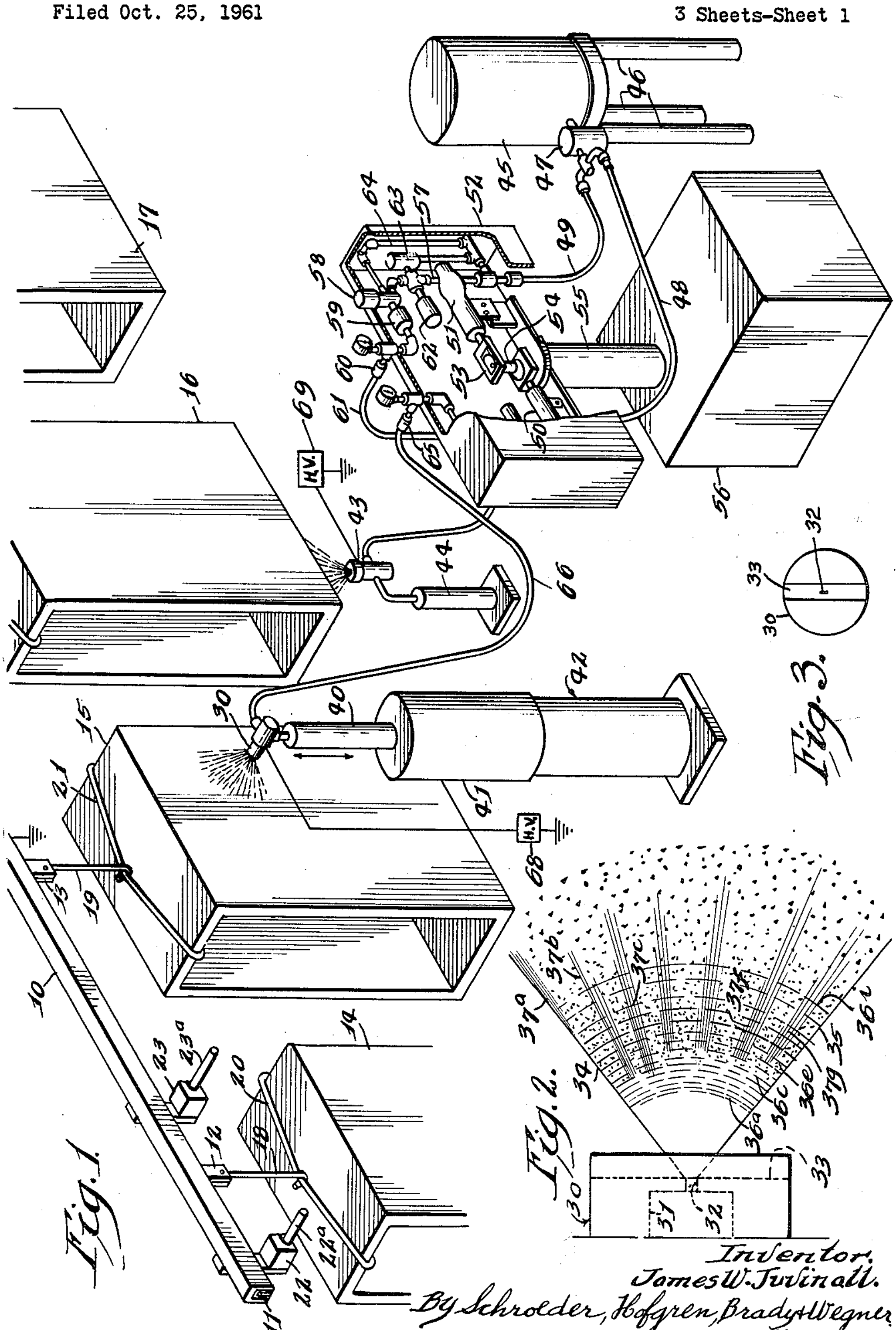
ELECTROSTATIC COATING METHODS AND APPARATUS

Filed Oct. 25, 1961 3 Sheets-Sheet 1



Inventor,
James W. Juvinall.
By Schroeder, Hofgren, Brady & Wegner
Attorneys.

ELECTROSTATIC COATING METHODS AND APPARATUS

Filed Oct. 25, 1961 3 Sheets-Sheet 2

Fig. 4

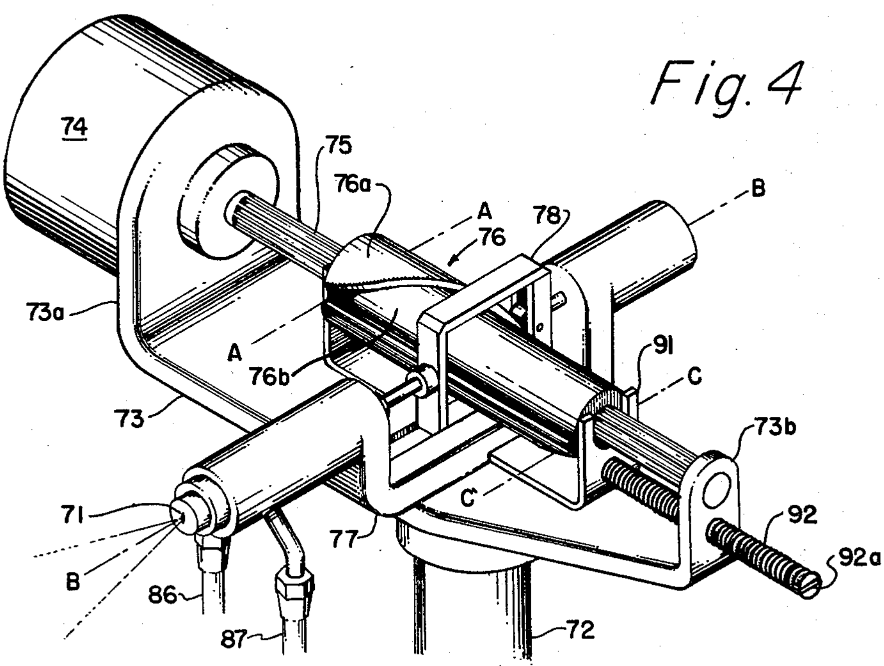


Fig. 5

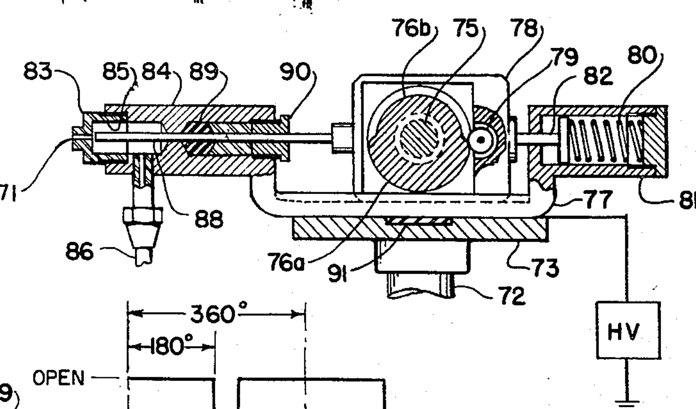
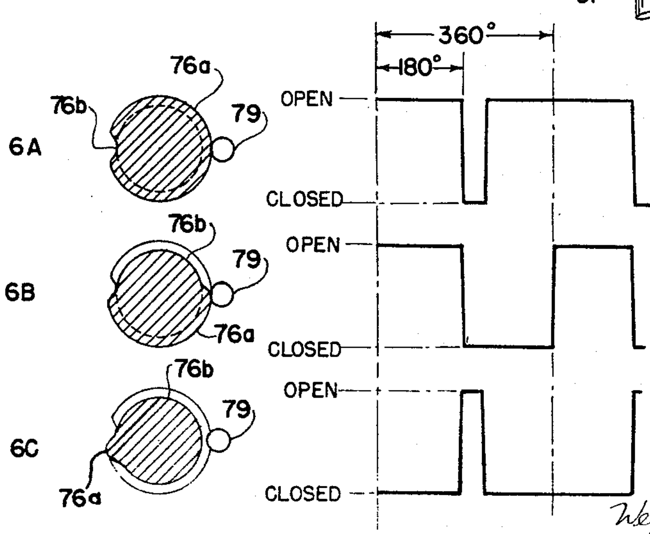


