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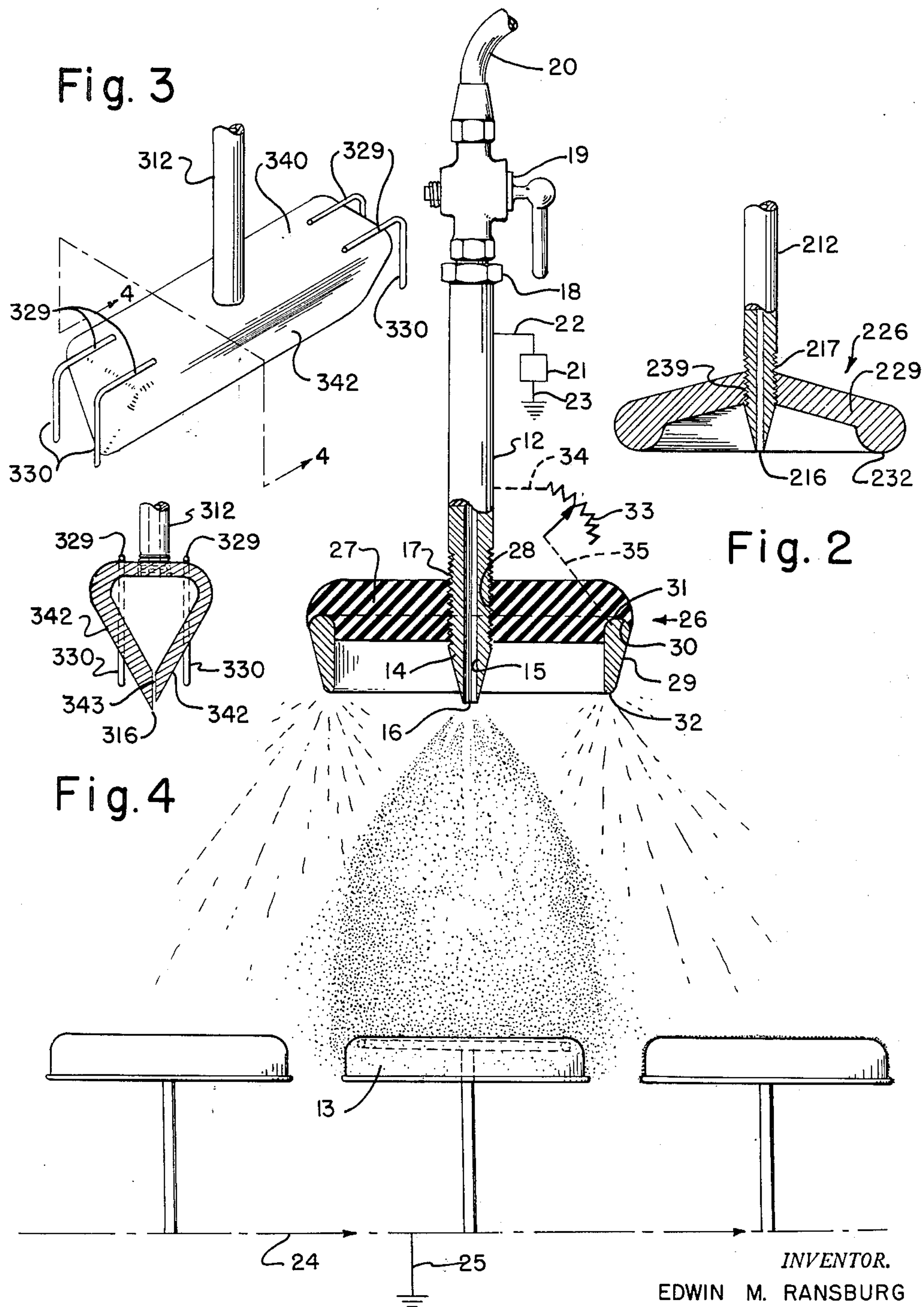

Fig. 1

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ELECTROSTATIC COATING METHOD AND APPARATUS

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This invention relates to the application of liquid coating 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. This general process of applying coatings is disclosed in the U. S. applications of William A. Starkey et al., Serial No. 556,390, filed September 29, 1944, William W. Crouse, Serial No. 13,174, filed March 5, 1948, and William W. Crouse, Serial No. 141,509, filed January 31, 1950, said application Serial No. 13,174 being now abandoned. The invention is particularly directed toward providing greater stability to the projected spray or jet and imparting a sharper edge definition to its issuing pattern.

