July 7, 1959 E. M. RANSBURG **2,893,894**

METHOD AND APPARATUS FOR ELECTROSTATICALLY COATING

Original Filed Feb. 13, 1950 2 Sheets-Sheet 1

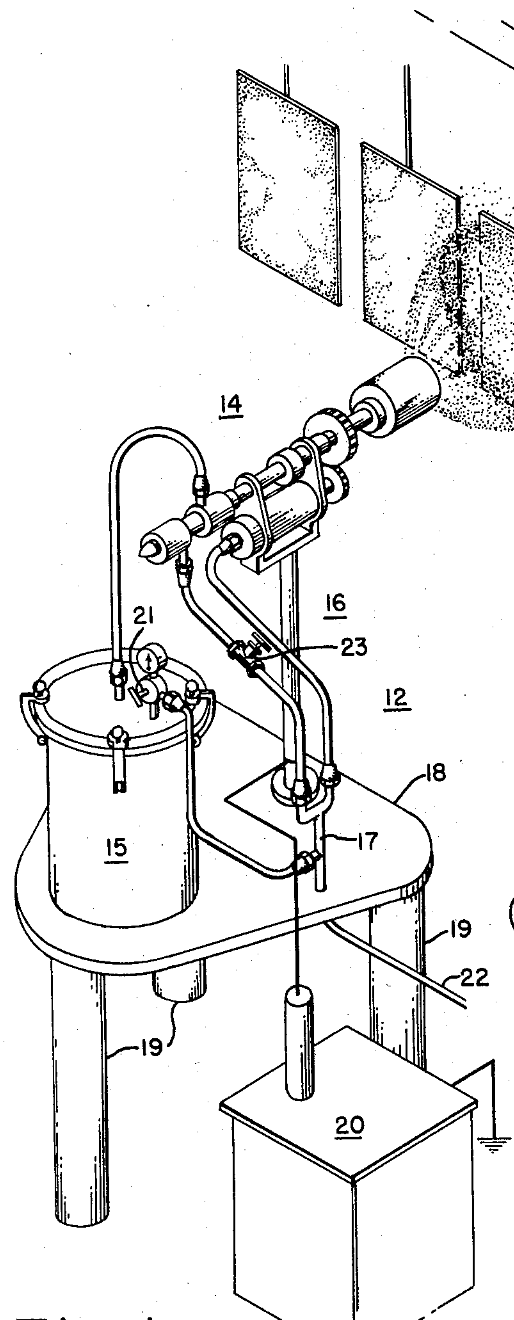

Fig. 1

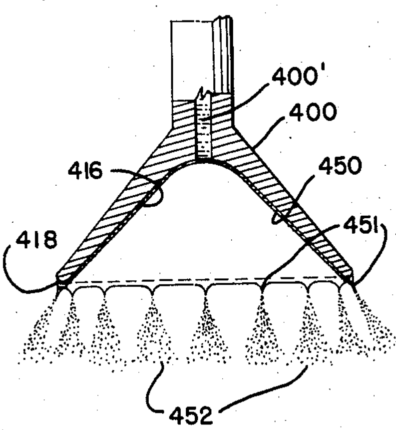

Fig. 5

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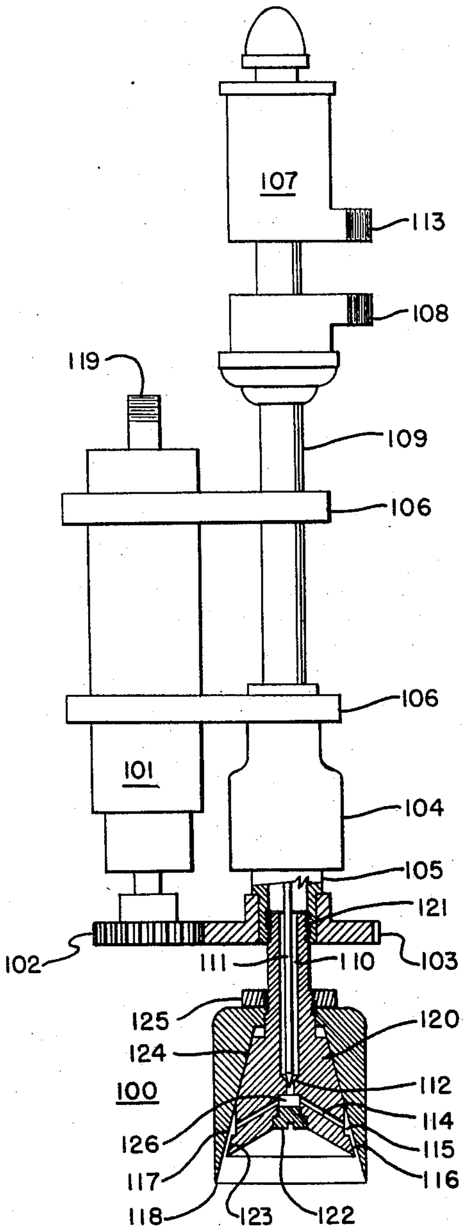

