United States Patent

Cowan

[15] 3,645,447

[45] Feb. 29, 1972

[54] ELECTROSTATIC PAINT SPRAY SYSTEM

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[73] Assignee: **Electrogasdynamics, Inc.**, Hanover, N.J.

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[21] Appl. No.: **788,148**

[52] **U.S. Cl.** 239/15

[51] **Int. Cl.** B05b 5/00, F23d 11/28

[58] **Field of Search** 239/3, 15; 310/5, 10, 11

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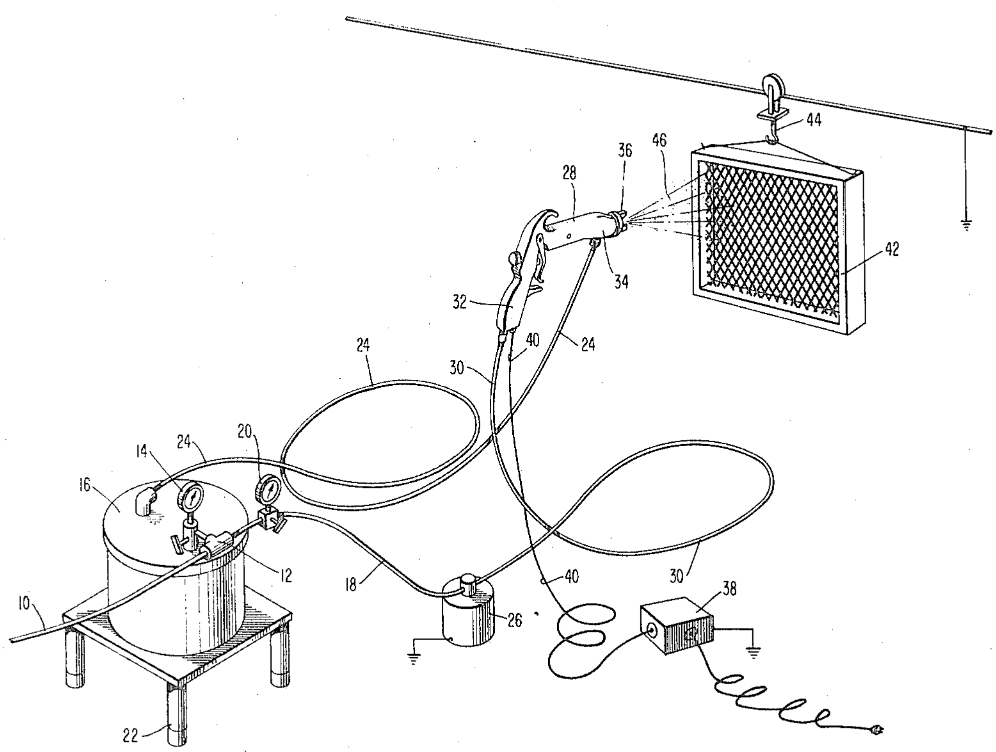
[57] **ABSTRACT**

Electrostatic air atomized paint spray system and spray device wherein power for charging air atomized spray droplets and for maintaining electrostatic depositing field is obtained from self-contained electrogasdynamic generator operatively responsive to the flow of seeded atomizing air therethrough.