In such electrostatic coating process as generally practiced, the article to be coated is supported in opposed spaced relation to a sharp edged electrode between which and the article a potential difference of sufficient magnitude is maintained to create an electrostatic field with an atomizing corona discharge in the region adjacent said edge. The coating material is arranged to be supplied to the edge and its region of corona discharge at a rate no greater than that at which it can be electrically atomized by the corona discharge, whereupon the charged particles are projected in spray form toward and deposited upon the oppositely charged article. In certain instances, possibly due to fluctuations in intensity of the corona discharge perhaps caused by minute imperfections at different portions of the electrode edge or for other reasons, the projected jet is unstable in the sense that its axis wanders erratically or shifts from one position to another while also varying in cross-sectional shape. Instability in the direction and form of the jet results in an undesirable, irregular scattering of the coating material upon the surface of the article. Since each particle composing the jet is charged to the same electrical sign, the inherent electrical repulsion effect causes the particles to spread laterally from each other.

This spreading action is more noticeable at the outer portions of the jet and results in an irregular, uneven and indistinct edge definition to the pattern of the coating material as deposited upon the article. I have discovered that by surrounding in close proximity the atomizing, projecting and depositing electrostatic field with a secondary electrostatic field that is substantially coextensive, longitudinally with the former, the projecting spray jet is stabilized, is made more

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definite in shape and more constant in direction, and the scattered spreading effect upon the particles, particularly at the outer portions of the jet, is materially reduced. This results in a deposited pattern which is more uniformly dense throughout and which has a sharp edge definition.

It is an object of the present invention to provide in an electrostatic method and coating apparatus of the character above set forth, a secondary stabilizing field adjacent the electrostatic spray atomizing, projecting and depositing field that is effective to stabilize the jet produced by the latter, both directionally and in respect to shape, and to give a resulting deposited pattern which has a relatively sharper edge definition, either throughout its entire periphery or over one or more portions of its periphery.

It is a further object of the invention to provide a method and apparatus of this character in which the atomizing projection in jet form, deposition and control of the jet—all three—are accomplished by a single form of energy. This adds materially to the simplicity and efficiency of the method, to compactness, smoothness and quietness of operation, and low cost of the apparatus for practicing it.

A further object of the invention lies in the provision of a simply constructed, unitary and inexpensive spray head for an electrostatic coating apparatus of the character set forth.

These and other features of the invention will be best understood and appreciated from the following description of various embodiments selected for purposes of illustration and shown in the accompanying drawings in which:

Fig. 1 is a side elevation of one form of the improved elecstrotatic atomizing apparatus with the secondary, stabilizing field control electrode mounted on the atomizing head and illustrates diagrammatically the general arrangement of the head in the electrical circuit and its disposition with respect to the articles to be coated,

Fig. 2 is a side view, partly in section, showing a modified form of said head and secondary field producing electrode,

Fig. 3 is an isometric view of a modified form of head with a correspondingly modified form of secondary field producing electrode, such head and electrode being adapted to disperse an extended, elongate wedge-shaped jet in contra-distinction to the generally conically formed jets produced by the types of heads illustrated in Figs. 1 and 2, and

Fig. 4 is a sectional elevation taken along the line 4—4 of Fig. 3.