Fig. 6



INVENTOR.
JAMES W. JUVINALL
BY Hofgren, Brady, Wegner, Allen & Stellman
Attorneys

Feb. 16, 1965 J. W. JUVINALL 3,169,883

ELECTROSTATIC COATING METHODS AND APPARATUS

Filed Oct. 25, 1961 3 Sheets-Sheet 3

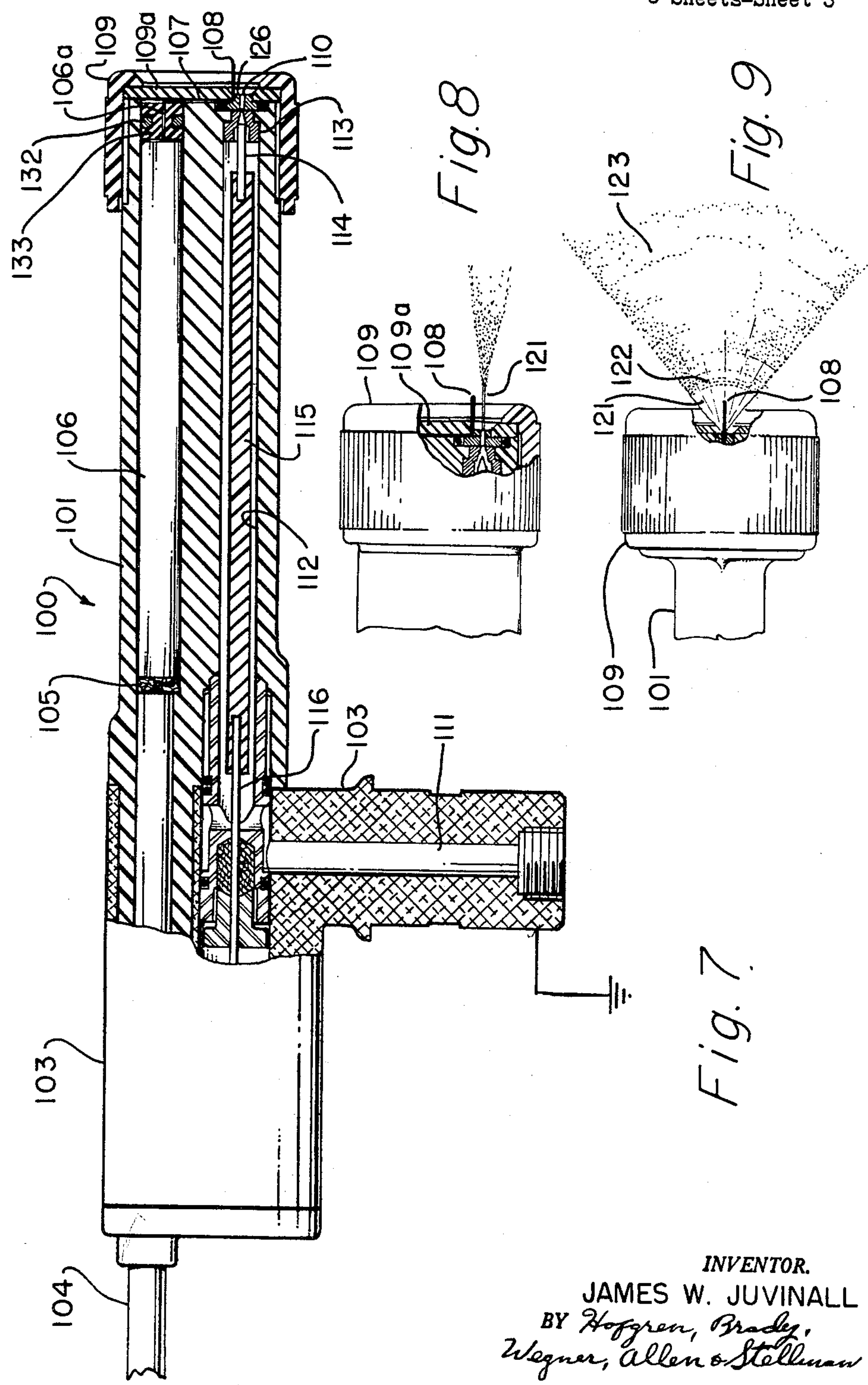


Fig. 7

Fig. 8

Fig. 9

INVENTOR.
JAMES W. JUVINALL
BY Hofgren, Brady, Wegner, Allen & Stellman
Attorneys

United States Patent Office 3,169,883 Patented Feb. 16, 1965

1

3,169,883
ELECTROSTATIC COATING METHODS AND APPARATUS

James W. Juvinall, Indianapolis, Ind., assignor to Ransburg Electro-Coating Corp., Indianapolis, Ind., a corporation of Indiana

Filed Oct. 25, 1961, Ser. No. 148,793
15 Claims. (Cl. 117—93.42)

This invention relates to electrostatic spray coating methods and apparatus for the application of liquid coating material, particularly paint, to provide a protective or decorative coating on a surface.

This application is a continuation-in-part of my application Serial No. 812,780, and now abandoned, filed May 12, 1959, which in turn was a continuation-in-part of my application Serial No. 486,247, and now abandoned, filed February 4, 1955.

In commercial production spray painting, the provision of smooth uniform coatings of the type desired and commonly provided on articles such as home appliances, housewares, and metal or other objects of all kinds, requires not only a relatively uniform distribution of the coating material during the spraying operation, but also deposition of the spray particles while still in liquid state and the use of particles of a suitable fineness. If the spray particles are too large they do not flow together satisfactorily when deposited and result in a coating which lacks the desired uniform appearance.

The use of an electrostatic depositing field is of material benefit in improving paint deposition efficiency in spray painting. Particularly where automatic spray systems are used in connection with a conveyorized production line, the use of an electrostatic depositing field results in avoidance of a substantial loss of paint which otherwise takes place, both as under-spray falling out before it reaches the articles being coated and as over-spray passing beyond or away from the articles and eventually going onto the booth walls or out the exhaust stack. Suitable charging of the spray particles and the utilization of an electrostatic field to the surface being coated results in the deposition on such surface of spray particles which would not otherwise have been deposited thereon, deposition efficiency being materially improved by the electrostatic effects. Where such a field is being used, fineness of atomization has a very important function in achieving optimum field effects and deposition efficiency regardless of the quality of finish desired. Charge on a liquid droplet is primarily a function of surface area under optimum electrical charging conditions; and since reduction in droplet diameter reduces its volume more rapidly than its surface area, fine droplets have a larger charge-to-mass ratio than larger droplets, and therefore may be better controlled by the depositing field.

