is not possible to successfully transfer them, and at best an unsatisfactory printing of the article will result. If the moisture content of the supply exceeds .3 percent, the particles tend to agglomerate or stick to each other.

For reasons discussed in more detail in the copending Johnson application Serial No. 393,817 it is desired that the electric field strength between screen **18** and the adjacent surface of the powder bed be relatively high. With the above spacing of slightly less than one-fourth inch, the output of voltage source **V1** is adjusted to give a potential difference of 8 to 10 kilovolts between screen **18** and the powder supply.

The upper field strength—i.e. the strength of the electric field between screen **18** and powder bed support **12**—is not as critical and the output of voltage **V2** is selected to give a field strength of between 20 and 25 volts per mil between screen **18** and the article surface.

With the foregoing physical arrangement, flat sided glass flasks are fed to the apparatus at the rate of one flask per one and one-half second decorating cycle.

A mixture of equal volumes of air at 95 percent relative humidity and at room temperature and nitrogen at 0 percent relative humidity vapor from a supply of liquid nitrogen is continuously supplied to the apparatus at a rate sufficient to maintain a one pound per square inch pressure differential across screen **18**. The composite relative humidity of the air-nitrogen mixture was between 45 and 50 percent and the temperature of the mixture as it entered chamber **14** was 35° F.

Voltage sources **V1** and **V2** were pulsed or momentarily energized to establish the electric fields referred to above during the 100 millisecond interval at which the flask was held stationary in the decorating position. Operation of sources **V1** and **V2** electrically charges and impels particles from supply bed **10** through the aperture of screen **18** to the article surface.

During operation under the above conditions, it was found that the screen temperature was approximately 96° F. during the actual particle transfer cycle and rose to a maximum temperature of 105° F. after the printing. The maximum screen temperature was reached after the transfer of the powder to the article surface occurred because the bottle or flask stayed in the decorating position, or close to it, for a short period after the powder transfer had been completed.

Under the foregoing conditions, images of satisfactory density and resolution were achieved. Up to twelve consecutive prints at the above decorating rate can be achieved with satisfactory results. The limitation on the number of consecuive satisfactory prints is primarily due to depletion and packing of the powder supply rather than adverse effects created due to the 1200° F. flask temperature.

To compare the above results with results attainable in the absence of a supply of cooled humidified gas to chamber **14**, the same physical set up was employed on the same type flasks without cooling gas into chamber **14**. In this experiment, six bottles were fed through the apparatus at the same rate of one bottle per one-half second interval as in the previous case.

In this second experiment, the initial conditions within chamber **14** found the chamber filled with air at atmospheric pressure at ambient room temperature of about 80° F. and approximately 50 percent relative humidity.

Of the group of six bottles which were fed through the apparatus during the second experiment, only the first bottle was printed. The screen temperature during the attempted printing of the sixth bottle was 415° F. Prior to the sixth attempted printing, the screen was at approximately 380° F. and rose to a temperature of 420° F. before the bottle was removed. The screen was found to be both blinded—i.e., clogged—and warped.

The fact that only the first of the six bottles was printed during the latter experiment was due to moisture loss in the frit occasioned by the exposure of the frit to the hot glass bottle. To maintain the .05 percent to .3 percent by weight bulk moisture content of the powder supply, the relative humidity in chamber **14** must be maintained at somewhat above 20 percent. When chamber **14** is cyclically exposed to the 1200° F. temperature of the bottles, unless some attempt is made to cool the chamber and to continuously supply moisture to the chamber ot replace moisture evaporated by virtue of its exposure to the hot bottle, the frit powder becomes dried to a point where it can not be electrically charged and transferred.

A second adverse electrical effect was encountered in the experiment where a cooling gas was not employed. This effect was that of the substantial decrease in the dielectric strength of the gaseous medium within the electric field.