Referring to Fig. 1, the apparatus comprises a length of relatively small diameter (on the order of $\frac{3}{16}$'' O. D.) tubing 12, preferably of electrically conducting materials. Tube 12 is arranged to be supported in any suitable manner in spaced relation with its longitudinal axis disposed at substantially right angle to the surface of the article 13 to be coated and with its nozzle or tip end 14 projecting toward the article. The nozzle or tip 14 is formed by beveling the outer surface of the tube from a point adjacent the end, gradually toward the end and toward the interior surface of the bore 15 (the bore being of a diameter on the order of $\frac{1}{16}$''), thus providing a continuous, annular edge 16 of knife-like sharpness. Adjacent the beveled tip 14, the tube is threaded exteriorly as at 17 for a short distance of its length for a purpose later to be described. The opposite end of the tube is connected to a valve coupling 18 having a hand operated valve 19 which is suitably connected by means of tubing 20 to the supply source of the liquid coating material (not shown), that is to electrostatically atomized, projected and deposited upon the article 13. The source of liquid material may be disposed at an elevation above the tube so that the liquid feeds by gravity through the bore 15 or, if desired, it may be fed under pressure by compressed air or the like to the bore 15 through which it is conducted to the discharge edge 16. The rate of flow of the coating material to the edge 16 should preferably be no greater than that which can be electrically atomized, whether such rate of flow is established by gravity or pressure feed or both.

A source of high voltage illustrated diagrammatically at 21 has one of its terminals connected by a conductor 22 to the tube 12 and its opposite terminal connected by a conductor 23, either directly to the conveyor 24 upon which the articles to be coated are mounted or to ground. In the event the conductor 23 is connected to ground, a conductor 25 may be connected from ground to the conveyor as shown. The voltage source 21 is preferably capable of producing voltages of unidirectional current upwardly from 22 kv. to 125 kv. With a voltage of 60 kv. applied to the tube, with its knife-like discharge edge 16 at a distance of approximately 14 inches from the surface of the article to be coated, it has been found that corona discharge will be formed in the region adjacent said edge of an intensity which is sufficient to break up or atomize into particled form the coating material which is being fed to said edge and project said coating material in a generally conical spray form toward the surface of the article being coated. The electrostatic field established between the discharge edge 16 and the surface of the article further imparts an electrical charge to each particle and causes the electrostatic deposition of the projected, atomized coating material onto the surface of the oppositely charged article.

As previously stated, under certain conditions possibly due to fluctuations in the brush or corona discharge, perhaps because of minute imperfections at different portions of the edge 16 or for other reasons, the projected jet wavers erratically and continuously, first at one angle and then another. This results in a scattered dispersion of the particles composing the jet and thereby causes the deposited pattern upon the article to have irregularly disposed lobes. In addition, the mutual electrical repulsion of the particles due to their being charged to the same sign causes them to spread and scatter laterally and particularly at the outer portions of the jet. This makes for a less sharply defined edge at the boundary of the deposited pattern. To overcome these objectionable characteristics, I provide a secondary field surrounding in close proximity the electrostatic atomizing field and coextensive in length with the latter. By coextensive I mean extending from an electrode having an edge which is supported substantially coplanar with but in spaced relation from the corona discharge atomizing edge to and terminating at the surfaces of the articles to be coated.

The means for effecting the establishment of a secondary field consists of an electrode or control member 26 which utilizes the electrostatic forces created by high voltage source 21 to create said secondary electrostatic field in the gaseous medium surrounding the jet. Control member 26 is comprised of a disk 27 of electrically nonconductive material having a centrally disposed bore 28 which is threaded to screw onto the thread 17 adjacent tip 14. The disk is of such diameter that its periphery extends outwardly from the outer surface of the tube by a distance on the order of 1⅜ inches. A cylindrical element 29 of electrically conductive material and of generally wedge-shaped cross-section and having its divergent side walls merging into its upper rounded, wider edge 30 is secured in a conformed recess 31 provided in the lower face of disk 27 adjacent its periphery. The opposite narrower edge 32 of element 29 projects beyond the plane of the lower face of disk 27 for a distance substantially equal to the thickness of the disk and in the general direction of discharge edge 16. Edge 32 is relatively sharp, but preferably the sharpness of this edge is substantially less than the sharpness of discharge edge 16 of tip 14. The assembled components of control member 26, just described, may be adjusted bodily, as a unit, longitudinally of tube 12 by simply rotating the member on the threads 17 to position the edge 32 closer to or further away from the plane of discharge edge 16.