Commercial electrostatic spray painting initially utilized conventional air-spray guns to atomize the paint or other liquid coating material into spray particles. The air blast from such a spray gun, however, detracted from the effect of the electrostatic field on the spray particles and resulted in lower deposition efficiencies than were theoretically possible. In recent years commercial electrostatic spray coating installations have, in many cases, utilized airless atomization in conjunction with the electrostatic deposition, thus avoiding the air blast effects. The basic provisions of such a system are disclosed in Starkey and Ransburg Patent No. 2,685,536 issued August 3, 1954, where the particular embodiments illustrated utilize electrostatic atomization. The commercial installations now being bade by the company owning such patent, however, utilize a rotating atomizing device, rather than the stationary atomizers illustrated in such patent, such rotating devices being the subject of Ransburg Patent

2

No. 2,893,894. Many commercial installations utilizing the rotating device employ rotational speeds such that electrostatic forces are still the principal atomizing force; and this sometimes presents difficulties in securing spray particles of a desired fineness. This is particularly true of certain coating materials which are more difficult to electrostatically atomize than the commonly used synthetic enamels and lacquers; examples of such more difficult materials being metallic pigment paints and water-in-oil emulsion paints. The introduction of the above mentioned airless atomizing devices thus provided commercial spray painting systems which overcame the disadvantage of strong air blasts and materially improved deposition efficiency; but they have the disadvantage that with certain types of coating materials it is difficult to secure spray particles which are sufficiently fine in size for the desired commercial paint finishes.

By utilizing a high pressure jet with certain characteristics desirable for atomization of the paint or other liquid coating material, substantial mechanical forces effective for atomization can be re-introduced in the system while at the same time maintaining quiescent the atmosphere at or near the article surface being coated. The term "quiescent" is used herein to indicate the absence of air currents of such velocity and volume as would, for many of the particles approaching deposition, overcome the electrostatic depositing forces and thereby cause a substantial proportion of the particles to escape deposition on the work. Rather than issuing a blast of air which strikes the paint to effect atomization as in the conventional air spray gun, a high velocity, expanding, thin film of the paint is caused to issue into relatively quiescent air with such high relative speed with respect to it that the interaction provides a very appreciable mechanical atomizing force. A solid circular stream of liquid, even though traveling through the surrounding air at very high relative velocities, does not give atomization of a desired type suitable for desired field control and for quality paint finishes; but issuance of the liquid in an expanding thin film, whether in the form of a hollow cone or fan-like, if certain conditions as to velocity and form are present, results in atomization into the very fine particles which result in the desired field control and a high quality finish; and optimum electrostatic deposition may be approached by use of such an atomizing device under proper conditions of spacing and field strength. The use of a hydrostatic jet, while still obviating the disadvantages of a carrier air blast in an electrostatic system, provides control factors not heretofore available with elimination of the air spray gun. The jet with a high velocity, expanding thin film not only permits control of fineness of atomization despite other factors not under ready control (as paint type and viscosity) but also directional and particle momentum control enabling control of film thickness under situations otherwise providing difficulties in an electrostatic system, as providing sufficient paint in the bottom of a depression or other area where the field alone might result in an undesirably thin coating.

One method of determining whether atomization is suitable as to particle size is to measure the diameter of spots formed by spray particles impinging on an appropriate target under controlled conditions. Conditions which have been used in practice involve passing a 4" by 6" flat target through the spray longitudinally of its longest dimension with one face in a plane perpendicular to the spray axis and at a distance of about 12" from the spray source with sufficient rapidity that the exposed face of the target is substantially free of overlapping spots. If the average diameter of the ten largest spots on the target (hereinafter called the "spray spot size") is less than about 0.015 inch, the spray is capable of producing finishes of high quality, although where finish requirements are less stringent sprays producing a spray spot size of 0.020 inch may be satisfactory, and spray with a spray spot size above 0.020 inch should only be used where the quality of finish is not critical, for example, in maintenance painting of factory walls or the coating of heavy equipment, such as farm machinery. Hereinafter, where reference is made to the size of spots produced by deposited spray particles it is to be understood that the size referred to is the spray spot size determined under the conditions just indicated.

In general, deposition of a quality finish with high efficiencies in an electrostatic system is obtained by use of a jet with a very small orifice arranged to cause the liquid coating material, which is supplied thereto at very high pressures, to issue in the form of an expanding film, with very high liquid velocities. In certain instances such velocities at least initially can be of the order of 10,000 feet per minute or more. The particles of spray so formed are capable both of producing satisfactory finishes and of possessing in an electrostatic field, charge-to-mass ratios great enough to render them highly responsive to electrostatic forces and to attain high deposition efficiencies. The electrostatic field employed may be one maintained either to the forward portion of the atomizer, the leading edge of the paint-film, or it may extend to a spray-charging electrode disposed close to the zone of atomization. In any event, such field should have an average potential gradient of at least 5,000, and preferably at least 10,000, volts per inch.

Various additional features and advantages of my invention will be apparent from the following description and from the drawings in which:

FIGURE 1 is a perspective view of a system utilizing a high pressure jet atomizing device and embodying the invention here disclosed;

FIGURE 2 is an enlarged view of a jet nozzle tip and the film issuing therefrom;

FIGURE 3 is an end view of the nozzle shown in FIGURE 2, at half scale relative thereto and looking from the right of such FIGURE 2;

FIGURE 4 is a perspective view of another embodiment of my invention;

FIGURE 5 is a vertical sectional view along the axis of the atomizer;

FIGURE 6 is illustrative of various operating conditions and comprises portions 6A, 6B and 6C, illustrative of operation in three different positions of the control cam;

FIGURE 7 is a longitudinal sectional view illustrating an atomizing apparatus incorporating another embodiment of the invention;

FIGURE 8 is a side elevational view partly broken away of the right-hand portion of FIGURE 7; and

FIGURE 9 is a top elevational view partly broken away of the right-hand end of the apparatus of FIGURE 7.

Referring now to the particular embodiment illustrated in FIGURES 1–6 of the drawings, a conveyor track **10** provides the enclosure within which a conveyor chain **11** slides, this chain being longitudinally moved by suitable conveyor drive means, not shown. At appropriately spaced intervals the chain is provided with hangers, as the hangers **12** and **13** illustrated, which are adapted to support the articles to be coated, as the cabinets **14–17** illustrated, by suitable means such as the hooks **18** and **19** and the holding members **20** and **21**. The overhead conveyor illustrated is adapted to move the articles along at an appropriate rate as, for example, at a speed of 10 feet per minute, through the coating zone provided by one or more jet spray heads. Microswitches **22** and **23** are adjustably mounted on and supported by the conveyor track **10**, and are provided with pivotally movable switch actuating fingers **22a** and **23a** which are contacted by the hooks, as the hook **18**, during passage of the articles along the conveyor path. Contact of the hook **18** with the actuating finger **22a**, for example, initiates spraying, and contact with the actuating finger **23a** terminates it, so that paint is not wasted between the articles.

