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[54] **ELECTROSTATIC SPRAY COATING APPARATUS**

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[51] **Int. Cl.** **B05b 5/00**
[58] **Field of Search**...239/15

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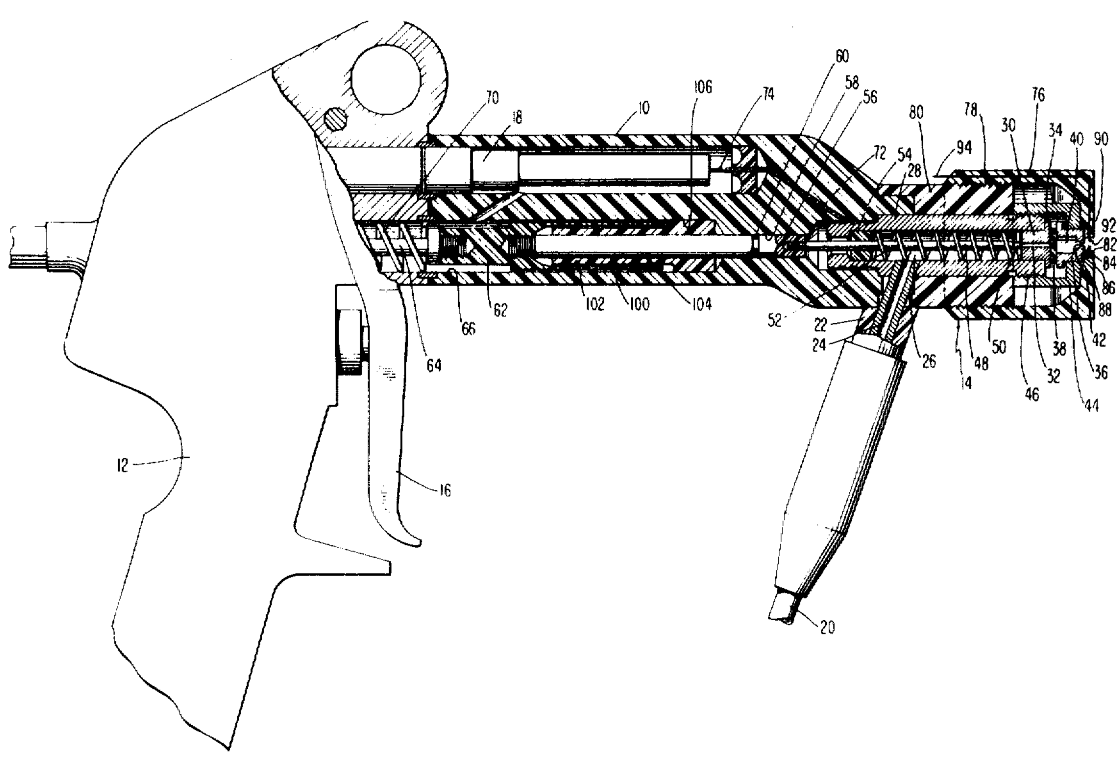
[57] **ABSTRACT**

Improved methods and apparatus for charging atomized coating materials and maintaining an electrostatic depositing field in the electrostatic deposition of coating materials. Improved charging is effected by the selectively directed passage of corona discharge current from a primary source thereof through emitted coating material intermediate its point of emission and its locus of atomization to an electrically floating electrode element whose collection potential is maintained by a corona discharge emanating from an exposed end thereof.

