Sept. 20, 1955 E. P. MILLER 2,718,477

METHOD AND APPARATUS FOR ELECTROSTATIC ATOMIZATION

Filed March 20, 1950 2 Sheets-Sheet 1

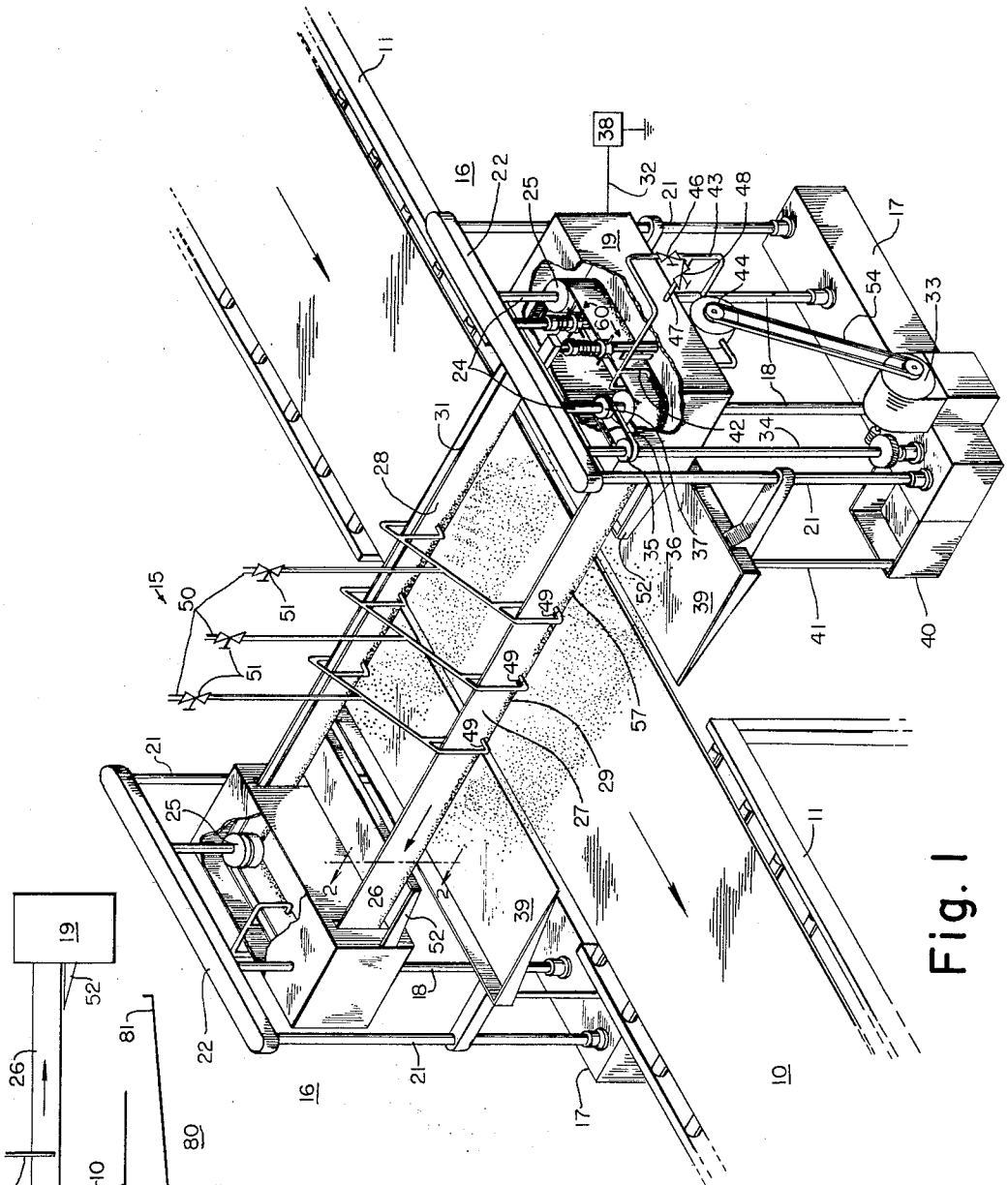


Fig. 1

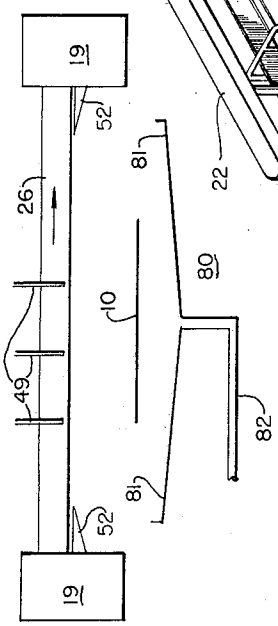


Fig. 8

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METHOD AND APPARATUS FOR ELECTROSTATIC ATOMIZATION

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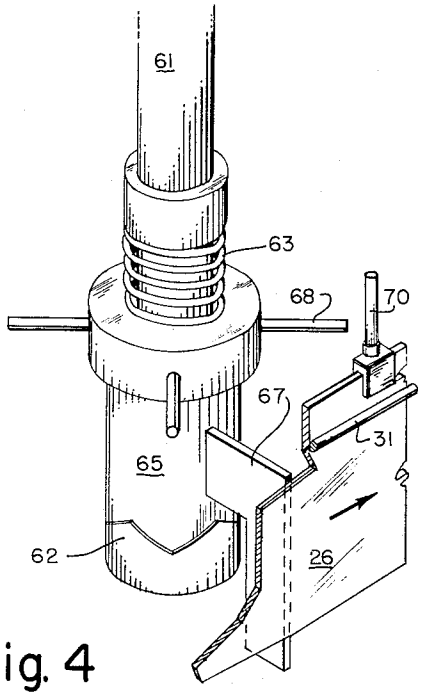


