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ELECTROSTATIC COATING

Filed Aug. 24, 1962

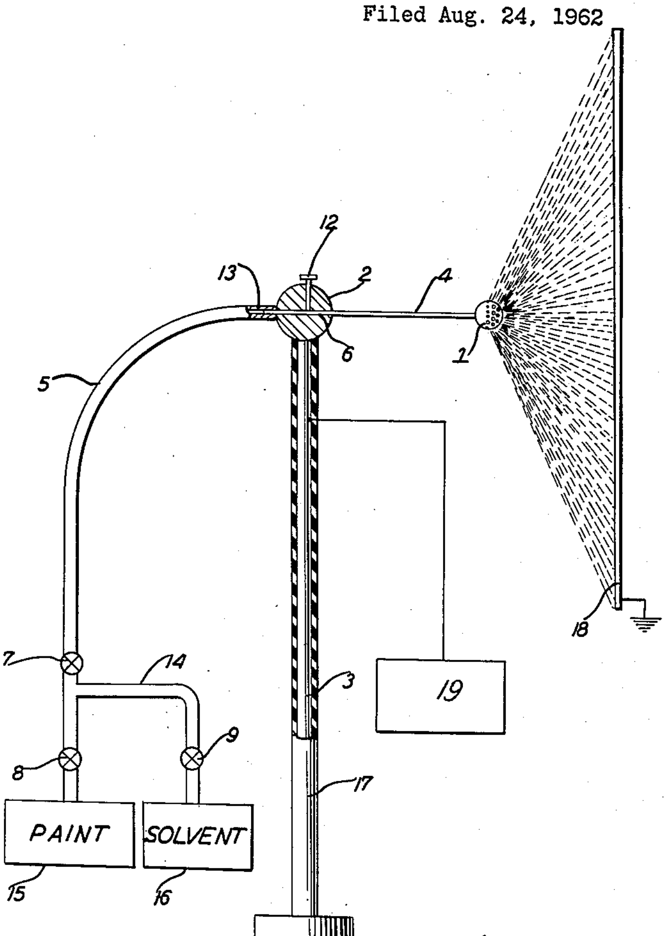

FIG. 1

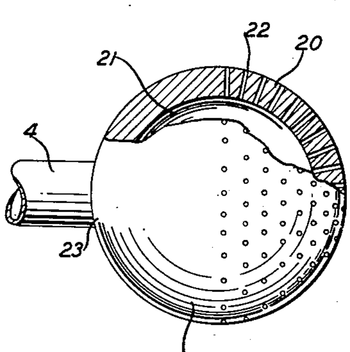

FIG. 2

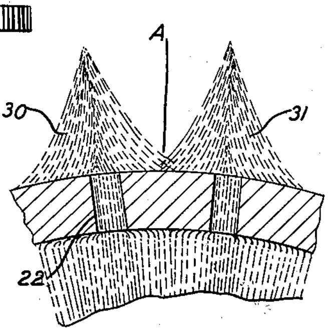

FIG. 4

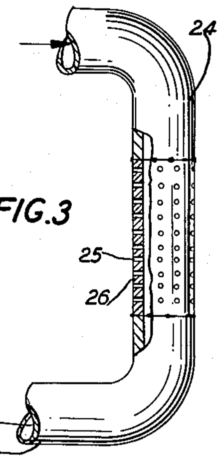

FIG. 3

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ELECTROSTATIC COATING

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This invention relates to the coating of articles by electrostatic deposition. In particular, this invention relates to the application of a fluid coating material to articles by electrostatically atomizing, projecting and depositing the coating upon the articles within an electrostatic field created between the articles and an issuing source of the coating material. More particularly, this invention relates to an apparatus for electrostatic deposition wherein the fluid to be sprayed is electrostatically atomized into discrete droplets from a curved surface.

This application is a continuation in part of my copending application, U.S. Serial No. 574,325, filed March 27, 1956, now abandoned.

The broad concept of electrostatic atomizing, projecting and depositing is known to the art. The improvement in electrostatic coating provided by this invention comprises atomization of the coating liquid from an electrically charged, curved surface having both significant length and significant breadth under essentially corona free conditions.