Fig. 2

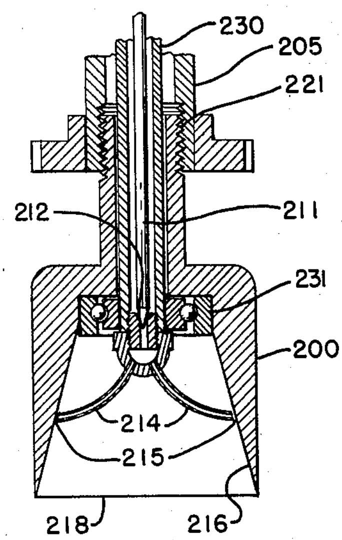

Fig. 3

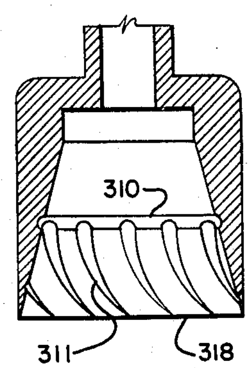

Fig. 4

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METHOD AND APPARATUS FOR ELECTROSTATICALLY COATING

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Continuation of application Serial No. 143,994, February 13, 1950. This application November 3, 1958, Serial No. 771,505

8 Claims. (Cl. 117—93)

This invention relates to methods for electrostatically applying liquid coating materials and to apparatus suitable for use in practicing such methods. More particularly, the invention relates to electrostatic coating methods in which liquid coating material is both atomized from a series of spaced points under the influence of an electrostatic field and electrostatically precipitated upon surfaces to be coated and to improved apparatus for effecting the electrostatic atomization.

In the copending application of W. W. Crouse, Serial No. 141,509, filed January 31, 1950, there are disclosed methods and apparatus employing electrostatic atomization and electrostatic precipitation of liquid coating material. The invention of that copending application contemplates that the liquid coating material will be fed to the site of atomization in the form of an extended, thin film between the leading edge of which and the surface to be coated an electrostatic field is maintained, such field serving to deform the leading film-edge into a series of cusps, to atomize finely divided particles of the coating material from the tips of such cusps, and to deposit the atomized particles upon said surface. In certain embodiments, the present invention utilizes the broader invention of the aforesaid copending application and constitutes an improvement upon it.

It is an object of the present invention to improve and to make more uniform the distribution of deposited coating material which has been atomized from a series of spaced points. A further object of the invention is to provide a method and apparatus by which it is possible to counteract any tendency of gravity or other influences to produce disuniformity in the distribution of electrostatically atomized liquid coating material within the pattern of the spray emanating from the atomizer. Still another object of the present invention is to produce an electrostatic atomizing apparatus which will provide a satisfactorily uniform distribution of liquid coating material within the spray pattern while permitting the atomizer to be made with greater manufacturing tolerances than are possible in the atomizer of the aforesaid copending application.