Fig. 4

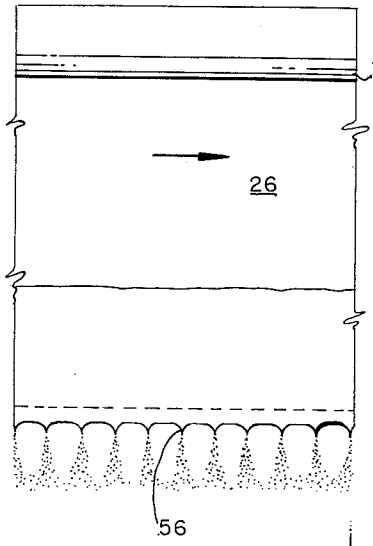


Fig. 3

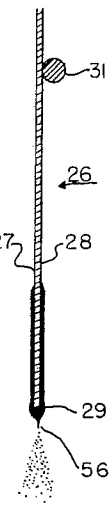


Fig. 2

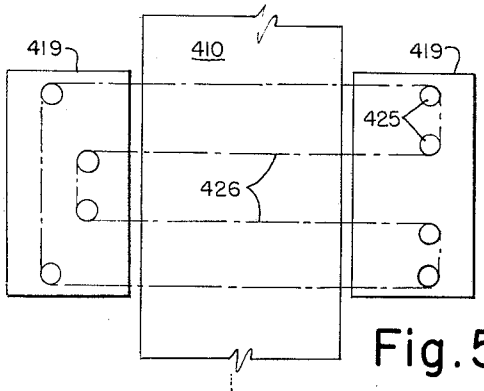


Fig. 5

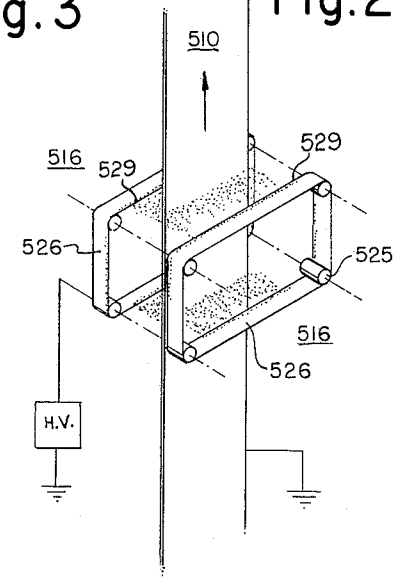


Fig. 6

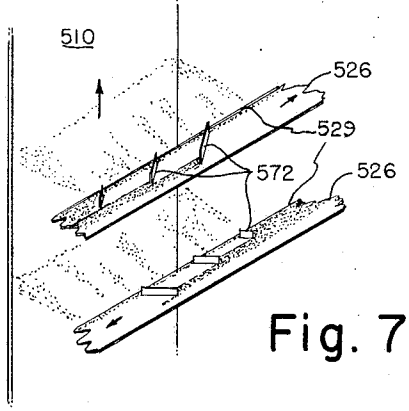


Fig. 7

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2,718,477

METHOD AND APPARATUS FOR ELECTROSTATIC ATOMIZATION

Emery P. Miller, Indianapolis, Ind., assignor to Ransburg Electro-Coating Corp., Indianapolis, Ind., a corporation of Indiana

Application March 20, 1950, Serial No. 150,713

16 Claims. (Cl. 117—93)

This invention relates generally to improvements in methods of and apparatus for effecting electrostatic atomization of liquids and especially to novel electrostatic atomizing methods and apparatus adapted for use in coating articles. More particularly, the invention relates to methods and apparatus in which atomization is effected from the edge of an extended supported film of liquid material.

One object of the present invention is to provide a novel method and apparatus for electrostatically atomizing liquids in which large quantities of liquids are handled efficiently and without requiring critical adjustments.

Another object of the present invention is to provide a novel method and apparatus for electrostatically atomizing liquids in which the film-supporting surface is maintained in a relatively clean condition.

Another object of the present invention is to provide novel electrostatic atomizing apparatus having a film-supporting discharge member of flexible material to permit ready change in the direction of movement of the discharge member or other facile manipulation of the discharge member.

Another object of the present invention is to provide a novel method and apparatus for applying electrostatically a continuous, uniform coating to large, extensive surfaces with great efficiency.

Another object of the present invention is to insure that atomization of liquid coating material attains a stable condition before the atomized coating material is permitted to be deposited on an article to be coated.

The above and other objects and advantages will appear more fully from the following detailed description together with the accompanying drawing, in which:

Fig. 1 is an isometric view of one form of apparatus embodying the invention;

Fig. 2 is a sectional view taken on the line 2—2 of Fig. 1 showing exaggeratedly the distribution of the liquid on the discharge member;

Fig. 3 is a fragmental side view of the discharge member showing liquid cusp formation and electrostatic atomization;

Fig. 4 is an isometric view, on an enlarged scale, illustrating more specifically the mechanism for cleaning the discharge member;

Fig. 5 is a schematic diagram illustrating an atomizing device in which the discharge member moves over the path of article travel four separate times;

Fig. 6 is a schematic diagram illustrating an embodiment of the invention capable of coating both sides of a moving sheet;

Fig. 7 is a schematic diagram illustrating the use of stationary material directing elements in the modification of my invention shown in Fig. 6; and

Fig. 8 is a sectional schematic diagram illustrating another embodiment of my invention as used to coat discontinuous surfaces.

Fig. 1 shows one form of apparatus constructed in accordance with the present invention for coating articles.

As shown in this figure, the article 10, which is in the form of a strip of sheet metal, is moved by a conveyor 11 in a horizontal plane in the direction of the arrow adjacent the sheet.