When the edge 32 is of a relatively lesser degree of sharpness than edge 16, as just described and as shown in Fig. 1, it has been found in practice that best jet stabilizing, pattern controlling and atomizing results are obtained with the edge 32 positioned within a range from a position where it is coplanar with edge 16 to a plane behind said edge up to and inclusive of a distance of ⅛ of an inch. With 60 kv. applied to the tube 12 and with control member 26 adjusted as just described, element 29, through its close proximity to tube 12, receives by induction an electrical charge which is of sufficient intensity to create a secondary electrostatic field, completely around, in close proximity to, and coextensive with the primary atomizing or jet producing field. Such secondary field effects a greater stability to the projecting jet, counteracts the tendency of the particles in the outer portions of the jet to unduly spread or scatter and results in the obtaining of a more densified over-all deposition of the finely divided material upon the surface of the article, which tends toward rendering a deposited pattern having a relatively sharper edge definition than may be obtained in the absence of such secondary field. Desirably, the differential in the potential gradients of the two fields adjacent the respective edges 16 and 32 should be adjusted and maintained in such balanced relation that the intensity created to produce the stabilizing and shaping effect shall always be slightly less than the corona discharge intensity produced to effect the atomization and projection of the coating material. Generally, this may be accomplished by the making of but a single, simple adjustment, that is, by rotating member 26 to advance or retract edge 32 toward or away from the plane of discharge edge 16. However, the potential gradient of the field terminating at the edge 32, while less than that at edge 16, may still be of sufficient intensity to produce a corona discharge.

It is noted that it has been found that as the degree of sharpness of edge 32 more nearly approaches the degree of sharpness of edge 16, effective concomitant jet stability and pattern controlling and proper atomizing functioning of the device requires edge 32 to be moved into a plane further behind the plane of the edge 16. That is to say, within a range from $\frac{3}{16}$ to $\frac{5}{16}$ inch. The distance between the separate planes occupied by the edges 16 and 32 is, of course, also governed to some considerable extent by the magnitude of the voltage applied to the tube, by the distance of the space between the element 29 and the tube, the relative discharge surface areas of the edges and also by the electrical insulating qualities of the material from which the disk 27 is fabricated.

Additional control means for establishing the proper balance in the difference in potential maintained between edges 16 and 32 may be provided if desired. This additional control constitutes a variable resistor 33 having a range on the order of 0–10 megohms connected as by means of conductors 34 and 35 across tube 12 and element 29 as shown. In such an arrangement, the element 29 receives its charge directly by conduction rather than by induction. It will be understood that the resistance means of adjustment may be used entirely independently of the screw-thread, planar-edge position adjustment, or vice-versa, or that both may be used together, the one to quickly bring the difference in potential into the proper general range and the other to obtain a precision degree of adjustment. Excellent atomization and jet stabilizing and pattern controlling results have been accomplished in using this type of head.

The rounding of the wider upper edge 30 of element 29 coupled with the backing of such edge by the rounded edge 31 of the disk 27, which it will be remembered is of nonconductive material, tends to prevent leakage or dissipation of charge from any portion of element 29 except at its discharge edge 32. If desired, with the element formed in general wedge-shaped cross section as shown, the element 29 can be mounted on the periphery of a disk such as 27 with its upper rounded edge 30 merging flush into the upper face of the disk, that is, without having the recess 31 provided in the disk and without the insulated backing to the upper rounded edge 30.

Fig. 2 shows a form of electrostatic atomizing head in which the tube 212 is constructed of conductive material and in accordance with the dimensions and design of tube 12 of Fig. 1. Tube 212 is likewise threaded as at 217 adjacent its discharge edge 216 to receive the similarly threaded aperture 239 of a control member 226. Control member 226 is formed of conductive material in the general form of a disk 229 with a depending curved crown 232 formed integrally with is periphery. Depending crown 232 has a radius of curvature on the order of $\frac{5}{16}''$ which serves as the jet-stabilizing and pattern-forming, field producing edge in this modification. With the lowest portion of the surface of the crown 232 adjusted to a position where it is coplanar with or tangential to the plane of the edge 216 and with a voltage on the order of 60 kv. impressed upon the tube 212, satisfactory atomization and spray pattern controlling effects have been produced with a head of this character. It is noted that the radius of curvature of the edge 232 presents a relatively much greater surface area than do the edges of the spray pattern controlling members heretofore described. The charge upon the disk 229 is in this instance received by conduction and this relatively more extensive surface area of the crown 232 is sufficient to reduce the intensity of the discharge emanating from the crown with respect to the corona atomizing discharge emanating from the edge 216, so that a proper balance in the differential of potential gradient in the spray atomizing and control fields is accomplished.