9 Claims, 4 Drawing Figures



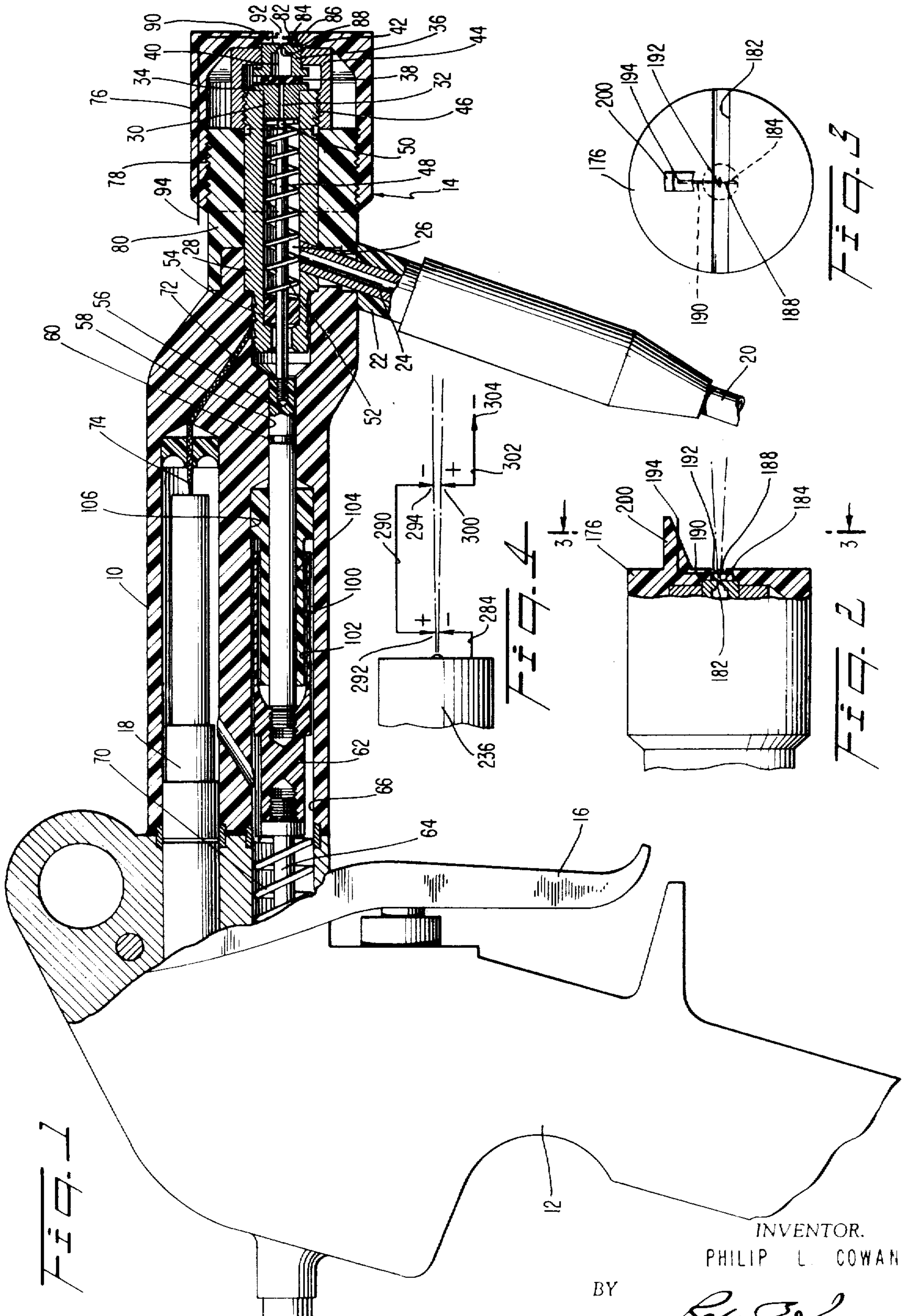


FIG. 1 FIG. 2 FIG. 3 FIG. 4

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ELECTROSTATIC SPRAY COATING APPARATUS

This invention relates to electrostatic spray coating systems and particularly to improved methods and apparatus for effecting the electrical charging of atomized fluids and maintenance of electrostatic deposition fields therefor.