Along the path of travel of the sheet 10, there is provided an atomizing device 15 which atomizes, disperses and deposits liquid coating material on the sheet 10. This device includes a pair of supporting structures 16—16, located on opposite sides of the path of sheet travel. Each structure 16 comprises a base 17 upon which is rigidly mounted a pair of standards 18—18 of electrically insulating material for supporting a container or tank 19 and another pair of standards 21—21, also of electrical insulating material, at the upper ends of which is affixed a crossbar 22. Two shafts 24—24 are journaled in the crossbar 22 and extend downwardly into the tank 19. Grooved pulleys 25—25 are affixed to the lower ends of the shafts 24—24 for supporting and guiding a movable, flexible discharge member 26 over a rectangular path for movement through the tanks 19 and over and in spaced relation to the sheet 10.

The member 26 may be a sheet metal belt with side surfaces 27 and 28 terminating in a discharge edge 29 presented toward and spaced from the sheet 10. Affixed to the member 26 is a flexible cable 31 which engages the grooved pulleys 25 to aid in guiding the member 26 in the desired manner and to avoid "hunting" of the member 26 as it passes over pulleys 25.

The motive power for driving the member 26 at a uniform speed is provided by one of two motors 33, which motors are supported respectively on the bases 17. This discharge-member driving motor 33 is adapted to drive shaft 34 which is made of electrically insulating material and is rotatably mounted in bearings on the base 17 and on the crossbar 22. A pulley 35 is affixed to the shaft 34 to rotate therewith. A belt 36 engages pulley 35 and a pulley 37 is affixed to one of the shafts 24 to transmit power from shaft 34 to shaft 24 for moving the member 26.

As the member 26 moves through one or both of the tanks 19 liquid is supplied to it, by means hereinafter described, to form a liquid film on either or both of the surfaces 27 and 28, and the movement of the member 26 carries such film or films into the coating zone above the sheet 10. To effect atomization and dispersion of the liquid thus carried into the coating zone and the deposition of the atomized, dispersed liquid particles onto the sheet 10, an electrostatic field of appropriate strength, for example, a field having an average potential gradient of 10,000 volts per inch, is maintained between the liquid on the discharge edge 29 and the sheet 10 which region may be referred to as a coating zone. For this purpose, the sheet may be grounded through the conveyor 11 while the liquid on the discharge edge 29 is electrically connected to one terminal of the high voltage source 38 by means of the member 26 and conductor 32. The other terminal of the voltage source is grounded. In the coating zone, the aforesaid field draws the liquid on the member 26 into a series of cusps 56, and atomization takes place from the tips of such cusps, as indicated in Fig. 3.

Desirably, the cusps are formed and atomization from their tips is stabilized before the cusps move into the coating zone above the sheet 10. For this purpose an electrostatic field may also be maintained between the liquid on the edge 29 and initiating members 39—39 which are rigidly mounted on the respective insulating standards 21—21 on opposite sides of the sheet 10 and spaced from the edge 29 substantially by the same distance as is the sheet 10. This latter field functions to form the cusps 56 and to initiate atomization of the liquid from the edge 29 just after the member 26 has moved from one of the tanks 19 and prior to its move-

ment opposite the sheet **10**. Since atomization is erratic and the particles are relatively coarse during the initial stages of atomization, the provision of members **39** permits these members to collect this undesirable coarse coating material and the sheet **10** then receives a uniform coating of relatively finely atomized liquid particles. The liquid collected by each of the members **39** is drained into a sump **40** by means of a pipe **41**. The material in the sumps **40—40** may be transferred to the tanks **19—19** by any suitable means to again be used in the coating operation.

