ABSTRACT: A spray gun for electrostatic coating of objects with atomized solid particles comprises a tube of electrically insulating material, the free end of the tube supporting an atomizer for the coating material and the other end being connected to conveying means for supplying coating material by means of a propellant gas stream. A high-voltage generator and electrodes are provided for the electric charging of the coating material and for maintaining a high-voltage field between the gun and the object to be coated. A plurality of electrodes are disposed on the internal wall of said electrically insulating tube and are connected to potentials of different amplitudes for producing corona discharge within the tube. The electrodes preferably are formed as spikes of tungsten successively projecting from the internal wall of the tube in the direction of flow of the propellant gas-coating material mixture, each electrode being connected to one stage of a voltage divider or voltage multiplier circuit so that the successive electrodes have an increasing potential relative to a reference potential.
APPARATUS FOR THE ELECTROSTATIC COATING OF OBJECTS WITH ATOMIZED SOLIDS PARTICLES

The invention relates to apparatus for the electrostatic coating of objects with atomized solids particles, comprising a tube of electrically insulating material, one of whose ends supports an atomizer for the coating material and whose other end is connected to conveying means for supplying a stream comprising propellant gas and coating material, and a high-voltage generator with connected electrodes for the electric charging of the coating material and for maintaining a high-voltage field between the apparatus and the object to be coated.

The prior art discloses various types of apparatus for atomizing liquid or pulverized coating material and for the electric charging of particles, such apparatus being subdivided into a few groups depending on the method on which they are based. In one group the coating material is first atomized and the atomized particles are then electrically charged. Electrodes, connected to a high-voltage and taking the form of spikes, needles, wires, rings etc. and which are disposed in the spraying jet or outside thereof and, preferably in hand-operated units, are mounted on the atomizing apparatus are used for charging. In another group the coating material in the form of a film is supplied to the electrodes, connected to a high-voltage and taking the form of stationary or rotary edges or spikes from which the coating material is atomized electrically into charged droplets. Apparatus of these two groups is generally powerful, that is to say a relatively large quantity of material is atomized in unit time and deposited on the object to be coated but, owing to the exposed electrodes which are connected to the high-voltage generator they suffer from the disadvantage that sparkovers can occur under certain circumstances to cause an explosion and that touching of the electrodes must be avoided.

Several measures have been proposed to eliminate these disadvantages. A current limiting resistor connected into the supply lead to the electrodes is the simplest in terms of circuit technology and manufacturing technique. However, such a resistor becomes ineffective if the capacitance of the electrodes and of the high-voltage cable connected upstream of the resistor is high because severe spark discharges may then nevertheless take place. In apparatus with spraying edges, which intrinsically have a high capacitance, it is therefore the practice for a high-value resistor to be connected directly to the spraying electrode so that the capacitance of the high-voltage cable is of no consequence in the event of a spark discharge. Apparatus in which, as has already been proposed, a valve high-voltage generator is combined with the atomizer apparatus in one hand-operated unit is also able to supply low-energy spark discharges if the electrode configuration is designed for a low capacitance and the high-voltage generator is suitably constructed because it is no longer necessary to have a high-voltage cable to supply the electrode configuration. Special circuits have also been developed which shut down the high-voltage generator and the supply of coating material to the atomizer when a spark discharge starts.

All the aforementioned measures do not prevent flashovers but ensure that any flashovers which occur shall have only a low energy.

In a third group of apparatus the coating material is first electrically charged and is then atomized. This method is of particular use in powder atomizers. The pulverized coating material is blown through a tube of electrically insulating material and having a high-voltage field is atomized, for example against a baffle member. An electrode connected to a high-voltage is provided in the tube to improve the charging of the powder.

The prior art also discloses atomizers for liquids in which said atomizers a wire electrode, connected to a high-voltage supply, is axially disposed in a tube of electrically insulating material and having a nozzle at the discharge opening, the end of said electrode being disposed downstream of the discharge opening as seen in the flow direction of the coating material. In this kind of apparatus and in apparatus of similar construction the electrode connected to the high-voltage generator is disposed within a tube of electrically insulating material to prevent touching thereof from the outside. If the distance between the electrode and the discharge opening is sufficiently long it follows that flashovers are practically eliminated. Accordingly, apparatus of this kind is safe and can also be used for the atomization of substances which are easily flammable but they suffer from the disadvantage of an unsatisfactory output.