Figs. 3 and 4 illustrate a modified form of head in which the tube 312 delivers the coating material to an elongated chamber 340 of generally triangular cross section. The converging walls 342 of chamber 340 feed the coating material through a narrow aperture 343 formed between two opposed faces adjacent the lower ends of the walls 342 toward the lower projecting edge 316 of one of the side walls 342, the edge 316 constituting the discharge edge in this form of head. The secondary field establishing electrode in this embodiment takes the form of a pair of L-shaped wires 329 secured to the head at each end thereof and terminating in downwardly directed portions 330 located outwardly beyond the ends of the corona discharge edge 316 with their own ends in a plane slightly above that occupied by said edge. This type of head and its control electrode produces a generally elongate wedge-shaped jet that is substantially coextensive in length with the length of discharge edge 316. Each pair of auxiliary electrodes 330 establish at each end of the elongated jet a secondary or control field which stabilizes the end portions of the jet, densifies the end portions of the deposited spray pattern, and sharpens the definition at the ends of such pattern.

It will be understood that in instances in the foregoing description where it has not been specifically stated that the tube members which have the numeral 12 included in their reference numerals are connected to a high voltage source such as 21, that such tubes are connected to such a voltage source in order to effect their atomizing and control function in the organization of the apparatus. It may be desirable in certain instances to have the conductor such as 22 enter the tube and come into direct contact with the coating material.

I am aware that it is known to surround with an electrostatic field a carrier stream or jet of air or other gas which carries suspended particles of coating material and which is directed at and substantially normal to an extended surface to be coated. In such method, which is shown in U. S. Patent No. 2,221,338, issued to Harry A. Wintermute, November 12, 1940, the field is employed for the purpose of precipitating coating-material particles which might otherwise be carried away with the air or other gas escaping laterally from the point at which the stream or jet impinges upon the surface to be coated. In other words, the field acts to offset or counteract for the diverting effect of the article being coated on the carrier gas stream and is intended to act only on coating-material particles which have been subject to the consequences of that diverting effect. Many of the particles, especially those near the axis of the jet, are deposited without ever acquiring a charge and hence without benefit of the field; and the field neither shapes nor stabilizes the carrier gas stream nor affects in any way the initial direction of particles leaving the discharge head or nozzle.

The secondary or stabilizing field which is created by the auxiliary or control electrode **26**, **226**, or **329** in the practice of my invention functions in an entirely different manner. Where the enclosing field of the prior art acted to precipitate coating-material particles in the desired region in spite of existent diverting influences tending to carry them beyond such region, I employ my stabilizing field to suppress the diverting influence or influences completely. I am enabled to do this because only electrostatic forces control and determine the respective paths of the coating-material particles during their atomization, their projection, and their deposition. It is an inherent characteristic of electrostatic fields that their lines of force cannot intercept or cross each other. Therefore, the secondary or stabilizing field of my invention distorts the primary (or the atomizing, projecting, and depositing) field, reduces its spread, and in general stabilizes it. As the coating-material particles, during the successive steps of their atomization, projection, and deposition, are accelerated along the lines of force of the primary field, the distorting effect of the secondary field on the primary field modifies the path of each individual particle in the outer portions of the jet from the instant such particle leaves the discharge head until it is finally deposited.

In the practice of my invention, the entire operation—i. e., the production of the spray and its control and deposition—is completely free of the turbulent, scattering, and difficultly controllable effects produced by air streams such as are customarily used in effecting atomization and spray-pattern control in conventional air-operated spray guns. The use of a single character of energy to effect atomization, projection, deposition, and pattern-control simplifies design and construction of the apparatus and effects a marked economy in its manufacture.