In electrostatic coating processes, as generally practiced, the fluid to be atomized is fed over a surface or through a small hole to a sharp edged electrode between which and the article a potential difference of sufficient magnitude is maintained to create an electrostatic field with a corona discharge in the region adjacent such edge. In most, if not all, commercial processes, centrifugal forces are utilized in conjunction with electrostatic forces to provide the desired atomization. It was considered necessary that the discharge electrode be provided with a very sharp radius of curvature in order to provide an electrical charge concentration sufficient to produce corona discharge. Apparatus and methods representative of these point-emission or edge-emission systems are disclosed in U.S. Patents 2,722,908, 2,685,536 and 2,658,009. However, these methods have exhibited certain undesirable characteristics resulting from the difficulties inherent in attempting to control a corona discharge. These have led to a search for auxiliary or secondary control systems to reduce or eliminate the resulting irregular scattering of coating material. The problem of fluctuations in the intensity of the field resulting from corona discharge from a sharp edge is discussed in the above cited U.S. Patent 2,658,009.

It now has been discovered that a highly effective electrostatic coating process can be effected by atomization from a curved surface having a broad, as contrasted to a sharp, angle of curvature under essentially corona free conditions. In accordance with this invention, the atomization is carried out from a relatively smooth, curved surface, the radius of curvature of which is above about one-fourth inch. The design of the applicator head may be varied in accordance with the broad principles of the method of this invention including, but not by way of limitation, the spherical and cylindrical heads hereinafter discussed in greater detail.

The characteristic advantages of the hereinbefore and hereinafter described invention are:

(1) The process admits of greater versatility in design of the applicator head, which
  (a) Permits coating of relatively large objects using an applicator head that is relatively compact and eliminating a requirement of edge atomization that

the applicator head be substantially co-extensive with the surface to be coated, and
  (b) facilitates adaptation of system to the coating of a variety of articles.
(2) Surface atomization admits of positioning a maximum number of atomization sites within a given radius about the center of the atomization area and hence maximizes atomization rate from such area.
(3) Surface atomization permits corona free operation and greater control of droplet size at high atomization rates, thus providing,
  (a) a more uniform coating of the article or work piece, and
  (b) a substantial decrease in volume requirements for paint.
(4) Surface atomization by eliminating the narrow atomization site of the edge or point reduces limitations on the viscosity of the coating liquid.
(5) Corona free surface atomization reduces electrical requirements per unit of coating material atomized and deposited with a resulting increase in safety and a decrease in the complexity and quality of the electrical system employed to produce atomization.

This invention will be more fully understood from the accompanying drawings which illustrate two representative embodiments of this invention.

In the drawings:

FIGURE 1 is a schematic side view of one embodiment of the apparatus used in the process of this invention showing the overall spray system.

FIGURE 2 is a partially cut-away view, to a larger scale, of the applicator head of FIGURE 1.

FIGURE 3 is a partially cut-away view of the applicator head of another embodiment of this invention.

FIGURE 4 represents a greatly magnified view in cross section of jets of coating liquid extending from the applicator head in accordance with one embodiment of the invention.

Referring more particularly to FIGURE 1, reference numeral 1 indicates generally an applicator, atomizer or spray head. Numeral 2 is a metal supporting element having a horizontal bore 6. Support element 2 is connected to a suitable (D.C.) high voltage source 19 through insulated cable 3 to maintain the atomizer head at a rather high potential with respect to ground. Support element 2 is, in turn, supported by stand 17 which is made of a suitable insulating material. Delivery tube 4, passing through horizontal bore 6, provides communication between the interior of head 1 and supply tube 5 and is secured in position by set screw 12. Tube 4 may be metal to provide an electrical connection between atomizer head 1 and support element 2. In the alternative, other means of electrical connection may be employed to introduce the requisite charge to head 1. Support element 2 is preferably spherical to eliminate sharp edges which tend to cause local buildup of charges upon the element and lead to a corona discharge, thereby impairing the efficacy of the system by reducing the intensity of the field. Tube 5 is connected by suitable means to end 13 of tube 4 which protrudes from support 2 and together with tube 4 and branch tube 14 provides a flow path from paint reservoir 15 and solvent reservoir 16 to atomizer head 1. Tubes 5 and 14 are made of an insulating material, e.g. rubber, polyethylene, polypropylene, etc., to prevent the charge on support element 2 and tube 4 from leaking to ground. Paint reservoir 15 from which tube 5 is pressured by suitable means, not shown, in order to provide the necessary pressure to flow the paint to the atomizing surface of the atomizer head. This pressure need only be sufficient to overcome the static head between the atomizing surface and the reservoir plus the pressure drop through holes 22 and may be eliminated entirely if the reservoir is located a sufficient distance above the atomizing surface. Solvent reservoir 16 is also pressured for similar reasons. Ordinarily, the paint or other coating material is mixed with a solvent and/or thinner before entering paint reservoir 15. However, the relative proportions of paint and solvent can be controlled by manipulation of mixing valves 8 and 9 in lines 5 and 14 respectively and the rate of flow of paint and solvent to the atomizing head can be controlled by manipulation of valve 7 in line 5. In the event it is desired to purge the system, the paint supply can be shut off via valve 8 and a stream of solvent run through the lines. Numeral 18 refers to the article to be coated.