The paint, which may for example be a conventional synthetic enamel, is here shown as being applied at two stations. One of these comprises the jet atomizer **30** mounted on an insulator **40** carried by the movable portion **41** of a hydraulic reciprocator **42**. This reciprocator is actuated by conventional hydraulic means (not shown) to reciprocate the spray jet vertically a desired number of times during the passage of a cabinet thereby. The other spray source is here shown as the jet **43** mounted on a fixed insulating support **44** and so placed as to coat the undersides of the cabinets as they pass down the line. A similar arrangement, at another point in the line could be used to paint the other sides and the tops of the cabinets. The source of paint is here illustrated as a paint tank **45** mounted on insulated supporting legs **46**. The paint being withdrawn from the tank passes through a first filter **47** and then through a pair of supply tubes **48** and **49** to pumps **50** and **51** in the housing **52**. Inasmuch as the pumps and associated parts are duplicated in each side of the housing, only one will be described. The pump is of the variable volume, positive displacement piston type, the piston being here shown as driven by a scotch-yoke drive arrangement **53**, preferably with adjustable eccentrics, from an insulating shaft **54** extending down through an insulating supporting sleeve **55** to drive means in the base **56**. Preferably a variable drive means is provided as, for example, one utilizing a variable speed drive arrangement in conjunction with an electric motor.

The high pressure outlet of the pump is connected through pipe **57**, a solenoid operated three-way valve **58** and an ultra-fine filter **59** to the outlet fitting **60**. Connection is made through a suitable high pressure hose **61** to the jet **43**. The ultra-fine filter is of a commercially available type preferably passing only particles of less than the order of twenty-five microns in diameter.

Connected to the pipe **57** is a pulse damper **62** comprising a housing having therein a diaphragm exposed to the very high pressure in the line, the diaphragm being capable of compressing sufficiently to smooth out the pulses of the positive displacement pump and insuring a very uniform, high pressure delivery of paint to the jet **43**. Also connected to the pipe **57** is a pressure relief valve **63** having a return connection to the inlet side of the pump and adjusted to open at some pressure slightly above the pressure being used, preventing damage in the event of a stoppage in the outlet.

The solenoid operated three-way valve **58** also communicates with the inlet side of the pump **51**, this connection being here shown as effected by the pipe **64**. When the valve is in one position, the pipe **57** communicates with the filter **59** and thus feeds liquid to the jet **43**, whereas actuation of the solenoid, as by the microswitch **23**, causes communication between the pipe **57** and the pipe **64**, with resultant recirculation through the pump which is still running and substantially instantaneous cessation of delivery from the jet **43**. This characteristic results in very desirable "triggering" of the spray from a remote point.

It will be understood that the system in the other side of the casing **52**, the left-hand side as viewed in the drawing, is similar. Accordingly, the liquid coating material would be similarly supplied to the jet **30** through the outlet fitting **65** and the hose **66**. It will be understood that in the system illustrated, the jets **30** and **43** are spaced apart by the distance between the conveyor hangers **12** and **13**, so that both guns can be triggered simultaneously even though one jet is painting the side surface of the cabinet **15** while the other jet is painting the underside of the cabinet **16**.

Referring now more particularly to FIGURES 2 and 3, it will be seen that the jet nozzle indicated in general as **30**, is of a type providing a fan-like film substantially in a single plane. Liquid under pressure in the interior passage 31 is delivered through a very small orifice 32 which is elongated in cross-section; i.e., as viewed from the right of FIGURE 2. For most applications the orifice should have a major and minor dimension which produce an orifice which is equivalent in cross-sectional area to a circular orifice which is no larger than of the order of .015 inch in diameter. One very satisfactory orifice is .012 of an inch along its major outlet opening diameter, and .005 of an inch across its transverse or minor diameter; and this has given very satisfactory results at suitable pressures. The discharge orifice is recessed somewhat below the outermost portions of the face of the nozzle, being here shown at the bottom of a semi-cylindrical depression 33 which extends parallel to the major diameter of the elongated outlet opening 32. The fan-like film issuing from the opening 32 when the liquids are supplied thereto at very high pressures is of a character illustrated in FIGURE 2. The particular film illustrated has almost exactly straight sides 34 and 35 with an included angle of about 80° therebetween.

It is important to provide sufficient pressure and fluid velocity in the expanding film to keep the film sides substantially straight, preferably almost exactly straight, in order to achieve atomization of the desired fineness. The included angle between such sides must be at least 25° for desirable results, although in certain instances the angle might be as small as 15°, but preferably is at least 50° or 60°. When liquid is delivered at high pressures through very small elongated orifices of the type here disclosed, there is a tendency to form "streamers" at each of the sides. "Streamers" are highly undesirable in the deposition of coating materials as they not only spoil the deposition pattern but also provide areas of large particle size with resultant detraction from field control and from the quality of the finish being applied. In order to obviate such streamers from these small orifices it is necessary to use liquid pressure of the order of 250 pounds per square inch and preferably well in excess of 300 pounds per square inch. In commercial work with the variables encountered on a commercial production line, I find it often desirable to use a pressure at least of the order of 800 pounds per square inch. In fact, very satisfactory deposition patterns and atomization of synthetic enamel from the jet orifice described have been attained with pressures in the neighborhood of 1700 pounds per square inch, for example.

In a film of the fan-like type illustrated in FIGURE 2, very high pressures result in the formation, at least at and near the edge of the film where it is breaking up into discrete particles, of arcuate waves identified as *36a* to *36i*; and radially extending striations or areas of greater and lesser density here identified as *37a* to *37g*. The arcuate waves appear at somewhat lower pressures than the striations. I find it important to drive the liquid fast enough relative to the surrounding air to cause the arcuate waves to have a very short wave length, preferably of less than of the order of one-twentieth of an inch, in order to provide atomization into particles of a suitable fineness. It will be understood that the drawing of FIGURE 2 comprises a magnification of several items, as it has been found in practice that the distance from the front edge of the film where it is breaking up into discrete particles, to the orifice 32, is preferably no more than an inch and most desirably not more than ¾ of an inch, very satisfactory operating results being secured when this distance is of the order of ¼ of an inch.

For production line painting it is important to make the nozzle, or at least the portion having the projection orifice therein, of highly wear-resistant material. Tungsten carbide or a jewel such as a diamond are very satisfactory, and stainless steel has also proven satisfactory. The orifice must be of small enough size that in conjunction with the very high pressures used it will produce the desired fineness of atomization at the required delivery rate. Where open articles, such as tubular steel chair frames or bicycle frames, are to be painted, delivery rates of less than 250 cc. per minute are most satisfactory and, in the painting of such articles, the greatest benefit from the electrostatic forces is realized. With less "open" articles, delivery rates can be increased to 400 cc. per minute, and the delivery rate may be further increased as the ratio of surface area to open area of the article also increases.

While a high velocity expanding fan-like film has been illustrated in the figure and described in detail, it will be understood that a circular rather than elongated orifice may be used in conjunction with a spinner insert in the passageway 31 to provide a hollow conical film; and that such a film will have the wave and other characteristics described and will also under such conditions provide suitable atomization. Satisfactory results have been obtained with circular orifices having the same general order of effective orifice diameter as those used with slotted orifices previously mentioned. In either case, with the pressures, velocities, and other conditions described, the atomization is substantially entirely a function of the mechanical effects set up in the high velocity expanding film by virtue of its relative movement with respect to the surrounding air and by virtue of the turbulent or non-laminar flow through the orifice, with any electrostatic field applied to the film having little atomizing effect.