The coating material supply means, which supplies liquid coating material to the surfaces **27** and **28** along which it flows in the form of a film **57** to the edge **29** as shown in Fig. 2, comprises one or more nozzles **42** disposed adjacent each of the surfaces **27** and **28** and rearwardly of the edge **29**. These nozzles are located remote from the coating zone and in the region of the tanks **19** and are connected to pipes **43** which communicate with the tanks **19** which hold a supply of liquid coating material. A pump **44** driven by motor **33** is connected into each of the pipe lines **43** to force the liquid from the tanks **19** to the respectively associated nozzles **42**. In order to maintain the pump **44** electrically insulated from ground, the belt **54** is made of electrically insulating material. A valve **46** may be provided in each of the pipes **43** to control the quantity of liquid fed to the nozzles **42**. Also, if desired, further control may be obtained by by-passing some of the liquid in the pipe **43** prior to its reaching the nozzles **42**. This may be accomplished by a pipe **47** connected between pipe **43** and the tank **19**. A valve **48** may be provided in the pipe **47** to control the amount of liquid that is by-passed.

Where it is desired to atomize in the coating zone more liquid material than can conveniently be carried thereto on the member **26**, nozzles **49** may be provided for supplying additional liquid material. The nozzles **49** are located in the coating zone and disposed adjacent the surfaces **27** and **28** of member **26**. The nozzles **49** are connected to pipes **50** which are in turn connected to a suitable supply of liquid coating material. Valves **51** may be provided in the pipes **50** for controlling the amount of liquid fed to the nozzles **49**. Pressure for moving liquid to the nozzles **49** for distribution to the discharge edge **29** may be obtained by means of a pump, by means of air pressure within the storage tank for the liquid or by gravity. This liquid feed mechanism is electrically insulated from ground as is the apparatus connected to the nozzles **42**. Since the nozzles **49** are located above the edge **29** and time is required for the liquid they discharge to flow down the surfaces **27** and **28** to the discharge edge, the nozzles associated with each transverse stretch of member **26** are desirably located nearer to that side of the coating zone from which such stretch enters than to the side from which it leaves. Whereas Fig. 1 shows the simultaneous use of both nozzles **49** and **42** it is to be understood that either set may be used independently where such use is desired.

The tanks **19** may be provided with drip troughs **52** affixed to the exterior walls at points where the member **26** leaves such tanks. These troughs function to capture the excess liquid material supplied to the member **26** and are inclined downwardly toward the tanks to permit this excess liquid to drain back into the tanks for further use.

Cleaning mechanism **60** which is shown in greater detail in Fig. 4, may be mounted on each of the crossbars **22** for cleaning the surfaces **27** and **28** of member **26**. This is desirable since it has been found that better atomization and improved uniformity of deposition is obtained where a clean discharge member is used.

The mechanism **60** includes rod **61** supported from the crossbar **22**. The lower end of the rod **61** has affixed thereto a positioning cam **62**. A sleeve **65** is slidably and rotatably mounted on the rod **61** above positioning cam **62**, and it is held in positive engagement therewith by

spring **63**. A cleaning element **67** is affixed to the sleeve **65** and may be brought into and out of engagement with the discharge member **26** by rotating the sleeve **65**. The upper end of the sleeve **65** is provided with four pins **68** equally and circumferentially spaced which are adapted to be engaged by pin **70** affixed to the member **26** for rotating the sleeve **65**. During periods when the pins **68** are out of engagement with pin **70** the positioning cam **62** and the spring **63** co-operate to maintain the sleeve **65** in a stationary, stable condition. In operation the pin **70** engages and moves one of the pins **68** and therewith the sleeve **65** one-quarter turn about the axis of rod **61** during each cycle of movement of the discharge member **26** over its path. This brings element **67** into engagement with the discharge member **26** for cleaning it on every fourth cycle of travel of the discharge member over its path of travel.

It is evident that the element **67** can be brought into engagement with the discharge member **26** more frequently and less frequently by varying the number and the arrangement of the pins **68**. Also, it is evident that, if desired, the element **67** may be maintained in continual engagement with the discharge member **26** by proper orientation of the sleeve **65** and the removal of the pin **70** from the discharge member **26**.