It is the object of the invention to provide apparatus for electrostatic coating, such apparatus being safe against touching and being also suitable for the atomization of highly flammable coating materials, all flashover spark discharge being avoided, the output of such apparatus being however substantially greater than that of known apparatus of the kind heretofore described.

The apparatus according to the invention comprises a tube of electrically insulating material, an atomizer for the coating material, said atomizer being at the end of said tube, conveying means for supplying a flow of propellant gas and coating material connected to the other end of said tube, a high-voltage generator and electrodes connected therewith for the electric charging of the coating material and for maintaining a high-voltage field between the apparatus and the object to be coated, a plurality of said electrodes being disposed on the internal wall of said insulating tube and being connected to potentials of different magnitude for producing corona discharge within said insulating tube.

In this way the charging of the coating material is substantially improved, safety against touching of electrodes is ensured and the appearance of harmful flashovers is prevented. The electrodes themselves may have any desired shape but are preferably constructed as spikes, needles or wires, extending from the internal wall of the insulating pipe.

The charging electrodes may be disposed at any position in the insulating tube, in one extreme case deep in its exterior, in the other extreme case near the discharge aperture. In a preferred embodiment and where the electrodes are disposed deep in the interior, the electrode spikes are disposed serially in the flow direction of the propellant gas/coating material mixture, for example on a helix, each being connected to one stage of a voltage divider or voltage multiplier circuit so that the successive electrodes have a potential which increases relative to a reference potential, for example earth potential and a fraction of the entire available voltage is always applied between two adjacent electrodes. This electrode configuration provides special advantages in the arrangement and construction of the tap changing elements of the voltage divider or voltage multiplier circuit. The aforementioned circuit elements may be disposed on the insulating pipe, the resistors of the voltage divider circuit being constructed in annular form for pushing on to the insulating pipe. It is also possible for a tubular resistor to be employed as voltage divider, individual positions of said resistor being connected to the electrodes. If a voltage multiplier cascade is supported by the insulating tube, these circuit elements are also appropriately mounted on the insulating tube.

In certain difficult cases it is possible for the high-voltage field, the conveying field, maintained between the electrodes disposed deep within the insulating tube, and the earthed object to be coated, to be too weak to ensure reliable coating. In order to obtain a stronger conveying field it is possible for the atomizer disposed on the insulating pipe to be provided with an additional electrode which is connected to one step of the voltage divider or voltage multiplier circuit. The additional electrode, preferably mounted near the discharge aperture, may be entirely embedded in the insulating material or may be surrounded with insulating material with the exception of a small zone of its surface. The conductive coating of the apparatus is obtained in accordance with the invention if the electrodes are disposed near the discharge opening at a distance therefrom which is no greater than the diameter of said discharge opening. To this end the electrodes are
preferably electrically combined in two groups of which the first electrode group is connected to the output of the high tension generator and the second electrode groups is connected to a lower potential. The aforementioned second electrode groups may be connected via a resistor to earth or each of the two electrode groups may be connected to one step of a voltage divider or voltage multiplier circuit system. In a preferred embodiment the electrodes are disposed in a plane which is perpendicular to the tube axis and are electrically interconnected so that successive even-numbered electrodes from one electrode group and successive odd-numbered electrodes form the other electrode group. This method ensures that the corona discharges which take place between the electrodes fill the entire tube cross section and furthermore ensure that the coating material is particularly well charged electrically on passing this zone. If the electrodes are supplied with high voltage by means of a voltage multiplier cascade in which the capacitors, serially connected in two columns, are interconnected in known manner by means of diodes, each of the two electrode groups will be connected to one column of capacitive elements and each capacitor is provided in accordance with the invention with a damping resistor, preferably connected between the last and penultimate capacitor of the column to form a RC network with the associated capacitor by means of which oscillations which accompany incipient spark discharge are substantially attenuated to prevent any dangerous flashovers.

