

- [54] **METHODS FOR ELECTROGASDYNAMIC COATING**
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Related U.S. Application Data

- [60] Division of Ser. No. 837,562, June 30, 1969, Pat. No. 3,673,463, which is a division of Ser. No. 601,270, Nov. 15, 1966, abandoned, which is a continuation-in-part of Ser. No. 512,083, Dec. 7, 1965, abandoned.

Foreign Application Priority Data

Apr. 21, 1971 Japan46/25242

- [52] U.S. Cl. **117/17, 117/93.1 CD, 117/93.4 R, 117/100 B, 117/161 UZ, 264/24, 310/6, 317/3, 118/621**
- [51] Int. Cl. **B05b 5/02**
- [58] Field of Search..... **117/93.4 R, 93.41, 93.42, 117/93.43, 93.44, 17, 100 B, 93.1 GD, 93.1 CD, 161 UZ; 239/3, 15; 264/24; 118/621, 622, 627; 310/5, 6; 317/3, 4**

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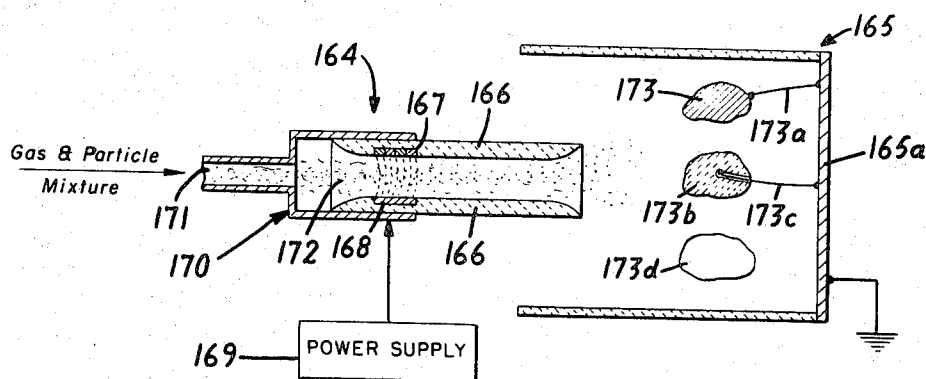
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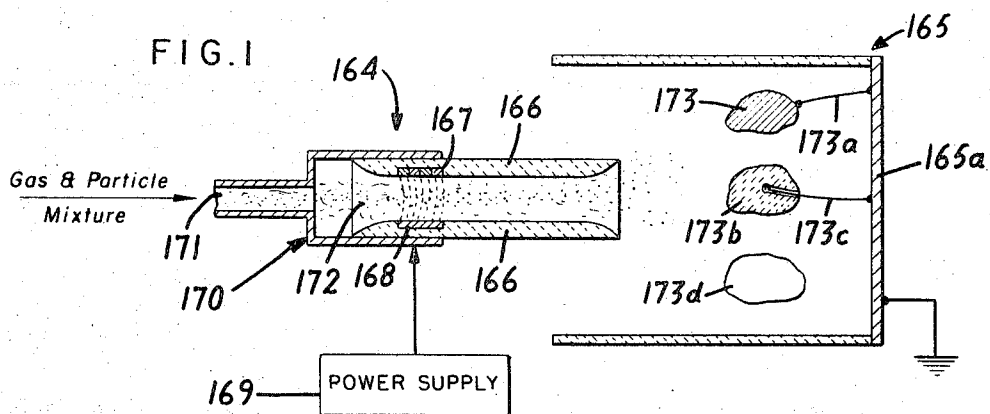
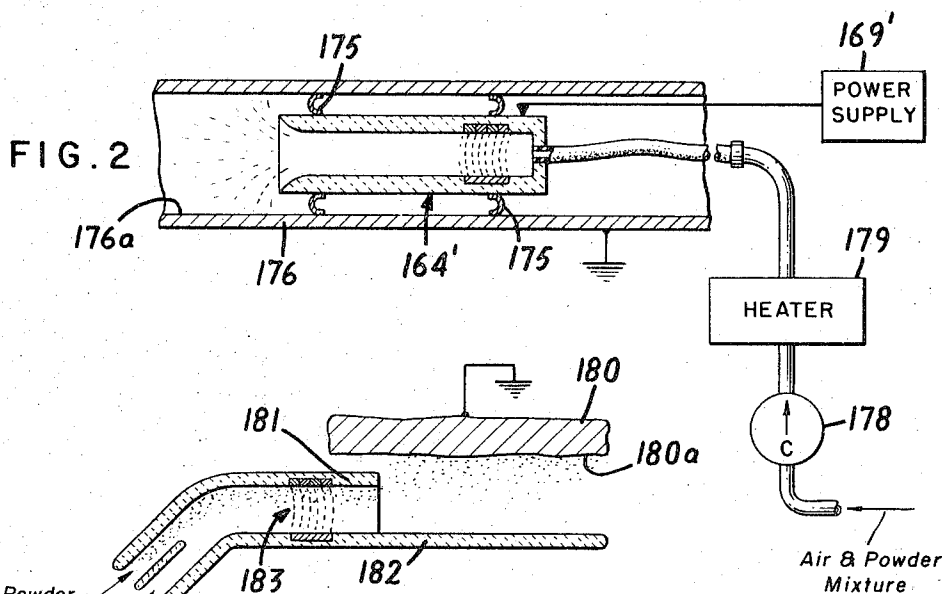
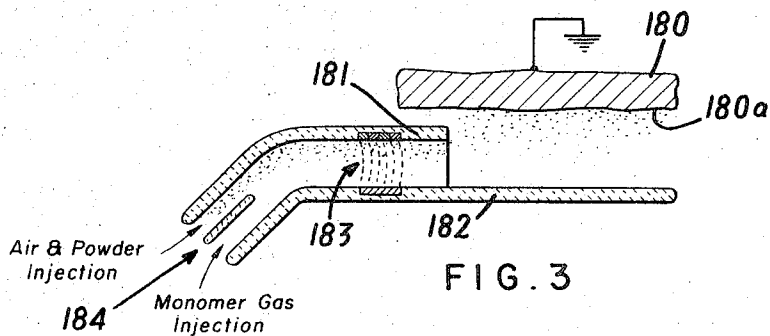
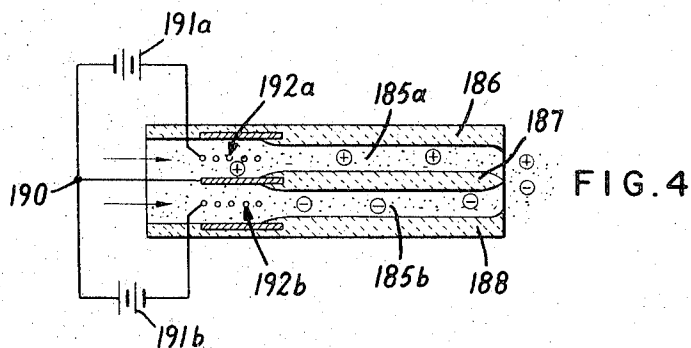
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ABSTRACT

Method for applying coating materials to articles, using electrogasdynamic apparatus providing a flow channel having a dielectric boundary which has a length/width ratio of greater than 2.5. Gas containing particulate coating material is ionized to create an electrical discharge field for imparting an electrical charge to the particles prior to passage through the dielectrically bounded flow path and thereby creating a high space charge potential. In special applications, a free-radical forming monomer gas or a fusible particle substance is carried in an inert gas into the electrical discharge field and through the flow channel toward the article to be coated. In any case, the charged particles are subjected to an axial charge repelling field (due to space charge effects) in the flow channel to raise the electrical potential of the particles, and thereby the potential gradient between the particles and the workpiece.