Referring now to FIGURE 2, it is seen that atomizer head 1 is a hollow sphere having fluid inlet 23 connected by suitable means such as welding or soldering to tube 4. The hollow interior of the head forms an inner paint reservoir 21. The exterior surface 20 of head 1 constitutes the atomizing surface. A series of equally spaced holes 22 connect the atomizing surface 20 with paint reservoir 21. In the embodiment shown, these holes cover one-half of the sphere but, depending on the nature of the object to be sprayed, these holes may cover more or less of the sphere.

Preferably, the diameter of holes 22 will be only slightly larger than the diameter necessary to permit the paint or other coating material to flow without plugging. This, of course, depends upon the coating liquid that is being sprayed; but it has been found that hole diameters in the range of about 0.002 to 0.020, preferably above about 0.005, inch are satisfactory for the common paints and lacquers. The relationship between the diameter of the hole and the length of the hole, i.e., the thickness of the exterior wall of the atomizer head, can be adjusted to provide the desired pressure drop. In most applications, a wall thickness of about 0.005 to 0.065 will be preferred for the atomizer head. This, of course, determines the length of the holes. With more viscous coating liquids, the upper limit of this range can be extended. The spacing of holes 22 is hereinafter discussed in detail with respect to different embodiments.

As aforementioned, the radius of curvature of the atomizing surface should be above about one-fourth inch. While there is no sharp upper limit to this measurement, the radius of curvature for most practical operating conditions will be in the range of about 0.25 to 3.0, preferably about 0.40 to 1.25 inches.

FIGURE 3 shows another embodiment of the applicator or atomizer head wherein coating material is atomized from a cylindrical surface. In FIGURE 3 attention is particularly directed to outlet 24. This outlet provides means whereby the liquid not passing through the holes 25 to atomization surface 26 may be recycled back to the fluid supply line 5, shown in FIGURE 1, thereby permitting higher flow rates through the system if it is desired. This arrangement is useful for returning foreign particles or aggregates of particles in the coating liquid to the supply sources and helps to prevent plugging of the holes of the atomizer head. If it is desired, a filter may be inserted in a recycle line to remove objectionable oversize particles.

Referring again to FIGURE 1, the atomizer head 1 is, in operation, charged to a high potential by suitable means. The charge is delivered through cable 3, support element 2, and tube 4 to head 1. The paint is fed under a slight pressure through tubes 4 and 5, fills up reservoir 21 and is then forced through holes 22 to atomizing surface 20. At the opening of each hole 22 on surface 20 a jet is formed due to the influence of the high field between the object or article to be sprayed 18 which is grounded and the highly charged atomizing head. The spray pattern obtained is uniform without rotating the head 1. This eliminates the need for rotating equipment with its attendant cost.

The minimum separation between holes on the atomizing surface is governed by the base diameter of a liquid jet formed by the action of the electrostatic field. The base diameter for a given set of conditions can be determined by direct measurement of a single jet. In general, the closer the holes are brought together, the greater the number of jets that can be established per unit surface area. This tends to maximize the rate of atomization and provides a more uniform spray. However, this has its limitations and if the holes are too closely spaced, the jets tend to coalesce, increasing the size of the droplets sprayed therefrom with resulting waste and irregularity of pattern. For most conventional paints and lacquers, it will be found desirable to maintain the base diameter of the jets within a range of about 0.015 to about 0.04 inch.