In carrying out the invention in its preferred form, the leading edge of an extended, thin film of liquid coating material is presented in spaced relation to the surface to be coated and an electrostatic field is created between such film-edge and surface, as in the aforesaid prior application; but in the present instance I cause the liquid cusps, from the tips of which atomization takes place, to move as a group transversely of the lines of force of the electrostatic field. Such movement is along the line occupied by the cusps and hence, although it does not alter the general shape of the spray formed by the material atomized from all the cusps tips, it does tend to promote uniformity of coating-material distribution within the boundaries of such spray. In the specific embodiments of the invention herein described, the liquid film is annular, the cusps lie on a circle, and cusp-movement is produced by rotating the film-supporting atomizer about the film axis; but equally within the scope of my invention in its broader aspects are atomizers, such as the one shown in the copending application of Emery P. Miller, Serial No. 150,713 (now Patent No. 2,718,477), embodying other forms of movable, film-supporting elements, and atomizers, such as are shown in my own copending application Serial No. 107,687 (now Patent No. 2,684,656), in which cusp-movement may occur although the film-support remains stationary.

The manner in which these and other objects and advantages of the invention are realized will be described in connection with the accompanying drawings.

Fig. 1 is an isometric, somewhat schematic view of a complete coating apparatus;

Fig. 2 is an elevation, partly in section, of the applicator means shown in Fig. 1;

Fig. 3 is an axial section of a modified form of atomizer;

Fig. 4 is a fragmental sectional view showing a further modification; and

Fig. 5 is an axial section showing still another modification.

For the purposes of illustrating this invention as employed in a method of and apparatus for applying liquid coatings, there is shown in Fig. 1 a form of apparatus adapted for coating discrete articles, such as the flat, extended plates shown. The articles **10** to be coated are supported from an overhead conveyor **11** which is so arranged as to carry the articles past and in spaced relation to the apparatus generally indicated at **12**.

That apparatus comprises applicator means **14**, coating material supply tank **15**, applicator-means support **16** and air supply lines **17**, which are all supported on platform **18** that is electrically insulated from ground by insulating supports **19**. Air supply line **17** is connected externally by means of an insulating rubber hose **22** to a source of air under pressure, not shown.

The applicator means **14**, shown in detail in Fig. 2, comprises atomizer **100**, air drive motor **101**, drive gears **102** and **103**, fluid-conveying coupling embodying stationary and rotatable members **104** and **105**, alignment blocks **106**, and air operated valve-motor **107**. In use, coating material under pressure delivered to connection **108** flows through connecting tube **109**, through rotating fluid coupling **104—105** and into the top of the atomizer **100** at passage **110**. Needle **111**, which is operatively connected to the valve-motor **107** blocks the further flow of the coating material into the head by being seated in orifice **112**.

When air pressure is applied to connection **113**, the valve-motor **107** operates to lift needle **111** from orifice **112** allowing coating material to flow into central chamber **126** and radial passages **114**. Coating material is thus circumferentially distributed about annular channel **115** from which it flows by way of the narrow annular slit **116** to the inner surface of external member **117**. It is thus distributed on that surface and will flow to the extended annular edge **118**, which edge is desirably sharpened as shown or otherwise attenuated.

The particular atomizer shown in this modification of the present invention is constructed of a central body section **120**, arranged at its upper end to screw into the rotatable coupling member **105** as at **121** and centrally drilled from the upper end to orifice **112** in order to receive needle **111** and still permit passage of material to orifice **112**. A plug **122** immediately below orifice **112** provides a ready means of cleaning the orifice and the associated chamber **126** and passages **114**. Externally, the central body section **120** is machined with two coaxial tapers **123** and **124**, the former offset inwardly from the latter by the desired thickness of slit **116**. Taper **124** fits into the internal taper of part **117**, insuring that this part is centrally positioned, that a liquid-tight seal is formed above channel **115**, and that slit **116** will be uniform in width within the accuracy of the machining process. External member **117** is held in place on the internal member by means of nut **125**. In this embodiment, the external member **117** is made of electrical conducting material, although insulating materials may be effectively used especially where the coating material being applied is electrically conducting to the same extent as the commonly used synthetic enamels.

By applying air pressure to orifice **119**, air motor **101** is caused to rotate and drive gears **102** and **103**, thus causing atomizer **100** to rotate in the bearing afforded by coupling member **104**. The extended edge **118** is thus moved longitudinally of itself in a cyclic manner.