In the particular embodiment illustrated in FIGURES 1–6 of the drawings, suitable high voltage power packs 68 and 69 have one terminal grounded and the other or "hot" terminal connected to the jet, so that the nozzle or the paint-film projected from it acts as one electrode of the field having the grounded article as the other electrode. In order to have sufficient electrical effect, particularly to pick up and carry forward particles which might otherwise be lost as under-spray dropping out before reaching the article, it is necessary in this particular embodiment to have the total potential difference of the field at least 40,000 volts. Where, as in the apparatus of FIGS. 1–6, the field exists between the atomizer and the articles, it is usually desirable that the atomizer be so located with respect to the articles that a substantial dispersion of the spray particles and a substantial decrease in their momentum will occur before they reach the immediate vicinity of the articles, as the tendency of the particles to be carried past the articles and lost as overspray may thereby be reduced. However, in the coating of articles having depressions, or for other reasons, the momentum of the particles may be employed as a control factor to produce adequate coating, and in that event it may be desirable to position the atomizer close enough to the articles to insure that the particles being deposited retain sufficient of their initial momentum to insure an adequate coating. Where particle momentum is not to be so employed as a control factor, in order to achieve maximum deposition efficiency, it may be desirable that the distance between the atomizer and the articles, measured along the spray axis, be at least 20 inches. Where the spray axis is perpendicular to the article path very satisfactory results have been obtained by spacing the atomizer 30 inches or a little more from that path. Closer spacings can be employed without substantial decrease in deposition efficiency if the atomizer is arranged to discharge at an acute angle to the article path. It has been found that with either of the gun orientations just menioned, particle charging is improved as the voltage gradient is increased. With either arrangement the voltage supply output and the electrostatic system configuration should be such as to maintain average potential gradients of at least about 5,000 volts per inch and preferably at least 10,000 volts per inch. When close spacings are used, as in the case where the nozzle or liquid film serves as the high voltage electrode and it is not deemed desirable to minimize the effect of particle momentum imparted by the hydrostatic pressure, supply voltages may be as low as 40,000 volts. When larger spacings are employed it may be desirable to employ supply voltages of 100,000 to 150,000 volts or even more.

The form of my invention illustrated in FIGURES 1 to 3, and heretofore described, is very satisfactory for most production lines, but there are situations where greater control of the rate of delivery from a given sized orifice is desirable. For example, where short runs of articles differing markedly in size are being painted in "batches," it may be undesirable to have to remove and replace jets frequently during a shift in order to provide the widely varying paint deliveries necessary for maintenance of a desired film thickness on articles of substantially different size moving at the same conveyor speed. Yet, with a given sized orifice, control of output by variation of pressure in the liquid coating material being supplied to the jet results in relatively small changes in output flow, since rate of flow of a given liquid through a very small orifice of the type with which I am here concerned is a function of the square root of the pressure. For example, if the system is operating on cabinets of a given size, and cabinets only half that size then come down the same line, output volume of coating material should be reduced by one-half. However, if the system has been operating at 1200 pounds delivery pressure to the jet, reduction of this pressure to 800 pounds only results in a reduction of volume of 18%. It would be necessary to drop delivery pressure to 300 pounds per square inch in order to cut the delivered volume to one-half; and yet where a high quality finish is desired, the atomization effected at 300 pounds pressure may be undesirable.

Accordingly, I have devised and am here illustrating in FIGURES 4 to 6 a jet atomizing system which enables liquid pressure to be maintained at a desired discharge level, as 800 pounds per square inch, and yet permits wide variation in the volume of coating material delivered, being adjustable even during operation of an electrostatic coating system. Generally speaking, I accomplish this by maintaining the liquid in a supply chamber immediately behind a jet orifice at the desired high pressure at all times, while rapidly opening and closing the communication between the orifice and the liquid supply chamber, with control of the volume of output being effected by variations of the relative duration of the open and closed periods.

I also find that some coating materials now being used commercially, as acrylic lacquers, have a tendency to settle out with even a brief cessation of flow. Under some conditions of triggering, the arrangement shown in FIGURES 1 to 3 permits undesirable settling of an acrylic lacquer, and accordingly, I have devised an arrangement which keeps the paint flowing at all times even if the atomizing orifice is closed.

Referring now more particularly to the embodiment of my invention illustrated in FIGURES 4, 5, and 6, the atomizer comprising the hydrostatic jet orifice **71** is again shown as mounted upon the vertically movable rod **72** of a reciprocator. This rod carries a first or main support bracket **73** having upturned ends **73*a*** and **73*b***. The end **73*a*** carries a motor **74**; and since the bracket and associated parts are at high voltage during operation of the system, this would be energized through an isolating transformer, or may be an air or hydraulic motor. A splined shaft **75** is journaled in the bracket ends and adapted to be rotated by the motor at some suitable and preferably relatively low speed as, for example, 300 r.p.m. The splined shaft carries a control cam member **76**, this cam having a raised portion **76*a*** and a recessed portion **76*b***. As may be best seen in FIGURE 4, the raised portion occupies a progressively greater portion of the periphery of the cam toward the left end of the cam as it is viewed in this figure, and a progressively lesser portion of the periphery toward the lower right-hand end of such cam. The left-hand portions of FIGURES 6A, 6B and 6C show representative cam portions along the section lines indicated on FIGURE 4.

A second bracket member **77** is fixedly mounted on the first bracket **73**, and in turn carries the hydrostatic jet atomizer (to the left as viewed in FIGURE 5) and the arrangement for controlling the average volume of liquid coating material atomized therefrom in a given length of time. Referring now more particularly to FIGURE 5, a yoke **78** is slidable in ways in the bracket **77**, being adapted to move right and left as viewed in this figure. The yoke surrounds the control cam **76**, and has mounted in one of its legs a cam follower or roller **79**. The yoke is constantly urged to the left (as viewed in FIGURE 5) by a spring **80** in a spring housing **81**, the spring bearing against a reciprocable rod member **82** mounted on the yoke **78**. Rotation of the cam **76** thus permits the spring to move the yoke to the left when a recessed portion of the cam is adjacent the roller **79**, and moves the yoke to the right an appreciable distance when a raised portion of the cam surface is in contact with the roller **79**.

Referring now more particularly to the part shown at the left of FIGURE 5, the jet nozzle **83** having the orifice **71** therein is mounted in a body member **84** in such a manner as to provide a supply cavity **85** immediately behind the jet orifice **71** and adapted to be in communication therewith. The atomizing orifice is of one of the type heretofore described in this application, as for example, an elongated orifice which may be 0.010 inch in vertical dimension and 0.004 or 0.005 inch as in transverse dimension. Liquid coating material is kept under high hydrostatic pressure in the supply chamber **85** at all times during operation of the equipment, preferably by a circulating system wherein a pump delivers liquid coating material through a supply tube **86** and has such material returned through tube **87**. In accordance with known methods of recirculating while maintaining pressure, the return passage would be provided at some point with a restrictive orifice so related to the capacity of the supply pump that it can at all times maintain in the supply chamber **85** a desired operating pressure, as 1,000 pounds per square inch. A valve rod **88** has one end close to the inner end of the orifice **71** and its other (or right-hand end as viewed in FIGURE 5) mounted on the yoke **78** to be moved thereby, and provides means for interrupting the supply to the orifice, and for minimizing clogging. A suitable packing arrangement is provided to prevent loss of liquid from the supply chamber **85** while permitting reciprocation of the valve rod **88**, this being here shown as packing means **89** held in place by a gland nut **90**.