If the status of the apparatus is to be employed as hand spraygun, it is possible for a housing attached to the insulating tube and adapted for accommodating the voltage converter or oscillator of a high-voltage generator to be constructed of the form of a gun handle, said gun handle being provided with a switch for switching on and off. The aforementioned hand spraygun is then connected merely by a low-voltage cable to the power supply source. If it is desired for only small quantities of material to be atomized it is possible to provide the insulating pipe with a conveying system having a material storage vessel. The aforementioned low-voltage cable and a propellant gas line will then merely extend from the hand spraygun to the appropriate unit which may be constructed in such lightweight manner as to enable them to be carried by the operator.

One embodiment of the subject of the invention is illustrated in the drawing in which:

FIG. 1 is a view of a hand spraygun in which the atomizer comprises a baffle member which is displaceable in the axial direction.

FIG. 2 is a section through the gun along the line II—II of FIG. 1.

FIG. 3 shows in diagrammatic form the circuit of a multiplier cascade with a transistORIZED voltage converter.

FIG. 4 shows the corresponding terminals of electrodes on a voltage divider.

FIG. 5 shows in diagrammatic form a hand spraygun with attached storage vessel for the coating material.

FIG. 6 shows as a sectional view another embodiment of the invention in which the hand spraygun,

FIG. 7 is a cross section through the front part of the gun apparatus along the line VII—VII of FIG. 6.

FIG. 8 is a cross section through the middle part of the apparatus according to the line VIII—VIII of FIG. 6.

FIG. 9 shows in diagrammatic form the circuit of a multiplier cascade with electrodes connected thereto and

FIG. 10 shows in diagrammatic form another circuit for supplying voltage to the electrodes.

Two rows of spike-shaped electrodes 1—6 and 1a—6a are inserted in a tube of electrically insulating material, preferably plastics, so that the aforementioned spikes extend radially relative to the tube axis and extend slightly beyond the internal wall. The electrodes of each row are disposed in a helix which extends around the tube surface. Each electrode is connected to one step of a voltage multiplier cascade comprising diodes 8 and capacitors 9. The diodes and capacitors of the cascade are disposed on the outside of the insulating tube. The multiplier cascade with the electrodes is illustrated in diagrammatic form in FIG. 3. The first electrode 1 of one row is connected via a conductor 10 to a transformer 11 constructed in toroid form and is disposed coaxially on one end of the insulating tube. A hose 33 for supplying a stream comprising a propellant gas and coating material may be connected to the aforementioned tube end. The insulating tube 7 with the diodes 8 and the capacitor 9 is encapsulated by casting with electrically insulating plastics to form a gun-shaped member 20 so that no voltage carrying part can be touched from the outside. A housing, constructed of an electrically conductive material, for example aluminum alloy, and shaped in the form of a gun handle 17, is mounted on the gun member 20. As disclosed by FIG. 3 the transformer 11 is connected to a transistORIZED voltage converter of known construction. The circuit elements of the aforementioned voltage converter, that is to say the transistors, 12, 13, the fixed resistors 14 and 15 and the variable resistor 16 are disposed in the form of a wash 18, for switching off and on of the voltage converter. DC voltage, for example obtained from a 12 V battery, is supplied to the voltage converter through a low-voltage cable 34 and through the switch 19.