At temperatures reasonably close to normal room temperature, the dielectric strength—i.e., the electric field strength at which sparking or breakdown occurs—is approximately 80 volts per mil for air. The dielectric strength decreases substantially with increasing temperature, and at the 420° F. temperature which existed while the sixth bottle was in decorating position, the dielectric strength of air decreases to approximately 20 volts per mil. Thus, the heating effect produced by advancing hot bottles in rapid succession into operative relationship with the decorating apparatus of the drawings will, in the absence of the supply of a cooled humidified gas to chamber **14**, alter the electrical characteristics of the particles to a point where they cannot be successfully charged. The heating effect may also restrict the electric potential difference, especially in the upper field, to a point such that successful decoration could not be achieved even if it were possible to charge the particles.

The dielectric strength of the lower field is also influenced by the humidity of the incoming gas in that the potential difference across the field increases when no charged particles are impelled from the bed to screen **18**. Movement of charged particles is analogous to a flow of electric current. In the event the moisture content of the powder bed becomes such that no particles move from the bed to the screen the lower field loses the series resistance and the electric field strength is increased, thereby increasing the tendency of the air or gaseous medium to break down or spark.

The exemplary mixture of cold, dry nitrogen gas and substantially saturated air at room temperature is but one of many examples of a cooled humidified gaseous mixture which would be operable under the specific conditions outlined above. As a general rule, the gaseous mixture should be cool enough, and supplied at a rate such that under repeated exposure of the apparatus to high temperature articles, the screen temperature does not exceed room temperature by any substantial amount. Moisture should be supplied to chamber **14** by the gaseous fluid at a rate sufficient to maintain the moisture content of the powder within a range at which the powder can be electrically charged. The moisture content of the powder necessary to enable the powder to be electrically charged will vary in accordance with the composition of the powder. However, for most glass frit powders the range of moisture content between .05 percent and .3 percent by weight bulk moisture is operable.

Where the gaseous fluid takes the form of an air-nitrogen mixture, the maintenance of a screen temperature of approximately 100° F. assures that the dielectric strength of the gaseocs medium is sufficient to withstand the electric fields to which it will be subjected. The constant supply of a gaseous fluid to the apparatus also affords the possibility of employing gases having a higher dielectric strength than air where higher electric field strengths may be required in the decorating process. Freon 12 and sulphur-hexafloride for example have dielectric strengths greater than twice the dielectric strength of air.

It should also be noted that temperature has a substantial effect on the dielectric strength of a gas and that vapor from liquid nitrogen is at least theoretically available at minus 320° F. In cases where an extremely high dielectric strength is required, the temperature and composition of the gaseous fluid employed may be chosen accordingly.

The cool gaseous fluid does not have any practical temperature effect upon the bottle being decorated because of the extremely high temperature, the relatively large mass of the hot glass, and the relatively short time which each individual bottle is exposed to the apparatus. The apparatus, on the other hand, is exposed to a rapid succession of relatively massive bottles at extremely high temperatures.

While one embodiment of the invention has been described in detail, it will be apparent to those skilled in the art that the disclosed embodiment may be modified. Therefore, the foregoing description is to be considered exemplary rather than limiting and the true scope of the invention is that defined in the following claims.

I claim:

1. The method of applying an image shaped layer of powdered frit particles to an article surface heated to a relatively high temperature comprising the steps of interposing a stencil screen having an image defining aperture therethrough between a supply of frit particles capable of being electrically charged and the surface of a heated article to be decorated with the screen disposed in spaced relationship to the supply and to the article surface, diffusing into the space between said supply and said screen a moisture laden gaseous fluid at a temperature substantially less than that of the article surface, and establishing an electric field between said supply and article surface operable to electrically charge and impel particles from said supply through the apertures of said screen to said article surface.

2. The method as defined in claim **1** further comprising the steps of maintaining a continuous flow of said gaseous fluid from said space between said supply and said screen through the image apertures of said screen to constitute said gaseous fluid as the dielectric medium substantially throughout the space between said supply and said article surface.

3. The method of applying an image shaped layer of frit particles to a glass article surface heated to a temperature of the order of 1000° F. comprising the steps of interposing a stencil screen having an image defining aperture therethrough between a supply of frit particles capable of being electrically charged and the surface of a heated article to be decorated with the screen disposed in spaced relationship to the supply and to the article surface, enclosing the supply to define a chamber containing said supply having a wall defined by said screen, diffusing into said chamber a moisture laden gaseous fluid cooled to a temperature substantially below room temperature to cool said chamber and said screen, and establishing an electric field between said supply and article surface of a field strength sufficient to electrically charge and impel particles from said supply through the apertures of said screen to said article surface and of a strength less than the dielectric strength of said gaseous fluid.