Average volume of flow from the jet orifice **71** in a given length of time, as one minute, is thus regulated by the amount of time during which the valve rod closes the orifice, relative to the amount of time during which the orifice is open to or in communication with the supply chamber. When the valve rod moves away from the orifice it substantially instantaneous (within a few thousands of an inch of valve rod movement) provides full connection between the high pressure liquid in the supply chamber and the orifice, resulting in immediate good quality atomization continuing for as long as such communication remains open.

Control of the effective rates of flow of the liquid coating material, the average volume atomized in a given length of time, is obtained by varying the relative duration between the period when the atomizing orifice is in open communication with the supply chamber and the period when such communication is interrupted. In order to effect this regulation, the cam **76** is movable along the splined shaft **75**, being moved to and held in a desired location by suitable adjustment means. The adjustment means is here shown as a bracket member **91** adapted to be moved by a threaded shaft **92**, threaded into the end **73b** of the main mounting bracket. Rotation of this threaded member **92**, as by use of a screw driver in the slot **92a** (which adjustment may even be effected during operation of the equipment by use of screw driver with a suitable insulating shank) changes the position of the cam along the splined shaft to provide an increase or decrease of the period of time when flow is permitted through the atomizing orifice **71** relative to the period of time during which such flow is interrupted. By opening communication with the orifice several times per second, as 5 times per second with the 300 r.p.m. rotation heretofore mentioned, satisfactory evenness of paint deposition may be secured on the article being coated, while at the same time substantial variation may be effected in the average volume of coating material being delivered.

In this regard, FIGURES 6A, 6B and 6C are representative of flow relationships which may be obtained. When the control cam is moved far down to the lower right (as viewed in FIGURE 3) until the section AA is in line with the cam following roller **79**, it will be seen in FIGURE 6A that liquid flow communication is kept open a large percentage of the time, so that the average volume of liquid coating material delivered would be about 85% of that which would be delivered if the jet were uninterrupted and operating at the same pressure. Referring next to FIGURE 6B and its associated graph, it will be seen that when the cam is in mid-position (as illustrated in FIGURE 4) the communication between the jet orifice **71** and the supply chamber **85** is open half of the time and closed half of the time, resulting in delivering an average volume of coating material which is half that which would be delivered by the same jet without any control means. FIGURE 6C shows the operative cam section and associated graph when only a very small flow is desired, communication between the atomizing orifice and the supply chamber being only about 15% of the time under these conditions. In each case the substantially instantaneous operation of the valve rod **88** provides a substantially square wave form, as illustrated, maintaining good uniformity and quality of atomization despite the periodic interruption. Moreover, the movement of the valve rod, and the ability to use a larger orifice at low delivery rates, avoids clogging of the nozzle by paint solids.

It will be apparent that this arrangement enables desired atomizing pressures (as 800 to 1000 pounds per square inch) to be maintained at all times in the supply chamber **85**; permits a wide range of control of the volume of coating material delivered by use of the control arrangement heretofore described; provides for continuous recirculation of coating materials requiring it; and eliminates clogging of the atomizing orifice.

Referring now to the embodiment of the invention illustrated in FIGURE 7, there is shown a spraying device **100** having a barrel **101** of insulating material. The barrel **101** is secured to a metal body **103** in a suitable manner and the body is electrically grounded. Extending through the body **103** and barrel **101** is an insulation covered lead line **104** connected to the hot terminal of a power pack (not shown) and by means of an electrical connection **105** to a resistor **106**. The resistor **106** may have a resistance of the order of 160 megohms, and is connected at its right-hand end to a contact member **106a** which in turn is connected to a fine wire electrode **107** having a terminal portion **108** which extends outwardly of an end cap **109** and nozzle plate **109a**, both of which may be of electrically insulating material, and lies closely adjacent but radially spaced from an orifice **110** from which the paint is expelled. The distance from the electrode terminal portion to the closest grounded gun part (the forward end of atomizer body **103**) is about six inches. It is preferred to use a slim electrode, one of no more than about 0.1 inch in diameter and most desirably one about .01 or .02 inch in diameter. The electrode is preferably pointed.

Like the orifices described in the other embodiments, the orifice **110** is formed in a nozzle member **126** of highly wear-resistant material such as tungsten carbide or diamond and has a .005 inch minimum or minor diameter, and a .015 inch major diameter, the combination producing an orifice approxiately equivalent to a circular orifice having a diameter of .009 inch.

Paint is delivered to the atomizer from a source (not shown) through a passage **111** in the atomizer body which connects to a longitudinally extending passage **112** in the barrel which is terminated by a valve seat **113** located at the end of the passage immediately adjacent nozzle **126** and communicating with the orifice **110**. The valve is controlled by the tapered end of a valve member **114** connected to an actuating rod **115** of insulating material, in turn connected to operating means not shown.

Paint under the high pressures previously described herein is supplied to the atomizer through passage **111** and emerges from the orifice **110** in the form of a fan-shaped film **121** as shown in FIGURES 8 and 9, which at a zone of atomization **122** breaks up into a fan-shaped spray **123** of atomized particles. Leakage of paint into the area of the barrel occupied by the resistor **106** is prevented by an O-ring **132** surrounding a fitting **133** through which the electrode contact member **106a** passes. Like the barrel **101**, valve actuator rod **115**, end cap **109** and nozzle plate **109a**, the fitting **133** is made of insulating material.

It will be noted from FIGURES 8 and 9 that the end **108** of electrode **107** is spaced from one surface of the film fan **121** and also terminates short of the zone of atomization **122**. Thus, the electrode wire is positioned out of the paint stream issuing from the orifice **110** and its terminal portion is located intermediate the orifice and the zone of atomization where the film breaks up into spray particles. In the particular embodiment illustrated, the exposed portion of the electrode is offset about ⅛ inch from the surface of the film and the terminal portion **108** is about ⅛ inch rearward of the zone of atomization **122**. It has been found that locating the electrode tip rearwardly of the zone of atomization in this embodiment provides more effective charging of the spray particles, and thus higher deposition efficiency than would be obtained if the electrode projected forwardly to or beyond the atomizing zone. Locating the electrode spaced from the film prevents electrical blunting of the electrode by the paint and also prevents the electrode from interfering with formation of the desired film and with the atomizing process. While one electrode is shown and is preferred for obtaining the best deposition efficiency, more than one electrode may be used. For example, satisfactory results have been obtained where two electrodes rather than one extend forwardly of the atomizer generally in a plane parallel to the face of the liquid film and terminate ⅛ inch rearwardly of the atomizing zone and are spaced ⅛ inch from the face of the liquid film and their terminal portions are spaced from each other about .05 inch.