An atomizer 35 is attached to the front end of the gun member 20. In the illustrated embodiment the atomizer 35 comprises a tube 36 of electrically insulating material and a baffle member 23, disposed in front of the discharge opening 21 and mounted on a rod 24. The rod 24 and the baffle member 23 are constructed of electrically insulating material, for example plastics, and may be constructed as an integral part. The rod 24 is supported by guides 25 and 26. A cord 27, connected to a push rod 28, is mounted on one guide 26. The cord 27 and the push rod 28 may be disposed in respective ducts or holes in the gun member 20. By displacement of the push rod 28 it is possible for the baffle member 23 to be displaced axially relative to the discharge opening 21 of the atomizer tube 36 thus enlarging or reducing the aperture angle of the spray cone. An annular field electrode 22, for example comprising a thin wire, is embedded in the atomizer tube 36 in the zone of the discharge opening 21 so as to be surrounded on all sides by insulating material. The field electrode 22 is connected by a conductor 37 to the last stage of the multiplier cascade. Instead of the annular field electrode it is also possible to employ spike electrodes or the endface of the baffle member may be provided with a field electrode in the form of a spike, connected to the conductor 37 through one of the guides 24 or 26 and a conductor disposed in the rod 36. Parts of the field electrode, preferably point-shaped or line-shaped zones thereof may also be freely exposed to the exterior. The aforementioned field electrode maintains an additional electrostatic high tension field between the atomizer 35 and the object to be coated thus increasing the efficiency of the spraygun. Atomizer nozzles of plastics material with discharge openings of different shape may also be employed instead of the aforementioned baffle member atomizer. It is appropriate for a set of such different atomizers to be provided and for the said atomizers to be constructed in interchangeable form so as to obtain optimum adaptation of the spraygun to the coating material employed in each case. Atomizers which do not carry a field electrode are then employed for easily flammable material while atomizers whose field electrode is entirely embedded in the insulating material is used for non flammable material and an atomizer having a field electrode which is partially exposed is employed for material of low flammability.

A voltage divider, comprising of a chain of resistors 29, end of said divider being earthed and the other end being connected to a terminal of a high-voltage generator 38 disposed outside the gun may also be used instead of a voltage multiplier cascade, as illustrated in diagrammatic form in FIG. 4. The resistors 29 of the voltage divider are once again disposed on the surface of the insulating pipe 7 and are encapsulated therewith.
The voltage divider resistors may also be constructed as rings which are pushed on to the insulating pipe.

A tubular, high-value resistor, into which the electrode spikes 1-6a are inserted may also be employed in place of the individual resistance rings.

A particularly maneuverable hand spraygun is illustrated in diagrammatic form in FIG. 5. A storage vessel 30 for the coating material is additionally mounted on the gun of FIG. 1, the lower part of said vessel being constructed in flared form and extending into a variable pneumatic conveying apparatus 32 with diffuser 31 of known construction. The conveying apparatus extends through a small compressed air cylinder and the voltage converter disposed in the gun handle is connected through a low-voltage cable 34 to a battery. The compressed air cylinder and the battery may be carried by the user of the hand spraygun.

In the embodiment illustrated in FIG. 6 a tube 7 of electrically insulating material is coaxially disposed in a tubular sleeve 20' preferably constructed of plastics, the rear end of said sleeve 20' having a tube extension 48, oriented downwardly at an angle and to the rear, for the supply of coating material by means of a stream of propellant gas. The rear end of the insulating tube 7 is closed by a guide 26 having an axial bore and in which a push rod 24 is slidably supported. The guide 26 is retained in a closure lid 46, screw-mounted on the tubular sleeve 20'. Space is provided in the sleeve 20' between the end of the insulating tube 7 and the closure lid 46 for insertion of a transformer 11 of toroid form and associated with a high-voltage generator 38 (FIG. 9). The secondary winding of the transformer 11 is connected to a voltage divider cascade whose capacitors 9, connected in the usual manner by diodes 8, are serially connected in two columns. A damping resistor 53 or 53a is connected in each column of capacitors 9, between the first capacitor 9a and the last capacitor 9b. The damping resistors 53, 53a together with the associated last capacitors 9a form RC networks adapted to dampen out any possible oscillations in the event of sparkovers. As can be seen in FIGS. 6 and 8, the two columns of capacitors 9 together with their damping resistors 53, 53a are disposed on the insulating pipe 7. The free space between the insulating pipe 7 and the sleeve 20' also contains the diodes 8 of the voltage divider cascade.

The front end of the sleeve 7, converging into the insulating pipe 7, is provided with external screw threading for the screw mounting of a union nut 41. A tubular atomizer or spray head 35 is mounted by means of the union nut 41 on the sleeve 20' and the insulating tube 7. The atomizer or spray head 35 comprises of telescoped, electrically insulated tubular sections of plastics material of which the inner tube section 7a has the same internal diameter as the insulating tube 7 and supports a guide 25 in the form of a spider for the push rod 24. The frontal, inwardly drawn end 36a of the outer tube member 36 forms the outwardly flared discharge opening 21 of the powder duct 7b which extends in the insulating tube 7 and in the internal tube section 7a and an internally disposed Said end of the internal tube member 7a is adapted to bear.