14 Claims, 4 Drawing Figures





METHODS FOR ELECTROGASDYNAMIC COATING

CROSS-REFERENCES TO RELATED APPLICATIONS

This is a division of application Ser. No. 837,562, METHODS AND APPARATUS FOR ELECTROGASDYNAMIC COATING, filed June 30, 1969, itself a division of application Ser. No. 601,270 for ELECTROGASDYNAMIC SYSTEMS AND METHODS filed Nov. 15, 1966, which in turn is a continuation-in-part of application Ser. No. 512,083, ELECTROGASDYNAMIC SYSTEMS MAINTAINING CONSTANT GAS SPEED, filed Dec. 7, 1965. Application Ser. No. 837,562 is now Pat. No. 3,673,463, and application Ser. Nos. 601,270 and 512,083 are now abandoned.

BACKGROUND OF THE INVENTION

Electrostatic coating techniques have been used for some time to deposit on a workpiece a homogeneous even coating of charged particles.

The apparatus used to carry out such coating generally consists of a hand-held or mounted spray gun device for atomizing a liquid supply of paint or other coating material, and for subsequently (or simultaneously) charging the coating particles. The particles are then drawn to the coating surface by electrostatic lines of force between the particles and the article. One disadvantage of known methods, however, is the undesirable "spreading" of the spray pattern, sometimes improved by implementing secondary electrostatic pattern-controlling fields.

Another disadvantage of such known apparatus is their failure to generate sufficient space charge (particle) potential to establish effectively strong field gradients between the particles and the surface of the object to be coated. To create strong gradients, it has been the practice to use electrostatic atomization, or to impose an external field (using extremely high voltages) between the spray source and the coating object. Where high external electric fields are used, the possibility of arcing is enhanced, necessitating sometimes elaborate safety precautions.

SUMMARY OF THE INVENTION

The present invention offers improved techniques and apparatus for applying a variety of particulate coating substances to surfaces by charging coating particles and passing them through a substantially, non-conducting flow path boundary to increase the space charge potential due to the electrical charge on the particles. Preferably, the flow channel has a minimum aspect ratio of length/width of 2.5, and the particles to be charged may be liquified by heat prior to charging, or can be formed by subjecting a monomer gas to an electrical discharge.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of these and other aspects of the invention, as well as the objects and advantages thereof, reference may be made to the following detailed description and to the drawings, in which:

FIGS. 1-3 are schematic illustrations in cross-section, showing various applications of electrogasdynamic

ionic ionizing apparatus in accordance with the invention to the coating of object surfaces; and

FIG. 4 is a cross-sectional view of a two-channel electrogasdynamic ionizer in accordance with the invention, in which the outlets of the channels are arranged to intermix the fluids exiting therefrom.

The principles of electrogasdynamic precipitation may be utilized in the coating of object surfaces, and because of the versatility and simplicity of electrogasdynamic apparatus, EGD coating systems may be operated on gas streams seeded with both organic and inorganic materials. Moreover, both insulative and metallic surfaces can be coated. EGD precipitation techniques are applicable to coating techniques because, in effect, the object to be coated serves as a collector electrode. Moreover, as in EGD precipitators, it is desirable to charge particles and create in a flow channel a high space charge potential without, at the same time, causing dielectric breakdown of the gas or coating aerosol.

In the above-noted application Ser. No. 601,270, EGD apparatus are disclosed, all of which have an aspect ratio of length (L) to width (W) exceeding 2.5, where the width W is taken as the maximum cross-sectional dimension of the channel (normal to the direction of flow) at the maximum space charge concentration. Alternately, for flow channels of cylindrical cross-section, the aspect ratio is expressed as L/R , where R is the cylinder radius; and the corresponding minimum aspect ratio is 5.

It has been found that similar limitations apply to EGD coating apparatus, where the flow channel should have an aspect ratio of L/R greater than 5, or L/W greater than 2.5 in order to achieve optimum space charge potentials without incurring dielectric breakdown. These aspect ratios take into account not only the maximum safe operating potentials for most coating operations, but also the maximum desirable transverse electric field within the channel due to space charge alone, while allowing for sufficient length to carry the charged particles away from the ionizing electrodes toward the workpiece.