The electrostatic deposition of liquid coating materials, such as paint, is widely employed in the commercial finishing field for the production of satisfactory surface finishes. Such electrostatic deposition conventionally requires the maintenance of an electrostatic depositing field intermediate the article to be coated and the remotely emitted coating material and the concurrent presence of an electrical charge on the particles of the atomized coating materials. Although many expedients have been employed over the years to effect such requisites, preferred variants, at least in those systems wherein atomization if effected by interaction of the coating fluid with air, include the utilization of an elongate corona discharge needle electrode disposed closely adjacent to or within the atomization zone or, in cases where the degree of electrical conductivity of the coating fluid permits, the direct charging of the fluid emitting orifice or passage. Although the utilization of a slender corona discharge electrode located closely adjacent to or within the atomization zone provides relatively efficient spray charging essentially independent of the electrical conductivity of the paint, commercial utilization thereof and particularly in hand spray guns and the like, is subject to decreased operational efficiencies resulting from undesired accumulation of the coating fluid thereon and to an undue degree of physical degradation because of bending and even breakage of the needle electrode due to their necessarily exposed positioning.

The present invention may be briefly described as improved methods and apparatus for electrically charging the atomized fluid particles and maintaining an electrostatic depositing field therefor in spray coating systems wherein atomization is effected by interaction of the coating fluid with air and which includes, in its broader aspects, the preferential directing of a corona discharge current emanating from a high potential primary corona discharge zone through the moving coating material, collecting of said corona discharge current in electrical isolation at a high potential less than that of the high potential primary corona discharge zone and the maintaining of such high collection potentials by discharge of the collected current through a tertiary corona discharge zone disposed remote from electrical ground. In its more narrow aspects, the subject invention generally includes as an improved construction for electrostatic spray device incorporating an atomizing nozzle assembly defining a point of hydraulically induced fluid emission and an externally adjacent locus of atomization disposed within a channel formed by surrounding insulating material, a primary charging zone located within said channel defined by a selectively positioned primary corona discharge electrode element and one exposed terminal end of an electrically floating electrode element at a particle attracting potential relative thereto disposed downstream thereof that preferentially directs current flow through the moving coating material in a path substantially transverse to the direction of displacement thereof. Associated therewith is the preferred incorporation of an air operable electrogasdynamic power generator in proximity to the atomizing nozzle assembly with its high voltage output terminal electrically connected with said primary corona discharge electrode element in conjunction with a permitted selective disposition of the free exposed end of the floating electrode element to maintain high potential thereon through a tertiary corona discharge therefrom.

Among the advantages of the subject invention is the permitted attainment of enhanced degrees of spray charging in commercially utilizable units and maintenance thereof for extended periods of time through minimization, if not through effective avoidance, of the electrode degradation and breakage characteristic of conventionally constructed units.

The primary object of this invention is the provision of improved methods and apparatus for effecting the electrical charging of atomized fluids and the maintenance of electrostatic depositing fields therefor in electrostatic spray coating systems wherein the coating fluids are atomized by interaction with air.

Other objects and advantages of the subject invention will become apparent from the following portions of this specification and from the appended drawings which illustrate, in accord with the mandates of the patent statutes, the principles of this invention as embodied in a presently preferred construction of an "airless" type of spray gun adapted for use in electrostatic spray painting system.

Referring to the drawings:

FIG. 1 is a side elevation, partially in section, of a so-called "airless" type of hand spray gun constructed in accord with the principles of this invention;

FIG. 2 is a fragmentary vertical sectioned view of the fluid emitting end of a spray gun type shown in FIG. 1 and illustrating an alternate electrode configuration;

FIG. 3 is an end elevation as taken on the lines 3—3 of FIG. 2; and

FIG. 4 is a schematic view of another electrode configuration utilizable in spray guns of the type shown.

Referring to the drawings and initially to FIG. 1, there is generally illustrated an electrostatic hand spray gun of the so-called "airless" type incorporating an electrogasdynamic high voltage generator as an integral power source therefor. While the particular construction shown effects atomization of the paint or other fluid by impacting a submerged high speed low pressure fluid jet on a small selectively shaped orifice to form an expanding coherent fan-shaped film of fluid which atomizes through interaction with air at its forward edge, as disclosed in Levey et al. U.S. Pat. No. 3,000,576, it will be apparent to those skilled in this art that the principles of this invention can be employed with equal facility in spray guns of the so-called air atomizing type, as for example in a preferred construction therefor as described in my copending application Ser. No. 788,148, filed Dec. 31, 1968 and now U.S. Pat. No. 3,645,447.