While satisfactory coating for some applications may be obtained by atomizing during only one sweep of the member **26** past the surface being coated, it has been found, especially where coating material is not applied to the member **26** during its travel in the coating zone, that coatings with improved uniformity are obtained where the member **26** carries liquid for atomization during two sweeps past the surface being coated, the sweeps being in opposite directions to each other.

While the apparatus in Fig. 1 shows the member **26** making two sweeps across the sheet **10**, it is understood that where thicker coatings or faster handling of articles being coated are required additional sweeps of the member **26** may be made across the articles being coated. One such apparatus is shown schematically in Fig. 5 where a discharge member **426** is supported and guided by pulleys **425** and moved by a means not shown through tanks **419** and past article **410** in four separate sweeps.

In Fig. 1, the surface being coated is moved in a horizontal plane; however, it is understood that the surface to be coated may be positioned in other planes.

Apparatus for moving sheet material in a vertical plane is illustrated schematically in Fig. 6 where the sheet material **510** is moved in a vertical plane past two separate atomizing devices **516** which include the discharge members **526** moved over pulleys **525** by means not shown. In such arrangement coating material is preferably fed only to the top side of that portion of the discharge member moving past the sheet. As shown in Fig. 7, stationary material directing element **572** may be mounted in a suitable manner, adjacent the flexible members **526** to aid in directing the coating material on the members **526** toward the edges **529**.

While the apparatus shown in Fig. 1 is best suited for coating continuous surfaces, it is desirable to modify it when the surfaces are discontinuous by replacing members **39—39** with device **80**. Fig. 8 is a sectional schematic diagram showing such modification. To maintain stability of the atomized pattern when no sheet is opposite the discharge edge **29**, the device **80** is disposed between tanks **19—19** and beneath member **26**. The device **80** includes member **81** which is sloped towards its center where it communicates with a pipe **82**. This arrangement insures that as the discharge member **26** moves from tank **19** across the sheet **10** atomization will be established by that part of initiating member **81** extending beyond the sheet as in Fig. 1 and operation will continue unaffected whether the sheet is present or not. Material atomized to member **81** will be returned to sump by the pipe **82** to be reclaimed.

The voltage source **38** utilized may provide full-wave or half-wave rectification or provide unrectified A. C. In general, the steadier the potential employed the better defined will the deposited pattern be and the more uniform and satisfactory will be the degree of atomization. The effectiveness of the electrostatic field in causing atomization and in promoting deposition of atomized material will vary in the same sense as the applied voltage, and it is therefore desirable in most instances to use voltages approaching the highest voltage consistent with freedom from possible sparking. Voltages which create between the atomizer and the article an average potential gradient of 8,000 to 12,000 volts per inch are very satisfactory. In most instances I prefer to space the discharge edge at about ten inches from the surface being coated and to employ a potential of about 100,000 volts.

The invention can be practiced without regard to the polarity of the potential maintained on the discharge member or article. In coating, either the discharge member or the article can be grounded; but in most instances it will be more convenient to ground the article. Articles of insulating character can in many instances be coated without the necessity for a backing electrode so long as their surfaces are maintained at a different potential from the atomized material.

It is not essential that the discharge member, or even that portion of it which supports the film, be made of conducting material. Most liquids, and especially most coating materials, are sufficiently conducting that if the discharge member is made of insulating material the potential can be applied to the film-edge through the film itself. Moreover, the current consumed in the atomizing operation is so small that it can be conducted to the edge of the discharge member through materials of relatively high insulating properties.

Fine atomization is promoted by the employment of a sharp-edged film-supporting discharge member. Where fine atomization is of no moment or undesired, the shape of the liquid supporting edge portion of the discharge member in cross section transverse to its extent is of little consequence.

In addition to the cross-sectional shape of the film-supporting discharge member the applied voltage and the rate of liquid flow influence the fineness of atomization. Increasing the applied voltage tends to increase the fineness of atomization, while an increase in the rate of fluid supply tends to decrease it. Obviously, the liquid should not flow to the film-edge at a rate greater than that at which the field will atomize it.