In practicing this invention, the applicator means shown in detail in Fig. 2 and described above may be placed as shown in Fig. 1 on its support stand **16**, and the entire assembly supported on stand **18**, which is electrically insulated from ground. The extended edge **118** of the atomizer is arranged in spaced relation to the articles **10** to be coated, supply tank **15** containing the liquid coating material to be applied to the surfaces of articles **10** is also supported on platform **18** and connected to air line **17** so that air pressure can be applied to force the coating material from the tank in a regulatable manner to the connection **108** of the applicator means and thence as described above to the extended edge **118** of the atomizer. Regulation of this pressure and hence of the rate of flow of material to the edge is accomplished by regulator **21**.

Air line **17** is also connected to connection **113** of the valve-motor **107** so that needle valve **111** can be opened and closed as desired by the application or release of pressure. Line **17** is also connected to connection **119** of the air motor so the atomizer can be rotated. In the conduit leading from line **17** to connection **113**, there is located an adjustable air valve **23**. By appropriately setting the valve **23**, the rotation of the atomizer **100** can be started at any desired time in advance of the withdrawal of needle **111** and the consequent flow of material to the atomizer. It is to be understood that means other than air could be used to withdraw the fluid needle and to rotate the atomizing head in place of the air devices shown.

One side of a high voltage source **20** is electrically connected to the atomizer, and the other side of this same source is connected to ground and through it by way of the grounded conveyor and article supports to the grounded surfaces to be coated. This source when electrically energized thus serves to establish an electric field between the continuous extended edge of the atomizer and the surface being coated. The air line connection to pipe **17** from a suitable grounded compressor is made by means of a hose of rubber or other insulating material, so that it will not interfere with holding the platform **18** at high potential with respect to ground. Appropriate air valves and electrical controls (not shown) permit the application of the high voltage and the air pressure as desired from a remote position by an operator at ground potential.

The liquid supplied to the atomizer **100** when the valve **111** is opened passes as an annular film through the annular slit **116**. Escaping confinement at the lower edge of the surface **123**, the liquid flows as a free-surfaced film over the inner surface of the external member **117** to the annular edge **118** where it becomes exposed to the action of the electrostatic field above described. As set forth in copending application Serial No. 141,509, the field acts to deform the leading edge of such liquid film into an annular series of spaced cusps from the tips of which finely divided liquid particles are atomized. The finely divided particles leave each cusp-tip as a narrowly divergent conical jet, and the aggregate of the jets from all the cusp-tips forms a hollow, generally frusto-conical spray which will be deposited in annular pattern on any extended, plane surface normal to the spray-axis. As the aforesaid copending application brings out, if liquid is supplied at a uniform rate to all points on the atomizing edge **118** and if the strength of the electrostatic field is uniform along such edge, the cusps into which the film is formed will be spaced at equal angular intervals about the axis of the atomizer. The spacing of the cusps will depend upon the strength of the electrostatic field, decreasing as field-strength increases.

Rotation of the atomizer **100** about its axis, which is the principal feature distinguishing the atomizers of this application from those specifically disclosed in the aforesaid copending application, has several important results. If the atomizer is disposed otherwise than with the edge **118** in a horizontal plane, rotation of the atomizer counteracts the effect of gravity in tending to produce an accumulation of coating material at and near the lowest point of such edge. If the inner surface of member **117** and the surface **123** are not accurately concentric, so that the film discharged through the slit **116** will not be of uniform thickness, the action of centrifugal force on the free-surfaced portion of such film lying outwardly beyond the slit **116** will promote uniformity of film thickness and uniformity of the rate at which coating material is supplied to all points of the edge **118**. The same is true if the passage **116** should become occluded at one or more points of its circumference. By rotating the atomizer at an appropriate speed, it may even be disposed with its axis horizontal, as in Fig. 1, and no significant disuniformity in the distribution of coating material over the extent of the edge **118**, and no significant disuniformity of distribution of atomized coating material within the limits of the spray, will result.

Rotation of the atomizer is also of advantage in that it destroys any lobal character of the deposited pattern which might result from the fact that atomization occurs at a plurality of spaced points rather than continuously along a line.