In more particularity, the illustrated hand gun includes a selectively configured insulating barrel portion **10** having a pistol grip type of conducting handle portion **12** and a fluid release actuating trigger **16** mounted at one end thereof and an atomizing nozzle and charging assembly, generally designated **14**, at the other end thereof. Disposed within the barrel portion **10** is a self-contained electrogasdynamic high voltage generator, generally designated 18, having its operating air introduced and vented through the botton of the handle 12. The details thereof and of the associated air assisted trigger assembly form no part of this invention and are disclosed in my copending application Ser. No. 35,428, filed May 7, 1970 now U.S. Pat. No. 3,653,592.

Suitable fluid coating material, such as paint, is introduced into the atomizing nozzle assembly of the gun through a paint supply line 20 connected to a suitable fitting 22 disposed on the underside of the barrel portion 10 and which contains an inlet duct 24 of electrically conducting material. The fluid inlet duct 24 is in direct fluid communication with the bore 26 of a generally cylindrically shaped sleeve member 28 mounted in the forward end of the barrel 10 and formed of conducting material and which serves as a temporary coating fluid reservoir or chamber. Threadedly mounted in the forward end of the sleeve member 28 is a conducting valve plug member 30 having a longitudinal bore 32 of a sufficiently large diameter to accommodate a low resistance flow of fluid therethrough. Positioned forwardly of the plug 30 and disposed in fluid communication therewith through a preorifice gasket assembly 34, is a selectively shaped orifice member 36. As shown, the pre-orifice gasket assembly 34 includes a small diameter passage 38 disposed in longitudinal alignment with the bore 32 opening into an enlarged bore or chamber 40 that forwardly terminates in a selectively contoured orifice 42 that controls the shape of the emitted fluid, preferably in the form of a coherent flat fan shaped film or a coherent hollow cone or the like, which, through interaction with the air downstream of the orifice 42, is atomized into a spray of discrete droplets. The general area within which the emitted coherent fluid film is converted into a spray of discrete droplets is conveniently defined herein as the "locus of atomization."

The orifice member 36 is positioned in longitudinally coaligned and compressively assembled relation with the pre-orifice assembly 34 and valve plug 30 by a conducting cap member 44 threadedly engageable, as at 46, with the extending forward end of the sleeve member 28.

Flow of liquid coating fluid through the above described nozzle assembly is controlled by a displaceable valve rod 48 within the sleeve 28 and whose forward end 50 is normally biased by the spring 52 in sealing relation with a valve seat surface at the entry to the bore 32 of the valve plug 30. The valve rod 48 extends rearwardly through a packing gland or ring 54 mounted in the rear of the bore 26 and is terminally connected to a connecting rod 56 of insulating material slidably disposed within the bore 58 in the barrel portion 10 of the gun. A second liquid seal element, suitable an O-ring 60, is included to minimize, if not preclude, coating liquid leakage at the interface of the rod 56 and bore 58. The rearward end of the rod 56 is connected to actuating rod element 64 forming a component of the trigger assembly through an intermediate insulating coupling element 62 slidably disposed within an enlarged bore 66 within the barrel portion 10 and coaxial with the bore 58.

In operation of the above described elements, actuation of the trigger 16 results in a conjoint retractive displacement of the rod 64, coupling 66, connecting rod 56 and valve rod 48 against the action of the biasing springs 52 and 70 and in an opening of the bore 32 in the valve plug 30. The high pressure fluid in the reservoir 26 flows outwardly through the bore 32 and is accelerated into a small diameter high speed and low pressure fluid jet by passage through the aperture 38 in the pre-orifice assembly 34. This small diameter high speed and low pressure fluid jet passes in submerged condition through the coating liquid accumulated in the chamber 40 in the orifice member 36 and impacts on the defining surfaces of the orifice 42 with a portion thereof passing through the aperture therein. As previously pointed out, the orifice 42 is preferably contoured to effect the emission of the coating liquid as a coherent and generally flat, fan shaped film or as a flattened hollow cone, which, through interaction with air a short distance downstream from the orifice, is converted into a spray of discrete droplets of coating material.