The spacing and form of the cusps **56** depend upon the viscosity and conductivity of the liquid being atomized, upon the rate of liquid-supply, and also upon the strength of the field at the discharge edge of the member **26**. With the discharge edge spaced at ten inches from the article and a potential difference of 100,000 volts maintained, the cusps will be spaced about fifty to the inch in the case of most commercial coating materials.

It is evident that speed of article movement, speed of the discharge member **26**, and fluid-delivery rate will all need to be correlated to obtain optimum coating conditions. Where continuous coating is desired these conditions should be such that striping is avoided. Enough material should be applied to the discharge member **26** to maintain atomization at a satisfactory rate throughout the full width of the sheet **10** or other article being coated. Any material remaining on the member **26** after it leaves the coating zone will continue to atomize above the member **39** or **81** and can consequently be recovered.

While I have described the invention above as embodied in a complete coating apparatus, it is to be understood that in its broader aspect the invention extends to the atomizing method and apparatus alone, without regard to whether the atomized liquid is deposited electrostatically or otherwise to coat an article. When used as an atomizer, satisfactory atomization may be obtained from the discharge edge by impressing on the discharge edge or on the liquid supported thereby an appropriate potential with reference to its surroundings. One way of obtaining the necessary potential gradient at the discharge edge of the discharge member is to connect it or the liquid it supports to the ungrounded terminal of a high-voltage source the other terminal of which is grounded. In such an arrangement, satisfactory atomization has been obtained with voltage sources of 100,000-volt output; but voltages as low as 10,000 volts have been used.

I claim as my invention:

1. In an electrostatic atomizer, an endless, flexible discharge member having a liquid receiving surface terminating in an endless discharge edge, means for supporting and moving said member in a closed path through supply and atomizing zones spaced along such path, means in said supply zone for flowing liquid onto said member at a point spaced from said edge, said supporting and moving means being so constructed and arranged as to support the member between the supply and atomizing zones in a position such that the liquid supplied to it may flow transversely to said edge under the influence of gravity, and means including a high-voltage source for creating at the surface of liquid carried into the atomizing zone on said edge an electrostatic field capable of atomizing such liquid.

2. In an electrostatic atomizer, a discharge member having opposite side surfaces terminating at a common edge portion, means including separate liquid dispensers for discharging liquid material on said side surfaces at points spaced from said edge portion for flow thereto and electrostatic atomization therefrom, and means including a high-voltage source for maintaining adjacent said edge portion a local potential gradient sufficient to electrostatically atomize the liquid material thereon.

3. In apparatus for electrostatically coating an article, a discharge member having opposite side surfaces terminating at a common edge portion, means for supplying liquid coating material to both said side surfaces for flow thereover to said edge portion, means for supporting the article in opposed spaced relation to said edge portion and for causing relative movement of the article and discharge member in a direction transverse to said edge portion, and means including a high-voltage source for maintaining between the article and the coating material on said edge portion an electrostatic field capable of atomizing fine particles from such coating material and depositing said particles on the article, said article means and said discharge member being spaced apart a distance sufficient to permit substantial electrostatic dispersion of said particles as they move toward deposition on the article.

4. Electrostatic coating apparatus comprising an atomizing device including an extended member having a discharge portion, means for moving said member along its extent successively from a supply zone to a coating zone, means for supplying liquid coating material to said member in said supply zone for distribution along at least a part of said portion, means for moving an article past and in spaced relation to said extended member and transverse to the path of movement of said member, and means including a high-voltage source for maintaining a potential difference between the liquid coating material on said portion and the article to electrostatically atomize into fine particles the liquid coating material on said portion, and electrostatically deposit the atomized particles on the article, said article-moving means and said member being spaced a sufficient distance apart to insure substantial electrostatic dispersion of the atomized particles prior to their deposition on the article.

5. The invention set forth in claim 4 with the addition of a collector beneath said liquid supply means and said member in said supply zone for collecting the excess liquid material leaving said portion.