Another form of atomizer which can be used to practice this invention is shown in Fig. 3. In that modification, an atomizer-body **200**, provided with threads **221** which attach it to a rotatable sleeve **205**, has an annular atomizing edge **218**. The coating material comes directly from orifice **108** (Fig. 2) by way of stationary tube **230**, which passes axially through rotatable sleeve **205** into the atomizer-body **200** which is rotatably supported from it through bearing **231**. Seat **212** at lower end of tube **230**, in cooperation with needle **211**, is arranged to regulate the flow of liquid material through tube **230** to distributor tubes **214**. Distributor tubes **214**, which are rigid with the lower end of supply tube **230** and hence stationary, terminate in openings **215** disposed to discharge, preferably with a wiping action, on to the inner wall **216** of head **200**. As such head rotates, the material discharged from the openings **215** forms a free-surfaced film flowing toward the edge **218** over the wall **216**, which flares toward such edge so that centrifugal force will promote feeding of the film.

This type of head has the advantage that a rotating, fluid-conveying coupling is not needed and hence the head is more freely rotatable. The diameter of the fluid openings **215** can be larger than the width of the restricting orifice **116** of the head shown in Fig. 2, and those openings will therefore not be as readily subject to stoppages by foreign matter in the coating material. To the extent that in the head of Fig. 3 the coating material is supplied to the wall **216** at one or more isolated points and distributed along the edge **218** by relative movement of the head-body and the orifice or orifices **215**, such head embodies the invention broadly claimed in my application Serial No. 57,260, now Patent No. 2,658,472, granted November 10, 1953.

Although the atomizer of Fig. 3 is shown as having a smooth inner surface **216** over which the material flows from orifices **215** to edge **218**, it has been found that advantage can sometimes be gained by providing this surface with a series of spiral grooves which are inclined toward the atomizing edge and rearwardly with reference to the direction of atomizer-rotation. Such a grooved atomizer, in Fig. 4, has a circumferential groove 310 about the head at the level of the orifices 215, and spiral grooves 311 of progressively decreasing depth extend from that groove to the edge 318 where they vanish. Coating material discharged from the orifices 215 is urged outward and edgeward in the spiral grooves by reason of its inertia as the atomizer rotates, and is thus fed to the edge 318 for atomization. It is understood that other shapes and arrangements of grooves could be used for this purpose without departing from the scope of the invention.

The atomizer shown in Fig. 5 comprises a body 400 adapted to be supported in any convenient manner for rotation about its axis and provided in its lower end with a recess the wall 416 of which is of a generally conical form coaxial with the body 400. A feed passage 400′ communicates with the apex of the conical recess. If liquid is fed through the passage 400′ while the atomizer is rotated, the liquid will distribute itself in the form of a free-surfaced film 450 over the surface 416 and will flow to the edge 418; and if it there becomes exposed to the action of an electrostatic field of adequate strength, it will be electrostatically atomized in the manner above set forth. The atomizer of Fig. 5, like the other atomizers described, can be disposed with its axis at any angle to the vertical; but if it is disposed with its axis displaced from the vertical, its speed of rotation should be such that centrifugal force, acting on the free-surfaced liquid film, will effectively counteract the effect of gravity on the distribution of the liquid within the film.

The apparatus shown in Fig. 1 has been successfully used to apply synthetic enamels to vertically extending surfaces such as those illustrated. In operation, an atomizer three inches in diameter was supported at a distance of approximately eight inches from the surfaces to be coated. A voltage of approximately 75,000 volts supplied by a half-wave, tube rectified, transformer-driven unit was used to produce the atomization and precipitation of the material, while the head was rotated at approximately 150 revolutions per minute.

Although the apparatus of Fig. 1 is shown being used to coat vertical surfaces, it is to be understood that it can be applied equally well to the coating of horizontal surfaces or surfaces otherwise oriented, or to the coating of articles having surfaces oriented at various angles. The apparatus can be used equally well to coat continuous sheet material. In that case, the sheet may be unrolled from a suitable storage reel and carried past in spaced relation to the atomizer and thence to some drying or baking apparatus.

It is likewise to be understood that other diameter atomizers, other voltages, and other spacings between the atomizer and the surface or surfaces to be coated can be used without departing from the spirit of this invention. It is also possible to obtain satisfactory results with the apparatus when the surfaces being coated are electrically charged and the atomizer is grounded. Most liquids are sufficiently conductive that if the atomizer is made of insulating material the potential can be applied to the film-edge through the film itself.