The inlet duct 24, sleeve member 28, valve plug 30, valve rod 48, orifice member 36 and assembly cap 44 are all desirably formed of suitable electrically conducting metal and are adapted to be charged to a high electrical potential, preferably negative, through the conductor 72 embedded in the insulating barrel 10 of the gun and connected to the high voltage output or collector electrode 74 of the electrogasdynamic generator 18. Because of the high potential applied to the nozzle assembly components, the forward end of the gun includes an insulating cap member 76 which is threadedly mounted, as at 78, on a barrel extension member 80, also formed of insulating material. The insulating cap member 76 serves to shroud the nozzle assembly components at the forward end of the gun and defines a relatively small channel 82 disposed in coaxial alignment with the orifice 42. The channel 82 is desirably of a length sufficient to extend slightly beyond the locus of atomization of the liquid coating material emitted from said orifice 42 and of a transverse extent sufficient to locate the defining walls thereof out of the path of the emitted coating material, so as to effectively avoid undesired coating material deposition on the surfaces thereof.

Mounted within the channel 82 defined by the insulating cap member 76 is a first or primary corona discharge electrode element 84 having one end 86 disposed in electrical contact with the orifice member 36 and its other terminal end portion 88, suitably of needle-like configuration, exposed and extending outwardly into the channel 82 intermediate the point of fluid emission from the orifice 42 and the locus of effectively complete atomization thereof. The exposed terminal end portion 88 extends outwardly into the channel 82 only for a short distance so as to be out of the path of any direct contact by the emerging fluid. Since the primary electrode element 84 is in electrical contact with the high potential output, preferably negative, of the electrogasdynamic generator 18 through the conductive components of the nozzle assembly, a negative corona discharge will be emitted from the exposed terminal end 88 thereof adjacent to the emerging fluid.

Also mounted within the insulating cap member 76 is a second and electrically floating electrode element, generally designated 90. The floating electrode element includes a first exposed terminal end portion 92 disposed in the channel 82 in relatively close proximity with, but essentially downstreams of, and in substantially diametrically opposed relation to the exposed terminal end 88 of the primary corona discharge electrode element 84. The first exposed terminal end portion 92 may suitably constitute a plate-like element disposed flush with the surfaces of the channel defining wall portion of the cap member 76 or may comprise a needle-like configuration extending outwardly into the channel 82. In this latter instance, the exposed terminal end should only extend into the channel 82 a short distance so as not to be directly contacted by the moving fluid. The above specified positioning for the first exposed terminal end portion 92 functions to preferentially direct at least the major portion of the corona discharge current flow from the exposed terminal end 88 of the primary corona discharge electrode element 84 to the first exposed terminal end portion 92 of the floating electrode element 90 through the emitted coating fluid and in a direction that is substantially transverse or normal to the direction of fluid flow. In operations where an extending needle-like configuration is employed for the first exposed terminal end portion 92 of the electrically floating electrode element 90, a relatively bright glow is readily observed about the exposed needle-like terminal end 92 adjacent to the passing coating material and such glow is believed to comprise an induced positive corona caused by the presence of a negatively charged terminal end 88 of the primary corona discharge electrode element 84 and by the above described current flow therebetween. Although the positive ions, that result from such induced secondary corona discharge should theoretically tend to neutralize some of the negative charge applied to the passing coating material through the primary electrode terminal 88, an overall increase in the effective charging results due to the apparent selective action of the exposed terminal end 92 of the floating electrode 90 in directing a fluid traversing corona discharge current flow from the primary corona discharge electrode 84 at substantially right angles to and through the moving spray and/or coherent film of emitted coating material.