The schematic illustration of FIG. 1 depicts the use of an electrogasdynamic ionizer 164 in a system for coating solid objects positioned within a chamber 165. The ionizing apparatus is in the form of a gun and consists of a single flow channel defined between parallel dielectric plates 166, corona and attractor electrodes 167 and 168, respectively, and a power supply 169 for applying an ionizing potential between the electrodes 167 and 168. The electrodes are of the type shown and described in detail in application Ser. No. 601,270.

The gun 164 is supported by a suitable structure, such as the conduit 170 having an inlet 171 receiving a carrier gas in which a coating substance in particle form is entrained. The gas and particle mixture enters the electrogasdynamic flow channel inlet 172 where it becomes charged in the electrical discharge field between the corona and attractor electrodes 167, 168. Ions and charged particles move downstream and are exhausted into the chamber 165, creating a space charge field. However, because the channel is relatively long, the charged particles exit a sufficient distance downstream of the electrode to inhibit the tendency of the particles to return to the gun structure at a lower electric potential.

For purpose of explanation, the chamber 165 is shown to contain three solid objects of arbitrary shape, the first object 173 being metallic and connected by a conductor 173a to a metal wall 165a of the chamber, which is referenced to ground. Another object 173b is of a dielectric material and is referenced to ground by the conductor 173c, which terminates internally of the mass 173b. Finally, a third object 173d, constructed of either metal or an insulative material, has no connection to a reference potential. As the charged particles are emitted from the gun 164 into the chamber 165, the objects 173 and 173b will both receive an even coating over their total surfaces, irrespective of the direction in which the surfaces of these objects face, since the space charge field in the chamber 165 is effective to induce the charged particles to seek a potential lower than the space charge potential. The object 173d, on the other hand, will receive a coating only on those surfaces exposed directly to the flow of particles from the outlet of the flow channel in the gun 164.

In FIG. 2 the electrogasdynamic gun 164' is shown supported by suitably resilient guides 175 at the interior of a conduit or pipe 176 of which the inner surface 176a is to be coated. An air and dry powder mixture is fed into a pump or compressor 178 and subsequently into a heating unit 179 where the individual particles are liquified by the application of heat. From the heater 179, the air and liquified particles continue into the flow channel of the gun 164' where the particles are charged and sprayed into the interior of the conduit 176. A power supply 169' excites the ionizing electrodes of the gun. Preferably, the conduit 176 is suitably connected to ground, as indicated. Upon reaching the interior of the conduit 176, the charged particles set up a space charge field and are deposited evenly over the total interior surface 176a. Thus, the conduit 176 itself functions as the collector electrode of an electrogasdynamic precipitator.

FIG. 3 shows an extension of the foregoing principles to the coating of a flat object 180. There, the electrogasdynamic apparatus includes a pair of dielectric plates 181, 182, with the longer of the plates 182 serving to direct the flow over the surface 180a. Further, as charged particles are blown into the space between surface 180a and the plate 182, the space charge field drives some of the charged particles to the dielectric plate 182. This plate soon reaches a condition of charge saturation and produces an electrical field gradient normal to the plate 182 in a direction tending to aid the space charge field in depositing the particles on the surface 180a.

At the inlet to the electrogasdynamic gun, an aerosol, such as an air and dry powder mixture of a desired material, is intermixed with a free radical-producing gas, e.g., a monomer gas. In the ionizer 183, the powder particles are charged and the monomer gas is broken down into free radicals, both charged and uncharged. The charged aerosols, along with the uncharged free radicals, are carried downstream into the "collector" which, in the FIG. 3 device, is formed between the dielectric plate 182 and the surface 180a of the object to be coated. By precipitating action, (as well as by diffusion), the uncharged free radicals and charged aerosol particles are deposited on the surface 180a, where the free radicals polymerize to form a thin film coating and assist in the fusion of the powdered particles. As an example, the monomer gas may be ethylene and the pow-

der polyethylene. When the ethylene free radicals and polyethylene powder are deposited on the surface 180a, they form a thick film without the application of heat.