6. The invention set forth in claim 4 with the addition of second liquid supply means for supplying liquid coating material to said member in said coating zone for distribution along at least a portion of said discharge portion.

7. In apparatus for applying a coating to an article, a support for the article, liquid supply means, an endless member having an extended, exposed edge, means for supporting said member for movement over a closed path including one portion spaced from and opposed to the article on said support and another portion adjacent said supply means, means for moving said member over said path, said supply means supplying liquid material to said edge as said member moves past said supply means, and means including a high-voltage source for maintaining an electrostatic field between said edge and the supported article of sufficient strength to electrostatically atomize into fine particles the liquid material on said edge, electrostatically disperse the fine particles and electrostatically deposit the dispersed, atomized particles on the article.

8. In apparatus for electrostatically coating an article, an endless, flexible member provided with an edge portion and a side surface adjacent said edge portion, means for applying liquid coating material to said side surface in rear of said edge portion for flow over said side surface to said edge portion, a support for supporting an article, means for supporting and moving said member over a closed path, said path including a rectilinear stretch in opposed spaced relation to the supported article, and means including a high-voltage source for maintaining a potential difference between the liquid coating material on said edge portion at said rectilinear stretch and the article to electrostatically atomize and electrostatically deposit atomized particles of the coating material on the article.

9. The method of electrostatically coating an article, comprising the steps of forming liquid coating material into a thin film having an extended terminal edge, moving said film in a direction generally parallel to its edge into a coating zone remote from the site of formation of said film with said edge disposed in spaced relation to an article to be coated, creating between said film and the article in said coating zone an electrostatic field capable of electrostatically atomizing fine particles of coating material at spaced points along said terminal edge, electrostatically dispersing the atomized particles, and electrostatically depositing the dispersed, atomized particles on the article.

10. The invention set forth in claim 9 with the addition that said film is continuous in extent from its site of formation to said coating zone.

11. The invention set forth in claim 9 with the additional step of adding liquid coating material to said film in said coating zone for atomization and deposition on the article.

12. The method of electrostatically coating an article comprising the steps of forming two films of liquid coating material, supporting said films to form a common terminus between them, supporting an article to be coated in

opposed, spaced relation to said terminus, creating between said terminus and the article an electrostatic field capable of electrostatically atomizing fine particles of liquid coating material at spaced points along said terminus, electrostatically dispersing the atomized particles, and electrostatically depositing the dispersed, atomized particles on the article and replenishing coating material to said films during atomization.

13. In an atomizer for forming a spray of electrically charged liquid particles, an endless flexible member having an edge and a side surface extending laterally of said member from said edge, means for supporting and moving said member over a closed path in at least one portion of which said side surface lies above said edge whereby liquid on said surface will flow to said edge under the influence of gravity for atomization from the edge, means for applying liquid to said side surface at a point spaced inwardly from said edge, and means including a high-voltage source for establishing an electrostatic field at said edge.

14. The invention set forth in claim 13 with the addition of means engaging said member at a point posterior to said atomizing zone with regard to the direction of member-movement to remove unatomized liquid from the member.

15. In a liquid atomizer, an extended discharge member, means for distributing liquid on said member for atomization therefrom, a cleaning device supported for movement into and out of engagement with said member, means for causing relative movement between said member and cleaning device in the direction in which said member extends, and mechanism operating cyclically in timed relation with said movement-causing means for moving said cleaning device alternately into and out of engagement with said member for removing from said member the liquid not atomized to maintain the quality of atomization.

16. Electrostatic coating apparatus having in combination, a conveyor for moving an article to be coated over a predetermined path, an atomizing device for producing an elongated spray of coating material, said device being disposed on one side of the article path and spaced therefrom, means including a high voltage source for establishing an electrostatic field between said atomizing device and the article for electrostatically depositing the spray on the article, and means for moving said atomizing device in the direction of elongation of said spray and transverse to the path of article movement.

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