Four spike-shaped electrodes 6, 6', 6a, 6a', which extend radially inwardly into the powder duct 7b, are inserted into the internal tube members 7a. The four spike-shaped electrodes 6, 6', 6a, 6a' are offset relative to each other by 90° C. Each in a plane which is perpendicular to the tube axis, the distance of the aforementioned plane of the electrodes from the plane of the discharge opening 21 being smaller than the largest diameter thereof. The disposition of the spike-shaped electrodes 6, 6', 6a, 6a' is disclosed in FIG. 7.

As shown by FIG. 9, the two electrodes 6, 6' 6a and 6a' opposite each other in each case, are electrically interconnected and are connected to two of the two output lines 55 or 55a respectively of the voltage multiplier cascade disposed at the ends of the two capacitor columns. This ensures that during operation of the apparatus each electrode is at a potential which is different from the potential of the two adjacent electrodes and, provided the potential difference between the electrodes is of sufficient magnitude, that corona discharges occur which completely fill the powder duct cross section. To facilitate the onset of corona discharges it is appropriate for the spike-shaped electrodes 6, 6', 6a, 6a' to be constructed of tungsten.

In the embodiment illustrated in FIG. 6, the connecting conductors 42, 42a in the space between the internal pipe member 7a and the external pipe member 36 take the form of tungsten wires, whose frontal pointed ends take the forms of electrodes 6, 6', 6a, 6a' extending through the wall of the internal tube section 7a and from said wires through an adjusting collar 45, carrying the high-voltage contacts, to the capacitor column terminals, not shown in FIG. 6 in the interests of clarity, as described hereinbefore. A tubular insert 43 of electrically insulating material, and where appropriate, a second adjusting collar 44 at the front end thereof are provided for the insulation and immovable retention of the tungsten conductor wires 42, 42a on the internal tube member 7a.

The push rod 24, slidably supported in the two guides 25 and 26 (FIG. 6) supports the baffle member 23, disposed frontally of the discharge aperture 21 and by means of which the coating material, for example a plastics powder is atomized in the form of a spray cone, the discharge angle of the spray cone being variable by displacement of the push rod 24. The push rod 24 may for example be constructed of silver steel in order to ensure unblocked sliding in the relatively long rearward guide 26, the front part of said push rod having an electrically insulating plastics covering 24a which extends as far as the baffle member 23.

If the apparatus described hereinbefore is to be used as a hand spraygun, the tubular sleeve 20' may be provided as in FIG. 10 a guard 80 for the push rod 24, FIG. 6, to guard against the spray nozzle 70. A guard 80 is shown in FIG. 10 in which a guard 80a is attached to the outer sleeve 20' in the space between the discharge aperture 21 and the tube section 7a, with the guard 80a being fixed in an insulating sleeve 85, mounted on the handle plate 84 and in a bore 52 of the handle plate 47 to ensure simple and rapid installation and wiring of the apparatus.

In one embodiment of the invention the maximum diameter of the discharge opening 21 was approximately 14 mm. and the spike-shaped electrodes 6, 6', 6a, 6a' were positioned approximately 12 mm. from the plane of the discharge openings. The voltage multiplier cascade was so constructed that one output 55a carried a voltage of 50 kv. while the other output 55 carried a voltage of 45 kv. The powerful corona discharges between the electrodes obtained at these operating voltages caused the particles of the coating material to be electrically well charged and for the charged particles to be guided in the conveying field between the electrodes and the earthed object to be coated so that a surprisingly high output rate could be adjusted while ensuring reliable coating and a high-deposition rate.

FIG. 10 shows in diagrammatic form another embodiment for supplying high voltage to the spike-shaped electrodes 6, 6', 6a, 6a'. One set of electrodes 6, 6a', disposed opposite each other are connected to a voltage multiplier cascade 54 and 55a to a high-voltage generator. The two other oppositely disposed electrodes 6, 6' are connected through a conductor 42 to a high-value diverter resistor 54 whose other terminal is connected to earth. In the operation of this circuit the electrodes
will be subject to a voltage differential which ensures an increased corona discharge at the electrode spikes. The free space which remains after assembly between the tubular sleeve 20' and the insulating tube 7 is appropriately filled with an electrically insulating casting resin.