As shown in FIG. 1, the other terminal end 94 of the floating electrode element 90 which is also desirably of a needle-like configuration also extends beyond the insulating cap 76 and may be positioned to extend rearwardly from the base flange portion of the insulating cap member 76 in the open air. The above described corona discharge current flowing from the exposed terminal end 88 of the primary corona discharge electrode element 84 across the fluid flow path and collected by the floating electrode 90 effectively emanates as a tertiary corona discharge at the second exposed terminal end 94 thereof and in a current flow therefrom to ground. Such tertiary corona discharge from the second exposed terminal end 94 of the electrically floating electrode element 90 serves, when such end 94 is suitably located, to effectively maintain a high collecting potential on the floating electrode which, however, is less that the potential on the primary corona discharge electrode element 84.

In order to assure the continuity of the selectively directed passage of a major portion of the corona discharge current emanating from the primary corona discharge electrode element 84 in series through the moving emitted coating material and to the electrically floating electrode element 90 and to assure the maintenance of a depositing field between the gun and workpiece of an appreciable strength exposed terminal end portion 94 thereof should be positioned relative to electrical ground so that the potential difference therebetween is substantially greater in magnitude than the potential difference between the primary corona discharge electrode element 84 and the electrically floating electrode element 90. Stated in somewhat different terms, such second exposed terminal end portion 94 should be disposed relative to electrical ground so that the impedance therebetween is substantially greater than the impedance intermediate the primary corona discharge electrode element 84 and the electrically floating electrode element 90. In commercial apparatus embodiments that incorporate the principles of this invention, the physical distance between the second exposed terminal end 94 of the electrically floating electrode element 90 to the nearest electrical ground, as for example the metallic handle portion 12, when the latter is grounded, should also preferably be not less than 10 percent of the distance between said exposed terminal end portion 94 and the workpiece being coated.

In the specifically illustrated embodiment, the self-contained air operable electrogasdynamic generator 18 inherently functions as a constant current type of power supply with the level of current flow being dependent upon the pressure of the operating air supply therefor. As such, the operating voltage at the forward end of the gun will be essentially determined by the product of the current flowing from the electrogasdynamic generator 18 and the overall impedance to ground of the combined electrode array. The operating voltage may thus, to a large extent, vary with the air supply pressure to the electrogasdynamic generator 18 and with the proximity of the forward end of the illustrated gun to both a grounded workpiece being coated and to the grounded handle portion 12. While other methods of maintaining a high impedance from the free end 94 of the floating electrode 90 to ground might be employed with equal effectiveness, as for example by the inclusion of a multi-megohm resistor, between the end 94 and ground, the illustrated corona discharge technique, as disclosed above, is compact and particularly well suited to the variable performance characteristics of the illustrated electrogasdynamic generator type of power supply under changing airflow conditions.

In order to effectively maintain the above described high impedance to ground for all components subjected to high potential, an elongation of the possible leakage path intermediate the valve rod 48 and the conducting elements of the trigger assembly is desirably included through a selective contouring of the intermediate coupling member 62. As illustrated, the intermediate coupling member 62 is provided with an elongate sleeve portion 100 defining a bore 102 sized to receive and contain an elongate insulating sleeve portion 104 having its remote forward end disposed effectively integral with the barrel portion, as at 106, and slidably containing the connecting rod member 56 therewithin. As will be apparent, the possible leakage path from the rearward end of the conducting valve rod 48 to the conducting members of the trigger assembly must effectively traverse the full length of the insulating connecting rod member 56, the inside surface of the sleeve 100 and the full length of the bore 66 from the terminal end of the sleeve 100 to the nearest conducting element in the trigger assembly. The increased air gap length presented by such elongated leakage path cooperates to assure the maintenance of desirable high impedance to ground for all portions of the charging assembly that are maintained in a high operating potential.