17 Claims, 18 Drawing Figures



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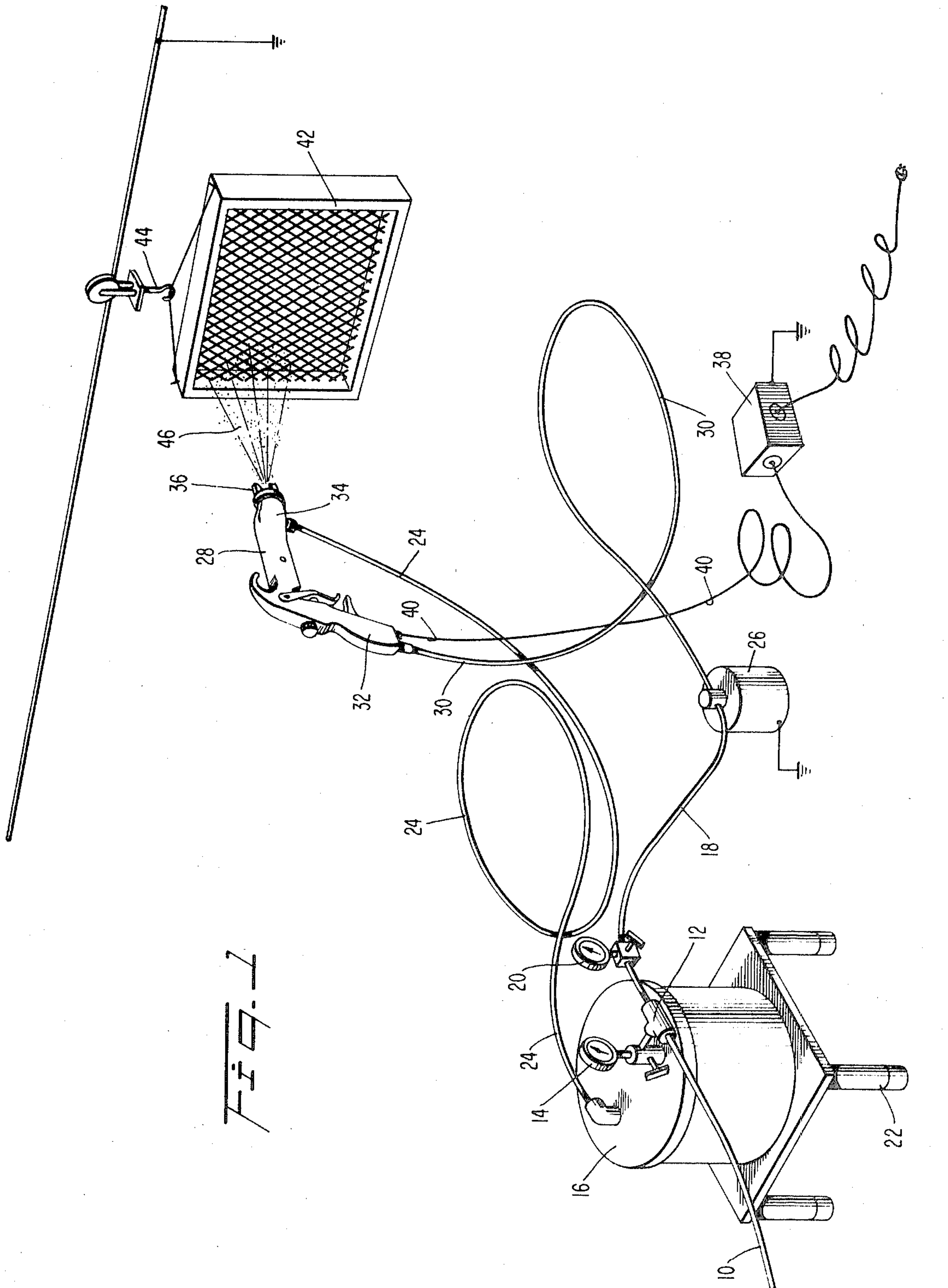

FIG. 1

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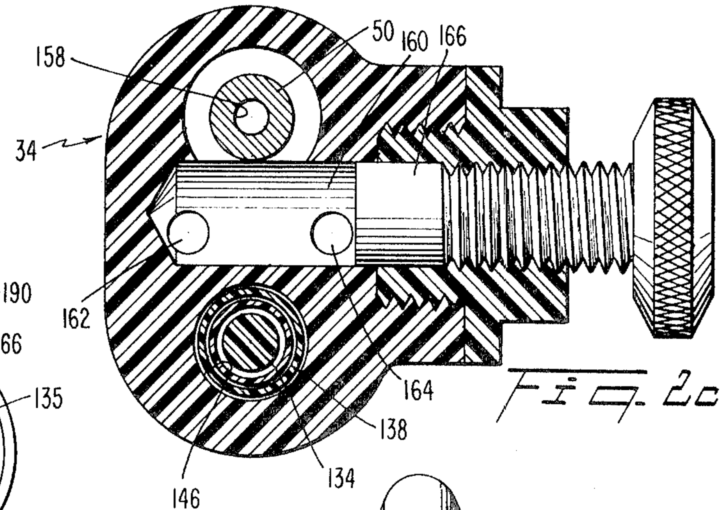