As a further example, a monomer gas alone may be used for surface coating. In such case, an inert gas, such as argon or neon, may be used as a carrier for the free radicals formed in the corona discharge of the EGD gun. Molecular ions and the charged free radicals formed in the corona discharge are not carried downstream by the flow to any appreciable distance, since they possess relatively high mobilities and are quickly attracted by the attractor electrode in the ionizer 183. Therefore, primarily only the uncharged free radicals exit into the collecting region. This phenomena is of advantage, since after an initial coating is built up on the object surface, charged particles thereafter deposited can burn the coating by discharging through the coating to the coated surface. It will be appreciated, that any of a number of monomer gases, such as styrene and propylene, may be employed.

The device of FIG. 4 operates identically to those shown in FIG. 1 to charge the particles dispersed in two separate thin flow channels 185a, 185b formed by the parallel dielectric plate structure 186, 187, 188. Each plate has associated therewith a plate attractor electrode 189, all of which can be electrically connected to be at the same potential, viz., the potential on the conductor 190. Ionization excitation sources 191a, 191b of opposite polarity are attached between the common conductor 190 and respective corona electrode arrays 192a, 192b in the flow paths to yield ionization fields of corresponding opposite electrical charges. As depicted, the gas in the channel 185a becomes positively ionized and the particles carried thereby positively charged, while the gas and particles flowing through the channel 185b are associated with negative charges.

At the exit end of the device, the flow channels 185a, 185b are directed toward each other in such a way that the flow through the one channel intermixes with the flow through the other channel. Thus, at the flow channel exits, the positively and negatively charged particles are in close proximity whereby they are mutually attractive. If, for example, particles carried in the stream in the channel 185a are liquid and those particles in the channel 185b are solid, the (negative) solid particles become coated with the (positive) liquid particles, the charge on at least one of the attractive particles becoming neutralized upon physical combination. It is apparent, of course, that the apparatus of FIG. 4 can be used in any manner according to the invention to bring about charging and combining of gas entrained particles in whatever physical state, whether liquid or solid. Moreover, the device is further advantageous in effecting ionization of the gas flowing in each of the separate flow channels whereby ions of the ionized gas become mutually attractive until chemical or electrical combination occurs. Accordingly, the term "particle" is used in its broadest sense.

The foregoing principles may be applied to the formation of a thin sheet of material by stripping the coating from the coated object in a well-known manner. For example, in FIG. 3 the flat object might represent one run of an endless belt so that the surface 180a thereof moves past the particle discharge. Subsequently, the coating may be peeled from the surface

180a by a knife-edge (not illustrated) to form a continuous sheet of the coating material.

I claim:

1. A method of applying a fixed coating to a substrate, including the steps of:
 - flowing a gas in a bounded flow path,
 - including in the gas a coating substance,
 - establishing an ionizing field between at least two electrodes at an upstream location in said bounded flow path, thereby subjecting the gas to said ionizing field to provide charged particles of the coating substance,
 - forcing the gas and entrained charged particles of the coating substance downstream through a portion of the bounded flow path to an exit from the bounded flow path,
 - emitting the charged particles out of the bounded flow path by said exit to a location less constricted than the bounded flow path, thereby creating, in the vicinity of the exit, a space charge field at an electrogasdynamically increased potential and separated from the charging electrodes by said portion of flow path,
 - continuing to force gas entrained charged particles through the bounded flow path portion and out of said exit in opposition to said space charge field, and
 - disposing the surface of the substrate to be coated beyond said exit so as to be contacted by said particles,
- said step of forcing the gas and entrained charged particles through a bounded flow path portion comprising flowing the gas and charged particles along a path portion sufficiently long to permit an electrogasdynamic potential increase to a very high potential without incurring dielectric breakdown.
2. A method as defined in claim 1, in which: the substrate to be coated is the inside surface of a conduit, and the flow path is located interiorly of the conduit.
3. A method as defined in claim 2, in which: the axis of the flow path is substantially parallel to the axis of the conduit.
4. A method as defined in claim 1 further comprising the step of: providing the substrate with a reference potential different from the space charge potential to thereby create a mutual electrical force between the substrate and the charged particles.
5. A method as set forth in claim 4, wherein: the substrate to be coated is an object of a dielectric material, and the reference potential is provided interiorly of the object relative to the surface to be coated.
6. A method as defined in claim 5, wherein: the substrate to be coated is located within a chamber having walls at said reference potential.
7. A method in accordance with claim 1, in which: the bounded flow path has an aspect ratio of length L to width W of at least 2.5 where width W is taken as the maximum cross-sectional dimension of the channel normal to the direction of flow at the maximum space charge concentration.
8. A method according to claim 1, further comprising the steps of:
 - flowing a monomer gas with the ionizable gas down the flow path; and