FIGS. 2 and 3 illustrate an alternative construction for the insulating cap member and for the electrode elements associated therewith. As there only fragmentarily illustrated and with component elements corresponding to those set forth on FIG. 1 bearing the same reference numeral increased by 100, the insulating cap member 176 that shrouds the forward end of the gun defines a relatively small channel 182 having a primary corona discharge electrode element 184 mounted therewithin with its exposed needle-like terminal end portion 188 extending outwardly into the channel 182 as described earlier. The insulating cap member 176 is selectively shaped to include a forwardly extending arm portion 200 adapted to contain the major body portion of the electrically floating electrode element 190. The first exposed terminal end 192 thereof, either in the form of a nonprotuding plate or an extending needle-like element is disposed in the channel 182 in close proximity with, downstream of and in substantially diametrical fluid traversing relation to the exposed terminal end 188 of the primary corona discharge electrode element 184. In contradistinction to the FIG. 1 embodiment, the second exposed and needle-like terminal end 194 of the floating electrode element 190 is forwardly directed and extends a short distance outwardly from the bevelled end of the extending arm portion 200 and in the general direction of the workpiece being coated. When so located, the tertiary corona discharging end 194 of the floating electrode element 190 is disposed adjacent the expanding spray of atomized coating material and forward of the locusof atomization thereof and the corona discharge therefrom, which is of similar polarity to that emanating from the primary corona discharge electrode element 184 will here serve to augment the charge already applied to the coating material by the fluid traversing current flow between electrode elements 188 and 192 disposed within the channel 182.

FIG. 4 schematically illustrates a further embodiment incorporating some of the principles of this invention and in which similar elements previously illustrated and described will bear similar reference numerals increased by 200. As there schematically set forth, there is provided a primary corona discharge electrode element 284 connected to a negative source of high potential, conveniently a fluid emitting orifice member 236. Disposed in close proximity to the exposed terminal end of the electrode element 284, but slightly downstream thereof and in substantially fluid traversing diametrically opposed relation thereto is the terminal end 292 of an electrically floating electrode element 290. In this embodiment, however, the second exposed end 294 of the floating electrode element 290 is disposed downstream and in general proximity to the path of advance of emitted coating material. Disposed in substantially diametrically opposed and fluid traversing relation with the exposed terminal 294 and preferably slightly downstream thereof is the first exposed terminal end 300 of a second electrically floating electrode element 302. The second exposed and corona emitting end 304 of the floating electrode element 302 is disposed further downstream and in the direction of the workpiece being coated.

As will now be apparent to those skilled in this art, the subject constructions provided for the directed flow of the major portion of the corona discharge current through the emitted coating fluid in the vicinity of the locus of atomization thereof which effects an enhanced charging of the particles of atomized coating materials and for the concurrent maintenance of the requisite electrostatic depositing field. For optimum operation, the exposed portions of the electrode elements located within the channels (82, 182) are desirably located in sufficiently close proximity to the fluid emitting orifice (42, 142) so as to permit the inertial energy of the emerging fluid stream to prevent electrostatic deposition of coating material thereon. While the requisite positioning thereof in the channel will depend in large part upon the character of the coating fluid being employed and the operating parameters of a given system, experiments have indicated that the exposed terminal end of the primary corona discharge electrode element is preferably located intermediate the fluid emitting orifice and the locus of complete atomization and most suitably within three-eighths inch of the orifice. In most instances, locations of the exposed end of the primary corona discharge elements about one-eighth inch from the fluid emitting orifice will produce optimum results.

As will also now be apparent to those skilled in this art, the application of the principles of this invention not only result in highly efficient charging of the particles of coating material and maintenance of an electrostatic deposing field, but also inherently provide a construction which permits the selective location of the material charging electrode elements within a protective surrounding housing of non-conducting material that minimizes, if not effectively prevents, degradation and breakage of the needle-like electrode tips.

Having thus described my invention, I claim:

1. In a fluid spray coating system wherein the coating fluid is atomized by interaction with a gaseous medium, an improved construction for electrically charging the atomized fluid spray and maintaining an electrostatic depositing field therefor, comprising

an atomizing nozzle assembly defining a point of emission of a coherent fluid stream and an externally adjacent locus of atomization therefor,

insulating means defining a channel disposed in surrounding relation to said locus of atomization and through which the fluid moves after release from the point of emission thereof,

a primary corona discharge electrode element mounted in said insulating means and having an exposed terminal end portion extending into said channel intermediate the point of fluid emission and the point of complete atomization thereof,