A plurality of atomizer or spray heads 35 which differ in length, shape and size of the discharge opening as well as in the number and arrangement of the electrodes may be provided for one gun so that the coating operation can be adapted under optimum conditions to certain requirements dictated by the kind of coating material and the shape of the object to be coated.

1 claim:
1. Apparatus for the electrostatic coating of objects with atomized solids particles, comprising a tube of electrically insulating material, an atomizer for the coating material, said atomizer being supported by one end of said tube, conveying means for supplying a flow of propellant gas and coating material connected to the other end of said tube, a high-voltage generator and electrodes connected therewith for the electric charging of the coating material and for maintaining a high-voltage field between the apparatus and the object to be coated, a plurality of said electrodes being disposed on the internal wall of said insulating tube and being connected to potentials of different magnitude for producing corona discharge within said insulating tube.

2. Apparatus according to claim 1, in which each of said electrodes are connected to one step of a voltage divider or voltage multiplier circuit.

3. Apparatus according to claim 2, in which said atomizer disposed on said insulating tube is provided with a supplementary electrode which is connected to one step of the voltage divider or voltage multiplier circuit.

4. Apparatus according to claim 3, in which said supplementary electrode is embedded in its entirety in insulating material.

5. Apparatus according to claim 3, in which the supplementary electrode is covered with insulating material with the exception of a small zone of its surface.

6. Apparatus according to claim 2, in which atomizers or supplementary electrodes and atomizers with supplementary electrodes may be optionally attached to the insulating tube.

7. Apparatus according to claim 1, in which the electrodes are disposed on the front end of the insulating tube which supports or forms the atomizer and are disposed at a distance from the tube discharge opening which is no greater than the diameter of the opening.

8. Apparatus according to claim 7, in which the electrodes are electrically combined into two groups of which the first electrode group is connected to the output of said high-voltage generator and the second electrode group is connected to a lower potential.

9. Apparatus according to claim 8, in which the second electrode group is connected to earth via a resistor.

10. Apparatus according to claim 8, in which each of the two electrode groups is connected to one step of a voltage divider or voltage multiplier circuit.

11. Apparatus according to claim 10 having a voltage multiplier circuit composed of two columns of serially connected capacitors and rectifiers, in which each of the two electrode groups is connected to one column of capacitors and each column of capacitors contains a damping resistor.

12. Apparatus according to claims 2, in which the electrodes are spikes which project from the internal wall of the insulating tube.

13. Apparatus according to claim 12, in which the spike-shaped electrodes are constructed of tungsten.

14. Apparatus according to claim 12, in which the spike electrodes are disposed along at least one helix on the insulating tube.

15. Apparatus according to claim 12, in which the spike-shaped electrodes are disposed in a plane which is perpendicular to the axis of the insulating tube and are electrically interconnected so that the even-numbered series of electrodes forms one electrode group and the odd-numbered series of electrodes forms the other electrode group.

16. Apparatus according to claim 2, in which the step circuit elements of the voltage divider or voltage multiplier circuit and the damping resistors are disposed on the insulating tube.

17. Apparatus according to claim 16, in which the resistors of the voltage divider circuit are constructed in annular form and are pushed upon the insulating tube.

18. Apparatus according to claim 16, in which the voltage divider is a tubular resistor, individual positions of which are connected to the electrodes.

19. Apparatus according to claim 1, having a high-voltage generator containing a voltage converter, in which the voltage converter is disposed in a housing on the insulating tube.

20. Apparatus according to claim 19, for use as hand spraygun, in which a housing attached to the insulating tube is constructed as gun handle for accommodating the voltage converter, the gun handle containing a switch for switching the voltage converter on or off, said converter being connected to the power supply source by means of a low-voltage cable.

21. Apparatus according to claim 20, in which conveying means having a material supply hopper and connected via a hose line to the supply of propellant gas, is mounted on the insulating pipe.