depositing on the substrate free radical material and particulate matter, whereby the free radical material polymerizes to form a mixed coating of the particulate matter and the polymer of the monomer.

9. A method as recited in claim 1, further comprising the steps of:
 - adding heat to the particles carried by the gas prior to contact with the substrate to be coated, thereby to condition the particles for fusion upon contact with the substrate.
10. A method as recited in claim 1, further comprising the step of: applying heat to the substrate, thereby to fuse together the particles contacting the surface.
11. A method as recited in claim 1, wherein the substrate to be coated is elongate and substantially flat, the method further comprising the steps of:
 - moving the flat substrate in the direction of its elongation to thereby subject the substrate to continuous coating by the particulate coating substance; and
 - stripping the coating from the substrate to thereby form a continuous sheet of the substance forming the particles.
12. A method of coating the surface of a substrate with a substance initially in the form of a monomer gas, comprising the steps of:
 - flowing the monomer gas to an electrical discharge field in the flow path to thereby form charged and uncharged free radical matter of the monomer,
 - flowing and emitting primarily only the uncharged of the free radical matter through the flow path and out the exit to a less constricted location,
 - restraining substantially all of the charged radical matter from flowing through the flow path and the exit by field opposition, and
 - disposing the surface of the substrate beyond said outlet to be contacted and coated by the uncharged free radical matter.
13. A method of coating first particles with a substance initially in the form of second particles, comprising the steps of:
 - providing first and second bounded flow paths having, first and second exits, respectively,
 - establishing a first ionizing field between at least two electrodes at an upstream location in the first bounded flow path,
 - establishing a second ionizing field between at least two electrodes at an upstream location in the second bounded flow path,
 - flowing a gas in the first path and including the first particles therein,
 - flowing a gas in the second path and including the second particles therein,
 - subjecting the gas and first particles in the first flow path to the first ionizing field therein to thereby impart charges of one polarity to the first particles,
 - subjecting the gas and second particles in the second flow path to the second ionizing field therein to thereby impart charges of an opposite polarity from said one polarity to the second particles,
 - forcing the gas and entrained charged first and second particles downstream through a portion of the respective first and second bounded flow paths to respective exits,

emitting the charged particles out of the bounded flow paths by said exits to a location less constricted than the bounded flow paths, thereby creating, in the vicinity of each exit, a space charge field at electrogasdynamically increased potential and separated from the respective charging electrodes of the associated flow path by said portion of the associated flow path, continuing to force gas entrained first and second charged particles through the bounded flow path portions out of said exits in opposition to said space charge fields, and admixing the first and second particles outside of their respective paths to thereby effect the combination of the particles bearing opposite charges due to the mutual electrical forces therebetween,

said steps of forcing the gas and entrained charged particles through a bounded flow path portion comprising flowing the gas and charged particles along respective path portions sufficiently long to permit an electrogasdynamic potential increase to a very high potential without incurring dielectric breakdown.

14. A method as defined in claim 13, in which: the charges are imparted to the first and second particles by subjecting them to respective electrical discharge between corona and attractor electrodes, wherein the electrical polarity of each corona electrode corresponds to the polarity of the charge imparted to the particles in the associated flow path.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,853,580

Dated December 10, 1974

Inventor(s) Meredith C. Gourdine

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

delete all of Item [30]. Col. 1,
line 17, "applicatiaon" should read --application--.

Signed and Sealed this

Second Day of November 1976

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,853,580 Dated December 10, 1974

Inventor(s) Meredith C. Gourdine

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