an electrically floating electrode element mounted in said insulating means having a first exposed terminal end portion in said channel and selectively positioned in relatively close proximity with the exposed terminal end portion of said primary corona discharge electrode element so as to preferentially direct fluid traversing current flow thereto from said exposed end portion of said primary corona discharge electrode element and in a direction substantially transverse to the direction of fluid flow through said channel, and

having a second exposed terminal end portion positioned so that the distance to the nearest electrical ground is not less than **10%** of the distance between said terminal end portion and a workpiece being coated and adapted to dissipate energy as a corona discharge emanating therefrom of a like polarity to that emanating from said exposed terminal end portion of said primary corona discharge electrode element for maintaining a continuous flow of current between said primary corona discharge electrode element and said electrically floating electrode element.

2. The construction as set forth in claim **1** wherein said first exposed terminal end portion of said electrically floating electrode element extends into said channel and is shaped to produce a corona discharge of opposite electrical polarity from that emanating from said exposed terminal end portion of said primary corona discharge electrode element.

3. The construction as set forth in claim **1** wherein the exposed terminal end portion of said primary electrode element and the first exposed terminal end portion of the electrically floating electrode element extend into said channel for a limited distance so as to be out of the path of direct impingement with the major portion of the flow of fluid therepast.

4. The construction as set forth in claim **1** including gas operable electrogasdynamic power generating means disposed in proximity with said atomizing nozzle assembly and having its output voltage terminal electrically connected with said primary corona discharge electrode element.

5. The construction as set forth in claim **1** wherein said atomizing nozzle assembly is insulatingly spaced from a groundable base assembly and the second exposed terminal end portion of said floating electrode element is positioned relative to the nearest electrical ground such that the potential difference therebetween is substantially greater than the potential difference between said primary corona discharge electrode element and said electrically floating electrode element.

6. The construction as set forth in claim **1** wherein the second exposed terminal end portion of said floating electrode element is disposed downstream of the first exposed terminal end portion thereof and in proximity to the path of advance of the atomized coating material.

7. The construction as set forth in claim **1** wherein said first exposed terminal end portion of said floating electrode element is disposed in relatively close proximity with and in substantially diametrically opposed relation to the exposed terminal end portion of said primary electrode element.

8. In a fluid spray coating system wherein the coating fluid is atomized by interaction with a gaseous medium, an improved construction for electrically charging the atomized fluid spray and maintaining an electrostatic depositing field therefor, comprising

an atomizing nozzle assembly defining a point of emission of a coherent fluid stream and an externally adjacent locus of atomization therefor,

a primary corona discharge electrode element having a high potential exposed terminal end portion disposed in proximity to the point of fluid emission,

an electrically floating electrode element having a first exposed corona discharge terminal end portion at a particle attracting potential relative to that of said exposed terminal end of said primary corona discharge electrode element positioned in proximity therewith so as to preferentially direct fluid traversing current flow therefrom in a direction substantially transverse to the direction of fluid flow, and

having a second exposed terminal end portion positioned so that the distance to the nearest electrical ground is not less than **10%** of the distance between said terminal end portion and a workpiece being coated and adapted to dissipate energy as a corona discharge emanating therefrom of a like polarity to that emanating from said exposed terminal end portion of said primary corona discharge electrode element for maintaining a continuous flow of current between said primary corona discharge electrode element and said electrically floating electrode element.

9. In a fluid spray coating system wherein the coating fluid is atomized by interaction with a gaseous medium, an improved construction for electrically charging the atomized fluid spray comprising

an atomizing nozzle assembly defining a point of emission of a coherent fluid stream and an externally adjacent locus of atomization therefor,

a primary corona discharge electrode element having an exposed terminal end portion disposed in proximity to the point of fluid emission,

at least one electrically floating electrode element disposed downstream of said exposed terminal end of said primary corona discharge electrode element and through which a major proportion of the current emanating from said primary corona discharge electrode element flows in series subsequent to traversal of the fluid stream substantially normal to the axis thereof,

and wherein the potential difference between said floating electrode element and electrical ground is substantially greater than the potential difference between said floating electrode element and said primary corona discharge electrode element.

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