In the atomizers of Figs. 2, 3, and 4, the edge (118, 218, or 318) from which atomization takes place is shown as knife-like in cross-section. Such knife-like form, while it facilitates the obtaining of fine atomization, is not essential. As a matter of fact, I prefer an edge rounded at a small radius, say at a radius at about 0.005 inch, as such an edge is less dangerous to personnel and less apt to be damaged, while the atomization obtained from it is not significantly coarser than is that obtainable from an edge of true knife-like character. If maximum fineness of atomization is deemed unnecessary, the edge from which atomization takes place may be blunt, as indicated at 418 in Fig. 5. The atomizer should of course be so shaped exteriorly and so disposed as to reduce electrical shielding of the leading film-edge. In order to promote uniformity of field-strength along the atomizer-edge 118, 218, 318, or 418, the atomizer should be so disposed that such edge is generally parallel to the surface being coated. Where the atomizer is used in the coating of a succession of articles moved past it over a predetermined path, the atomizer edge is desirably disposed parallel to such path.

Fig. 5, in addition to illustrating a blunt edge 418, also indicates the manner in which the field deforms the film-edge. This showing may be regarded as typical of the action of the field in any of the other atomizers illustrated. The cusps formed by the field at the edge of the film are indicated at 451, and the individual jets emanating from each cusp-tip are shown at 452. The small number of cusps 451 illustrated in Fig. 5 would ordinarily exist only at relatively low field strengths. In the specific example set forth above, cusp-spacing was about thirty to the inch. Wide cusp-spacing is promoted by high viscosity of the liquid and by high rates of liquid supply, as well as by low field-strengths.

I have indicated above that voltage and spacing between the atomizer and articles being coated may vary from the values set forth in the specific example described. In general, the potential maintained between the atomizer and the articles being coated should be as high as possible consistent with freedom from possible sparking; for high potentials effect finer atomization and permit higher outputs of atomized liquid. In practice, I prefer to employ potentials which will result in the existence between the atomizer and the article of an average potential gradient in the neighborhood of 10,000 volts per inch, but materially lower potential gradients can be used if desired.

The invention herein described is applicable to the coating of articles irrespective of the electrical conductivity of the material from which those articles are made. In the case of articles made of materials possessing exceptionally high insulating properties, a backing electrode or some other expedient may be necessary to obtain satisfactorily uniform distribution of the deposited coating material; but many materials ordinarily thought of as insulators possess sufficient conductivity, either over their surface or otherwise, that no backing electrode is necessary.

In some types of coating apparatus, as for example that shown in Fig. 11 in the prior Crouse application above mentioned, the atomizer is bodily moved during the coating process in order to permit the application of coating material to surfaces having an extent greater than that of the spray which the atomizer produces. The present invention is adapted for embodiment in such apparatus; but when so embodied the liquid film, and the cusps at its leading edge, will possess a motion in addition to that previously mentioned. Accordingly, when in the above description and in the appended claims I describe the film as being moved in the direction of its transverse extent or the cusps as being moved along the line in which they lie, I do not exclude situations in which the film and its cusps possess components of motion in other directions as well.

The speed at which my atomizer is rotated in order to obtain the benefits of the invention will depend upon several factors. If the atomizer axis is vertical with the cusp-tips lying in a horizontal plane, and rotation is employed solely to effect uniformity of distribution, the atomizer may rotate slowly, say at a speed of a few dozen turns per minute. If the atomizer-axis is not vertical and rotation is relied upon to counteract the force of gravity, higher rotational speeds will be employed; but even with the atomizer-axis horizontal and a liquid of relatively low viscosity being atomized, the tendency of the liquid to collect at and near the low point of the atomizer edge can be effectively counteracted by rotating the atomizer at a speed which will subject the liquid to a centrifugal force equal at most to several times the force of gravity. It may be convenient in some cases to employ speeds higher than necessary, as where higher speeds would simplify or lessen the cost of the atomizer-rotating means.