The electrode **107** is maintained at high electrostatic potential by being connected in the manner described to a power pack so as to produce normally a potential on the electrode terminal portion **108** of the order of 50,000 volts. Inasmuch as the forward end of the atomizing gun **100** is adjacent the electrode **107** and is insulated from ground it acquires a potential normally substantially equal to the potential on the electrode **107** or, at least a pottential which differs from the potential on the electrode by not more than a small percentage (normally less than 10%) of the voltage applied to the electrode. Assuming a normal electrode-to-target spacing of ten inches, this would provide a field to the article with an average potential gradient of 5,000 volts per inch, and with the grounded atomizer body **103** spaced only about six inches rearwardly of the electrode terminal portion **108**, there would also be a field to the grounded body with an average potential gradient in excess of 8,000 volts per inch. The presence of the grounded atomizer body at a fixed and relatively short distance from the electrode has certain advantages. Being fixed, a minimum potential gradient is insured adjacent the electrode despite any variations in distance between the atomizer and the articles to be painted. The relatively short distance between the charging electrode and the grounded body makes it possible to achieve a high local potential gradient adjacent the electrode tip and hence effective charging of the atomized paint with a lower voltage applied to the electrode, and the use of a lower applied voltage in turn makes possible the use of a smaller and less expensive power pack and a lighter and more flexible high voltage lead line, the latter being of particular importance when the atomizer is to be hand operated. A further reduction in electrode potential can be achieved without serious loss in deposition efficiency by still further reducing the distance between the charging electrode and the grounded body. Very satisfactory results have been obtained with a device of this type providing an electrode-to-ground spacing of about three inches and operating with an electrode potential in the order of 25,000 volts.

Use of a spray-charging electrode like 107 in the apparatus shown in FIGS. 7–9 provides far more effective charging of the spray particles than has been found to be possible where the nozzle only is maintained at high voltage for the pupose of charging the film. An electrode like 107 can be used where the potential difference between such electrode and the article provides the sole charging field. This may be accomplished by eliminating grounded body portion 103, in which event the entire atomizing device may be of conducting material suitably isolated from ground. For most effective results, this arrangement requires quite high voltages to compensate for the greater distance between electrodes, the second electrode being the article. Also, in this arrangement if the distance between the electrode and the article varies appreciably, it is necessary to make a significant compensating voltage change in order to maintain consistent charging effectiveness. Satisfactory results can be achieved, however, with a constant applied voltage particularly when the atomizer to article distance does not vary over wide limits. In the arrangement shown in FIGS. 7–9, charging effectiveness is maintained reasonably consistent even if there are relatively large changes in the spacing between the atomizer and the article without making appreciable compensating voltage changes.

While I have shown and described certain embodiments of my invention, it is to be understood that it is capable of many modifications. For example, the atomizing devices, particularly device 100, can be adapted for use as a hand-held spray gun by forming the metal body 103 at the rear end of the gun to provide a handle. The use of the resistor 106 is particularly advantageous in a hand-held gun as it serves to limit the intensity of any electrical discharge which would occur upon approach of the electrode 107 to any grounded object or any portion of the operator's body, and thereby reduces fire and shock hazards. Where reduction of such hazards is important, it is advisable to make the contact member 106*a* and the electrode 107 as small as possible in order to reduce their electrical capacitance. For the same reason, it may be desirable to make the nozzle member 126, the valve seat 113, and at least the forward end of the valve member 114 of insulating material. If the forward portion of the gun is made of conducting material the foregoing hazards will not be eliminated.

I claim:

1. The method of electrostatically spray-coating an article which comprises continuously supplying liquid coating material under high hydrostatic pressure of at least two hundred fifty pounds per square inch to a small orifice in a single-fluid atomizing head, said orifice having an effective opening equivalent to a circular orifice of not greater than about fifteen thousandths of an inch in diameter, projecting the coating material therefrom into the surrounding atmosphere with a very high velocity, the coating material forming a thin expanding film with generally straight sides defining an angle of at least 15° and having a forward edge, the thickness of said film being less than the transverse extent thereof throughout the length of said film, to effect atomization of the coating material from said edge into fine spray particles, the distance of the center of said film edge from said orifice being not in excess of about three-quarters of an inch, whereby the particles are of a size providing on deposition a spray spot size of not greater than of the order of twenty thousandths of an inch in diameter, effecting relative movement between said head and the article surface transverse to the general direction of spray particle movement while maintaining the space between the article and said head great enough to permit substantial dispersion of the spray particles and at least several inches, maintaining a quiescent atmosphere adjacent the article, and providing an electrostatic charging field having an average gradient of the order of five thousand volts per inch electrostatically to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, the relative movement being such as to effect a substantial displacement between the article surface and head transverse to the general direction of spray particle movement during particle deposition.

2. A method of the character claimed in claim 1 wherein the coating material is projected in a thin hollow conical film.

3. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice, projecting the coating material therefrom into the surrounding atmosphere with a very high velocity as a thin expanding fan-like film with generally straight sides defining an angle of at least 15° and having an edge, said pressure being great enough that the projection of said film from said orifice to said edge is not in excess of an inch, and said film having a thickness less than its width throughout the length thereof, to effect atomization of the coating material from the film edge into fine spray particles of a size providing on deposition a spray spot size of less than twenty thousandths of an inch in diameter, effecting relative movement between said head and the article surface transverse to the general direction of spray particle movement while maintaining the space between the article and said head great enough to permit substantial dispersion of the spray particles and at least several inches, maintaining a quiescent zone in the atmosphere adjacent the article, and providing an electrostatic field having an average gradient of the order of ten thousand volts per inch extending between the article and the edge of said film electrostatically to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, the movement of said article being such as to effect a substantial displacement of the article surface transverse to the general direction of spray particle movement during particle deposition.

4. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice in a single-fluid atomizing head, projecting the coating material therefrom into the surrounding atmosphere with a very high velocity as a thin fan-like film having an edge and substantially straight sides with an included angle of at least 25°, said pressure being at least three hundred pounds per square inch and sufficient that the length of the film from said orifice to said edge is less than one inch, to effect atomization of the coating material from the film edge into fine spray particles of a size providing on dep-

osition a spray spot size not larger than about .020 inch, effecting relative movement between said head and the article surface transverse to the general direction of spray particle movement while maintaining the space between the article and said head great enough to permit substantial dispersion of the spray particles and at least several inches, maintaining a quiescent zone in the atmosphere adjacent the article, and providing an electrostatic field having an average potential gradient of at least five thousand volts per inch electrostatically to charge and to carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, the relative movement being such as to effect a substantial displacement between the article surface and head transverse to the general direction of spray particle movement during particle deposition.

5. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice and projecting the coating material therefrom into the surrounding atmosphere as a thin expanding fan-like film having an edge and substantially straight opposite sides which diverge to define an angle of at least 15°, said pressure being sufficient that the length of said thin expanding film to said edge is no more than approximately one inch, to effect atomization of the coating material from the film edge into fine spray particles which when deposited have a spray spot size no greater than of the order of .020 inch, maintaining a quiescent zone in the atmosphere adjacent the article, the distance of the article from the orifice being sufficient to permit substantial dispersion of the spray particles and at least several inches, providing an electrostatic charging field extending from a terminus between said orifice and the edge of said film and between the sides of the film, said field having an average potential gradient of at least five thousand volts per inch, electrostatically to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, and effecting relative movement between the orifice and the article surface transverse to the general direction of spray particle movement during particle deposition.

6. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice having an effective opening equivalent to a circular orifice of not greater than fifteen thousandths of an inch in diameter and projecting the coating material therefrom into the surrounding atmosphere with a very high velocity as a thin expanding film having an edge and generally straight diverging sides which define an angle of at least 15°, said pressure being at least three hundred pounds per square inch and sufficient that the length of said thin expanding film to the center of said edge is no more than approximately one inch, to atomize the coating material from the film edge into fine spray particles which when deposited have a spray spot size no greater than of the order of .020 inch maintaining a quiescent zone in the atmosphere adjacent the article, the distance of the article from the orifice being sufficient to permit substantial dispersion of the spray particles and at least several inches, providing an electrostatic field extending from an electrode adjacent the film to the article having a total potential difference of at least twenty-five thousand volts electrostatically to affect charging and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, and effecting relative movement between the orifice and the article surface transverse to the general direction of spray particle movement during particle deposition.

7. The method of claim 6 wherein said field extends from a substantialy point-like terminus.

8. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice and projecting the coating material therefrom into the surrounding atmosphere with a very high velocity as a thin expanding film having substantially straight diverging sides defining an angle of at least 15° and a forward edge, said pressure being sufficient that the projection of said film from said orifice to said edge is between about 1% and 10% of the distance of the article from the orifice but in no event in excess of one inch, to effect atomization of the coating material from the film edge into fine spray particles of a size providing on deposition a spray spot size no greater than .020 inch, maintaining a quiescent zone in the atmosphere adjacent the article, the distance of the article from the orifice being sufficient to permit substantial dispersion of the spray particles and at least several inches, providing an electrostatic field to the article having a total potential difference of at least twenty five thousand volts electrostatically to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, and effecting relative movement between the orifice and the article surface transverse to the general direction of spray particle movement during particle deposition.

9. The method of claim 8 wherein said field is provided from a terminus located between said orifice and the edge of said film.

10. The method of electrostatically spray-coating an article which comprises supplying liquid coating material under high hydrostatic pressure to a small orifice and projecting the coating material therefrom into the surrounding atmosphere with a very high velocity as a thin expanding film with substantially straight diverging sides which defines an angle of at least 15° and a forward edge, said pressure being sufficient that the distance from said orifice to said edge is no more than one inch, the thickness of the film at said edge being substantially less than the extent of such edge, to atomize the coating material from the film edge into fine spray particles which upon deposition on said article provide a spray spot size no greater than of the order of .020 inch, frequently interrupting the supply of coating material to said orifice for regulating the average rate of coating material delivery therefrom, maintaining a quiescent zone in the atmosphere adjacent the article, the distance of the article from the orifice being sufficient to permit substantial dispersion of the spray particles, providing an electrostatic field to the article having a total potential difference of at least forty thousand volts electrostatically to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, and effecting relative movement between the orifice and the article surface transverse to the general direction of spray particle movement during particle deposition.

11. Apparatus for electrostatically spray-coating an article comprising: a single-fluid atomizing device having therein means defining a small elongated orifice with a ratio of length to width of at least 2 and so formed that liquid supplied under high hydrostatic pressure to said orifice will be ejected therefrom as a thin expanding fan-like film having an edge and almost exactly straight sides with an included angle of at least 15°; means for supplying liquid coating material to said orifice under hydrostatic pressure so high that the length of the film to the center of said film edge is no greater than about one inch and that the coating material is atomized from the film edge into fine spray particles having a size providing on deposition a spray spot size of not greater than of the order of twenty thousandths of an inch in diameter; and a high voltage power pack connected to said

atomizing device providing an electrostatic field having an average gradient of at least five thousand volts per inch extending between said atomizing device and the article to be coated, electrostatically to affect deposition on said article while still in liquid state of a substantial portion of the spray particles which would not otherwise have been deposited thereon.

12. Apparatus of the character described in claim 11 wherein said atomizing device includes a slender electrode connected with said high voltage power pack and having a terminal portion disposed in a position spaced from but close to one face of said film but between the sides of said film.

13. Apparatus for electrostatically spray-coating an article, comprising: a single-fluid atomizing head having therein means defining a small elongated orifice with a maximum dimension not greater than about fifteen thousandths of an inch; means for supplying liquid coating material to said orifice under high hydrostatic pressure well in excess of three hundred pounds per square inch, to effect projection of the coating material from said orifice means into the surrounding atmosphere at a rate of less than about four hundred cubic centimeters per minute but with a very high velocity, said orifice means having a configuration such that said coating material is projected as a thin expanding film having substantially straight sides with an included angle of at least 15° and a forward edge from which coating material is atomized into fine spray particles of a size providing on deposition a spray spot size of less than about twenty thousandths of an inch; means for frequently interrupting the supply of coating material to said orifice for regulating the volume of liquid coating material atomized from said orifice in a given length of time; means for moving the article through quiescent atmosphere along a path such that the distance of the article from said orifice when the path intersects the axis of the orifice is great enough to permit substantial dispersion of the spray particles; and a high voltage power pack providing an electrostatic depositing field having a total potential difference of at least forty thousand volts extending from said orifice means to the article to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, the movement of said article being such as to effect a substantial displacement of the article surface transverse to the general direction of the lines of force of the field during particle deposition to cause such lines of force to sweep such article surface.

14. Apparatus for electrostatically spray-coating an article comprising: a single-fluid atomizing head having therein means defining a small elongated orifice having an effective opening equivalent to a circular opening not greater than about .015 of an inch in diameter and so formed that liquid supplied under high hydrostatic pressure to the orifice will be ejected therefrom as a thin expanding film having an edge and substantially straight sides defining an angle of at least 15°; means for supplying liquid coating material to said orifice under hydrostatic pressure so high that the length of the film to the center of said film edge is no greater than about one inch and that the coating material is atomized from the film edge into fine spray particles having a size providing on deposition a spray spot size of not greater than about .020 of an inch in diameter; means for moving the article through quiescent atmosphere along a path such that the distance of the article from said orifice when the path intersects the axis of the orifice is great enough to permit substantial dispersion of the spray particles; a thin wire electrode mounted on the atomizing head and extending forwardly therefrom in the direction of ejection of said film adjacent but spaced from one face of said film and between the sides thereof; and a high voltage power pack connected to said electrode for providing an electrostatic field having a potential gradient of at least 5,000 volts per inch for charging the atomized particles to charge and carry through said quiescent atmosphere and deposit on said article while still in liquid state a substantial portion of the spray particles which would not otherwise have been deposited thereon, the movement of said article being such as to effect a substantial displacement of the article surface transverse to the general direction of spray particle movement during particle deposition.

15. Apparatus of the character described in claim 14 wherein the electrode has a terminal portion and the spacing between the terminal portion and the extension of the orifice axis is less than the distance between the terminal portion and the orifice.

References Cited by the Examiner

UNITED STATES PATENTS

2,302,289	11/47	Bramston-Cook.	
2,491,889	12/49	Bennett et al.	
2,685,536	8/54	Starkey et al.	117—93.4
2,710,773	6/55	Sedlacsik	239—15

RICHARD D. NEVIUS, *Primary Examiner.*