In the embodiments of my invention shown in Figs. 1 and 2, the electrodes **32** and **232** which create the respective stabilizing fields are circumferentially continuous and completely surround the jet-source. In many instances, it may not be deemed necessary to control and stabilize the entire peripheral portion of the jet; and in such instances the auxiliary electrode which creates the secondary field need not completely surround the jet-source. One such arrangement is contemplated in Figs. 3 and 4, where the secondary field created by the auxiliary electrodes **330** is fairly well confined to the region adjacent the ends of the elongated jet projected from the elongated discharge head. Where the auxiliary field is to have any considerable extent over the periphery of the projected jet, the discharge electrode may either have a relatively sharp edge continuous over the desired extent or it may comprise a plurality of pointed elements similar to the electrodes **330**.

In electrostatic atomizing heads of the type set forth in the copending applications above referred to, the region outside of but immediately adjacent the projected jet will contain some lines of force terminating on the atomizing head above or in rear of the jet-source. The field which those lines of force might be regarded as constituting is not such a secondary stabilizing and controlling field as is employed in the practice of the present invention, primarily because its intensity is too low to produce any significant stabilization of the peripheral portions of the jet or any significant sharpening in the edge definition of the deposited pattern. For the accomplishment of my purpose, the composite electrostatic field, including both the component which has been herein referred to as the atomizing, projecting, and depositing field and the component referred to as the secondary or stabilizing field, must be characterized by the existence in, or approximately in, a plane spaced from the article surface being coated of two or more regions of relatively high potential gradient separated by an intervening region or regions of relatively low potential gradient, with atomization of the coating material taking place at one of the regions of high potential gradient while the other or others of such regions constitute the terminal portions of the secondary or stabilizing field. Thus, in each of the heads shown in Figs. 1 and 2, the field will have a region of high potential gradient at the discharge edge **16** or **216** and a second region of high potential gradient at the edge **32** or **232** of the control electrode; while in the region between the discharge edge and the edge of the control electrode the potential gradient of the field will be much lower. Similarly, in the device of Figs. 3 and 4, a region of high potential gradient will exist along the discharge edge **316** and at the tip of each of the control electrodes **330**; but between each end of the discharge edge **316** and the tips of the adjacent control electrodes **330** the potential gradient of the field will be low.

Atomizing heads shown in the copending applications referred to above do not meet the requirements just mentioned; for the potential gradient of the field over the surface of the atomizing head decreases substantially progressively away from the localized region or regions at which atomization takes place.

I claim as my invention:

1. In the deposition of liquid material onto a surface, the steps of electrostatically atomizing liquid material from a source thereof, electrostatically projecting the atomized liquid material in the form of a jet onto the surface, and maintaining a corona discharge spaced from said source but sufficiently close to control the jet of atomized liquid material.

2. In the deposition of liquid material onto a surface, the steps of electrostatically atomizing liquid material from a source thereof, electrostatically projecting the atomized liquid material in the form of a jet onto the surface, and maintaining a corona discharge surrounding and spaced from said source but sufficiently close to control the jet of atomized liquid material.

3. In apparatus for electrostatically forming a divergent jet and applying particles of liquid coating material composing said jet upon a surface of an article, a nozzle having a discharge edge of knife-like sharpness, means for support-

ing said nozzle and presenting its discharge edge toward the article to be coated and in spaced relation therefrom, a tube communicating with said nozzle and adapted to convey a stream of said liquid material to said edge, an electrically conductive member having a discharge edge of a lesser degree of sharpness than said first named discharge edge, means for insulatingly supporting said conductive member with its discharge edge substantially coplanar with but in spaced relation from said first discharge edge and similarly presented in spaced relation toward the article to be coated, high voltage means connected with said first named edge for maintaining it at a potential different from the article and for creating a corona discharge thereabout to electrostatically atomize said material from said first edge and project such atomized material in particled jet form to the surface of the article to be coated, said high voltage means and first named edge being effective to impress by induction an electric field around the edge of said electrically conductive member of a potential sufficient to electrostatically stabilize the jet axially and shape the diverging spray formation of the particles as they are removed and propelled by the corona discharge emanating from said nozzle edge.

4. In apparatus for electrostatically coating an article with coating material, an applicator means, means for supporting said applicator means in spaced relation from an article to be coated, two members on said applicator means, said members having opposed surfaces defining a passage, one of said members projecting toward the article beyond said other member, a surrounding control member supported substantially coplanar with said projecting member in spaced relation therefrom, means for supplying coating material to the projecting member of said applicator means, and means for creating an electrostatic field of high potential between said applicator means and the article to be coated to electrostatically atomize the coating material delivered to said projecting member and electrostatically deposit it on the article being coated, said field creating means being also effective to create a surrounding field between said control member and said article.