Experiments establish that such centrifugal force as is imposed on the liquid by my rotating atomizer has far less effect than field-strength on either the degree of atomization or on the shape of the liquid spray, and that if the field has the preferred strength—i.e. an average potential-gradient of the order of 10,000 volts per inch—the speed of atomizer-rotation has no significant effect. For example, if an atomizer like that of Fig. 5 having an annular edge two inches in diameter, is positioned opposite an extended flat plate and an electrostatic field having an average gradient of 10,000 volts per inch is created between atomizer and plate, the fineness of atomization and the shape of the spray are substantially the same at 5,000 r.p.m. as they are at 200 r.p.m. But if, under the same conditions, the atomizer is rotated at a constant speed—say 1,000 r.p.m.—and the field strength is gradually reduced by lowering the potential-difference maintained between atomizer and plate, the spray begins to spread and atomization becomes much coarser, which coarser atomization can be prevented by maintaining an adequate potential gradient at the leading edge, irrespective of the polarity thereof.

I am aware that it has heretofore been proposed, as in United States Letters Patent No. 1,861,475, granted June 7, 1932, to atomize a liquid by feeding it to a rotating element driven at such a speed that the liquid is broken up into drops as it is thrown from the element by the action of centrifugal force. It is my experience, however, that in such atomizers, even when they are rotated at speeds sufficient to subject the liquid to centrifugal forces many hundred times that of gravity, the atomization is very materially coarser than that which can be produced electrostatically with a field having a potential gradient in the neighborhood of 10,000 volts per inch.

While atomizers of the type described above are especially suited for use in the application of liquid coating materials, they may have other uses. Atomization can be affected by merely creating an appropriate potential difference between the film-edge and its surroundings, as by connecting the film (or the atomizer if it is of conductive material) to one terminal of a high-voltage source the other terminal of which is grounded. Alternatively, the high-voltage source may be connected between the film-edge and an attracting electrode positioned in opposed, spaced relation to the film-edge.

This application is a continuation of and a substitute for my copending application Serial No. 143,994, filed February 13, 1950, which latter application was in turn a continuation-in-part of my earlier application Serial No. 57,259, filed October 29, 1948, and now abandoned.

I claim as my invention:

1. In a method of electrostatically spray coating the surface of an article with liquid atomized from an annular atomizing zone, the steps of flowing liquid coating material at a controlled rate from a source of supply to a rotatable head, forming it into a thin film supported on said head and advancing said supported film toward said atomizing zone by rotating the head, said film having a uniform edge of an extent many times its thickness, establishing between said film-edge and said article an

electrostatic field of sufficient strength to form said film-edge into a series of spaced cusps and to electrostatically atomize finely divided discrete particles of liquid as a spray from said cusps, and electrostatically dispersing and depositing said particles on the article surface while still in liquid state, said article surface being in a substantially quiescent atmosphere and at a distance from said atomizing zone sufficient to permit substantial dispersion of the liquid spray particles as they proceed toward the article.

2. The method of claim 1, further characterized in that the film-edge is a circle.

3. A method as set forth in claim 2 further characterized in that said film is conical and flares toward its circular edge.

4. A method as set forth in claim 2 further characterized in that the liquid is fed as a stream discharging on to the head at an eccentric location spaced inwardly from the circular edge of the film.

5. A method as set forth in claim 1 further characterized in that the liquid is fed to said head at a location thereon spaced inwardly from the edge of said film.

6. A method as set forth in claim 1 further characterized in that the speed of head rotation is insufficient in itself to produce comparable atomization.

7. Apparatus for electrostatically spray coating the surface of an article with liquid atomized from an annular atomizing zone, comprising an atomizing head mounted for rotation about the axis of said atomizing zone, means for feeding liquid coating material at a controlled rate from a source of supply to said head, means for rotating said head, said head including means effective in rotation of the head for forming said liquid into a thin supported film and for providing said film with a substantially uniform leading edge at the atomizing zone, means for establishing between said film-edge and said article an electrostatic field of sufficient strength to draw the liquid of the film-edge beyond its support and form said film-edge into a series of spaced cusps, to electrostatically atomize said liquid from said cusps into a spray of finely divided discrete particles, and to disperse and deposit said particles on the article surface while still in liquid state, and means for maintaining said article surface in a substantially quiescent atmosphere and at a distance from said atomizing zone sufficient to permit substantial dispersion of the liquid spray particles as they proceed toward the article.

8. Electrostatic spray-coating apparatus as set forth in claim 7 further characterized in that said feeding means includes a conduit discharging on to said head at a location spaced inwardly from said leading film-edge.

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