In one preferred embodiment, the positioning of these holes is an on-center distance equal to the base diameter of the liquid jets to be formed at such holes. This embodiment is illustrated in FIGURE 4. In FIGURE 4, individual jets 30 and 31 are shown each being fed by a different hole 22. Here the base of the jets barely touch at A. In addition to making use of essentially all of the atomizing surface, this provides the additional advantage of interposing a layer of dielectric material, i.e., the coating liquid, between the charged atomizer head and the grounded article which serves to further retard or prevent the formation of conditions admitting of corona discharge. This is of somewhat greater significance when the workpiece, i.e., the article to be coated, is made positive with respect to the atomizing apparatus.

An individual jet base diameter is a function of the intensity of the electric field, the diameter of hole 22, the mass rate of fluid flow, the viscosity, conductivity and surface tension of the fluid. For a given fluid and a certain diameter of holes 22, the jet base diameter varies inversely with the voltage applied to the spray head. The optimum value of the voltage on the atomizer head, therefore, would be in the range of about 80 to 100 percent of the value of the voltage that could be applied without objectionable corona discharge. All other factors being equal, the diameter of the base of a jet at a voltage within this range varies little and this distance is herein termed the minimum jet base diameter for a specified diameter of hole 22 and a given fluid. Once the atomization has been initiated and the desired jet size attained, the voltage may be lowered appreciably from the initiation voltage without any significant loss of efficiency. For instance, with a surface upon which the optimum jet size is achieved at 150,000 volts, the voltage may be reduced after initiation by as much as 20,000 to 30,000 volts without any noticeable change. This provides a relatively wide area of operation below the field intensity of the onset of corona discharge and simplifies operational control.

The relationship between the pressure drop through holes 22 and the pressure differential between the top and bottom of the reservoir 21 should be such that pressure drop through the holes is much greater than the pressure differential within the reservoir to assure that the reservoir will be completely filled and the fluid will flow through holes adjacent the top of the reservoir at substantially the same rate as through those adjacent the bottom.

The pressure differential within the reservoir is due solely to the hydrostatic head within the reservoir. The pressure drop through the holes is expressed by the formula:

$$DP=\frac{8lu}{\pi R^4}\frac{dv}{dt}$$

where:

DP is the pressure drop through the holes
l is the length of the hole;
u is the viscosity of the liquid flowing through the hole;
R is the radius of the hole; and

$\frac{dv}{dt}$ is the volumetric rate of flow

The pressure drop DP through the holes should preferably be about 10 times the pressure differential from top to bottom of the reservoir to assure a uniform spray from the atomizer head. This sets the upper limit upon the diameter of the holes for a fluid of given viscosity.

In a second preferred embodiment, the holes through which the fluid to be sprayed is introduced to the atomizing surface are positioned slightly farther apart than in the embodiment hereinbefore discussed. In this embodiment, the base diameter of the fluid jet is somewhat less than the distance between these feeder holes. Here, the holes are positioned so as to utilize the greatest possible amount of the atomization area without bringing the individual jets into contact with each other. In this embodiment, the distance between the feeder holes preferably would be only slightly in excess of the base diameter of the fluid jets, i.e., jet base diameters of about 90 to about 99.5 percent of the distance between holes. It has been found that this method of spacing and feeding minimizes or completely eliminates the tendency of closely spaced jets to coalesce. This embodiment has proven to be particularly effective when the atomizer head is a cylinder or the surface closely approximates a cylindrical surface. Although the polarity of the article and atomizer can be reversed in each of the various embodiments of this process, it surprisingly was found to be particularly desirable to operate with the article negative with respect to the atomizing surface when the base of the fluid jets are not permitted to overlap.

The invention will be more fully understood from the following example which is herein set forth for purpose of illustration only and should not be construed as a limitation upon the true scope of the invention, as set forth in the appended claims.