5. Apparatus for applying atomized liquid coating material to an article, comprising an applicator means including a member with a discharge edge, means for supporting said applicator means with the discharge edge spaced from the article being coated, a control electrode supported in spaced relation to said discharge edge and the article being coated, means for supplying liquid coating material to said discharge edge, and means for creating an electrostatic field of high potential between said discharge member and the article to be coated to electrostatically atomize in the form of a jet the coating material supplied to said discharge edge and electrostatically depositing the atomized coating material on the article being coated, said field-creating means being also adapted to create a secondary electrostatic field between said control electrode and the article being coated for controlling the jet of atomized coating material.

6. Apparatus for applying atomized liquid coating material to a surface, comprising a head, means for supporting said head in opposed spaced relation to such surface, said head having spaced first and second projecting portions extending toward such surface, said second projection being annular and surrounding the first projection, means including a high-voltage source for maintaining between such surface and the first projection a primary electrostatic field capable of producing a corona discharge at the first projection and for maintaining a secondary field between the surface and second projection, and means for supplying liquid coating material to the first projection for atomization within such corona discharge, said primary field serving to precipitate on to said surface the electrically charged particles resulting from such atomization.

7. Apparatus as set forth in claim 5 with the addition that said control electrode is annular and surrounds the discharge edge, said discharge edge extending toward the surface at least as far as does the control electrode.

8. Apparatus for applying atomized coating material to an article comprising a support for the article to be coated, an applicator means including a member with a discharge edge, means for supporting said applicator means with the discharge edge spaced from an article on said support, a control electrode supported in spaced relation to said discharge edge and the article being coated, means for supplying liquid coating material to said discharge edge, and means for creating an electrostatic field of high potential between said discharge member and the article to be coated sufficient to electrostatically atomize in the form of a spray the coating material supplied to said discharge edge and to move the spray particles through quiescent air and electrostatically deposit the atomized coating material on the article, the space between said discharge edge and the article on said support being sufficient to permit the spray particles to be dispersed during their movement toward the article, said field creating means being also adapted to create a secondary electrostatic field between said control electrode and the article being coated for controlling the spray of atomized coating material.

9. Apparatus for applying atomized coating material to an article comprising a support for the article to be coated, an applicator means including a member with an extended discharge edge, means for supporting said applicator means with the discharge edge spaced from an article on said support, a control electrode supported in spaced relation to said discharge edge and the article being coated, means for supplying liquid coating material to said applicator means, means for forming the material supplied to said applicator means into a thin sheet-like body having a longitudinal extent many times its transverse thickness and for moving the body toward said discharge edge, and means for creating an electrostatic field of high potential between said discharge member and the article to be coated sufficient to electrostatically atomize in the form of a spray the coating material from said body and to move the spray particles through quiescent air and electrostatically deposit the atomized coating material on the article, the space between said discharge edge and the article on said support being sufficient to permit the spray particles to be dispersed during their movement toward the article, said field creating means being also adapted to create secondary electrostatic field between said control electrode and the article being coated for controlling the spray of atomized coating material.

10. Apparatus for applying atomized coating material to an article comprising a support for

the article to be coated, a single fluid atomizing means including a member with a discharge opening, means for supporting said atomizing means with the discharge opening spaced from an article on said support, a control electrode supported in spaced relation to said discharge opening and the article being coated, means for supplying liquid coating material to said discharge opening, and means including another electrode for creating an electrostatic field, extending to the coating material supplied to said opening, and extending over the surface of the article to be coated of sufficient strength to electrostatically atomize in the form of a spray the coating material supplied to said discharge opening and to move the atomized spray particles through quiescent air and electrostatically deposit the atomized coating material on the article, the space between said discharge opening and the article on said support being sufficient to permit the spray particles to be dispersed during their movement toward the article, said field creating means being also adapted to create a

secondary electrostatic field between said control electrode and the article being coated for controlling the spray of atomized coating material.

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