4. The method as defined in claim 3 further comprising the steps of controlling the moisture content of the gaseous fluid to maintain the moisture content of the powder supply substantially constant in the face of the exposure of said supply to heat radiated from the article.

5. The method as defined in claim 3 further comprising the step of diffusing said gaseous fluid into said chamber at a rate sufficient to establish a continuous flow of said fluid from said chamber through the image aperture of said screen into the space between said screen and article surface whereby said gaseous fluid constitutes the dielectric medium of said electric field.

6. The method of applying an image shaped layer of powdered frit particles to a glass article surface heated to a temperature of the order of 1000° F. comprising the steps of locating a supply of frit particles capable of being electrically charged in a chamber having its top defined by a stencil screen having an image defining aperture therethrough, positioning the surface of a heated article to be decorated in vertically spaced registry above the screen, diffusing into said chamber a cooled humidified gaseous fluid consisting of a mixture of approximately equal volumes of vapor from a liquefied gas and saturated air at ambient temperature, and establishing an electric field between said supply and article surface operable to electrically charge and impel particles from said supply through the apertures of said screen to said article surface.

7. The method as defined in claim 6 wherein said gaseous fluid is diffused into said chamber at a rate to establish and maintain a pressure differential of between approximately ½ p.s.i. and 5 p.s.i. between the interior and exterior of said chamber to thereby establish and maintain a continuous flow of said gaseous fluid through the image apertures of said screen into the space between the screen and article surface.

8. Apparatus for applying an image shaped layer of powder particles to the surface of each of a plurality of articles while said articles are heated to a relatively high temperature comprising means defining a chamber having one wall thereof defined by a stencil screen having image defining apertures therethrough, means for supporting a supply of printing powder particles within said chamber in spaced registry with the image defining apertures of said screen, support means for supporting the surface of a heated article to be decorated in adjacent spaced relationship to said screen at the exterior of said chamber, electric power supply means for establishing an electric field between the supply and article surface operable to charge the powder particles of said supply and impel the charged particles through the image apertures to the article surface while the article is supported upon said support means, and means for maintaining the moisture content of said supply of printing powder particles substantially constant during exposure of said supply to successive heated articles supported upon said support means.

9. Apparatus as defined in claim 8 wherein the means for maintaining the moisture content include means for supplying to said chamber an adjustably regulated mixture of a plurality of gases in known proportions at a temperature substantially below that of the heated articles and of controlled humidity.

10. The method of decorating glass articles heated to temperatures of the order of 1000° F. by applying an image shaped layer of powdered frit particles to a surface of each article comprising the steps of supporting in a bed a supply of frit particles having a moisture content sufficient to enable the particles to be electrically charged upon an electrically conductive plate in spaced registry beneath a stencil screen having an image defining aperture therethrough, advancing heated glass articles in succession to a decorating position in closely spaced registry above said stencil screen, applying electric voltage pulses of opposite polarity to said plate and each article while the article is in said decorating position to electrically charge and impel particles from said bed through the aperture of said screen to the registered article surface, and continuously diffusing a cooled humidified gas into the space between said screen and said bed to maintain the moisture content of said particles and the temperature of said screen substantially constant in the face of repeated exposure to the heated glass articles.

11. The method as defined in claim 10 further comprising the steps of adjusting the moisture content of the supply of particles to an initial moisture content of between .05 percent and .3 percent by weight, and regulating the moisture content of said gas to maintain the relative humidity of the gas between said bed and said screen at at least 20 percent during the decorating of the articles.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,294,017 December 27, 1966

Douglas F. St. John

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 4, line 70, for "one-half" read -- one and one-half --; column 5, line 19, for "ot" read -- to --; column 6, line 4, for "gaseocs" read -- gaseous --.

Signed and sealed this 24th day of October 1967.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

EDWARD J. BRENNER
Commissioner of Patents