Example

Electrostatic atomization, projection and deposition of various coating fluids and enamels was carried out in accordance with the invention hereinbefore described employing an atomizer head of cylindrical shape. The following equipment sizes and operating conditions were employed:

Atomizer head diameter, in	0.5–0.88
Length of atomizer head, ft	3–7
Feeder hole diameter, in	0.003–0.10
Feeder hole/ft. lgth. (atm. head)	1400–2400
Spray rates, gal./hr./ft. lgth. (atm. head)	0.6–2.0
Electrode spacing, in	8–30
Electric current flow, microamperes	10–20
Voltage range, volts	90,000–200,000
Polarity of atomizer head	+ and −
Paint viscosity—#4 Ford Cup, sec	20–200
Paint resistivity, megohm/centimeter	1,000–7,000

The various coating materials employed in the above-recited tests included the following:

(1) Pigmented primers and enamels
- (*a*) epoxy and alkyd primers
- (*b*) alkyd melamine enamels, including metallics and non-metallics
- (*c*) acrylic paints, non-metallic

(2) Clear alkyd resins

The solvents employed in the process of this invention are well known in the art. The conductivity of some commercial paints or other coating fluids may be such that it is difficult to use such material in an electrostatically propelled system without additions. Such paint should have included in their thinner some polar solvent such as methyl alcohol, acetone, etc. to raise their conductivity. If the paint conductivity is satisfactory, it may be thinned by conventional non-polar solvents. For most applications, it is preferred to operate with the paint at a viscosity between about 1.5 and about 20 poise.

The terms "coating liquid" and "coating fluid" as employed herein include paint, lacquer, ink, petroleum, the various fractions and derivations thereof, coal tar derivates and other coating materials that can be electrostatically atomized, propelled and deposited upon a surface. The term "coating fluid" shall be understood to include both liquids and liquid coating materials which contain finely divided solid materials such as pigments, etc.

What is claimed is:

1. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head, means for supplying said coating fluid to said spray head, and means for maintaining an electrical potential between the spray head and the object to be sprayed, the improvement which comprises a spray head having an interior surface and an exterior curved surface having a radius of curvature above about 0.25 inch and communicating with said interior surface through a plurality of small openings in said spray head.

2. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head, means for supplying said coating fluid to said spray head, and means for maintaining an electrical potential between the spray head and the object to be sprayed, the improvement which comprises a spray head having an interior surface and an exterior curved surface having a radius of curvature above about 0.4 inch and communicating with said interior surface through a plurality of small openings in said spray head.

3. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head having an opening therein through which said coating fluid can be supplied for dispersal to said object, means for supplying said coating fluid to said opening, and means for maintaining an electrical potential between the spray head and the object to be sprayed, the improvement which comprises a spray head having an interior surface and an exterior curved surface having a radius of curvature above about 0.25 inch and communicating wtih said interior surface throught a plurality of small openings in said spray head.

4. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head having an opening therein through which said coating fluid can be supplied for dispersal to said object, means for supplying said coating fluid to said opening, and means for maintaining an electrical potential between the spray head and the object to be sprayed, the improvement which comprises a spray head having an interior cavity and a curved exterior surface having a radius of curvature above about 0.4 inch and communicating with said interior cavity through a plurality of small openings in said spray head distributed over a portion of said exterior surface subtending a substantial central angle.

5. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head having an opening therein through which said coating fluid can be supplied for dispersal to said object, means for supplying said coating fluid to said opening, and means for maintaining an electrical potential between the spray head and the object to be sprayed sufficient to atomize, project, and deposit on said object coating fluid supplied to said opening, the improvement which comprises a substantially cylindrical spray head having an interior cavity and an exterior surface having a radius of curvature above about 0.25 inch and communicating with said interior cavity through a plurality of small openings in said spray head distributed over a portion of said exterior surface subtending a substantial dihedral angle.

6. In an apparatus for electrostatically spraying an object with a coating fluid comprising a spray head having an opening therein through which said coating fluid can

be supplied for dispersal to said object, means for supplying said coating fluid to said opening, and means for maintaining an electrical potential between the spray head and the object to be sprayed sufficient to atomize, project, and deposit upon said object coating fluid supplied to said opening, the improvement which comprises a substantially spherical spray head having an interior cavity and an exterior surface having a radius of curvature above about 0.25 inch and communicating with said interior cavity through a plurality of small openings in

said spray head distributed over a portion of said exterior surface subtending a substantial solid angle.

References Cited in the file of this patent

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3,017,115	Artman et al.	Jan. 16, 1962

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166,458	Australia	Jan. 5, 1956