Fig. 2c

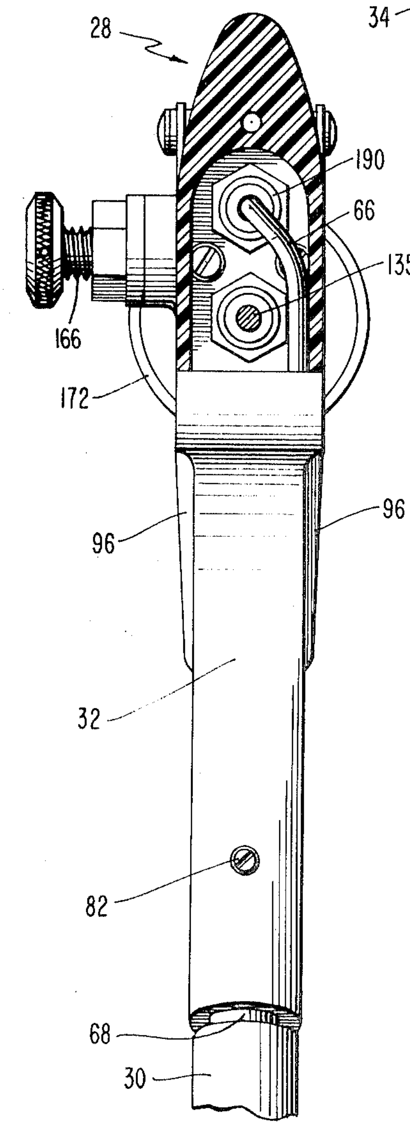

Fig. 2a

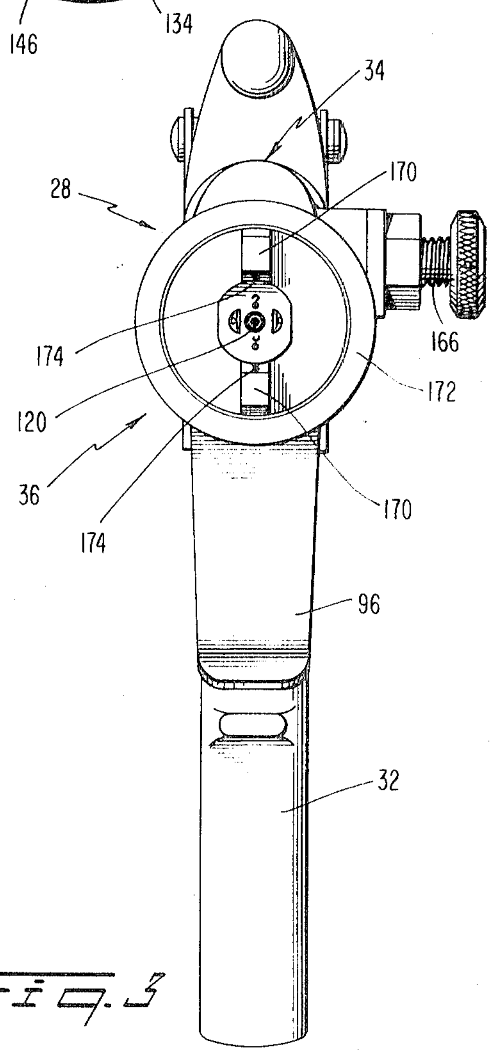

Fig. 3

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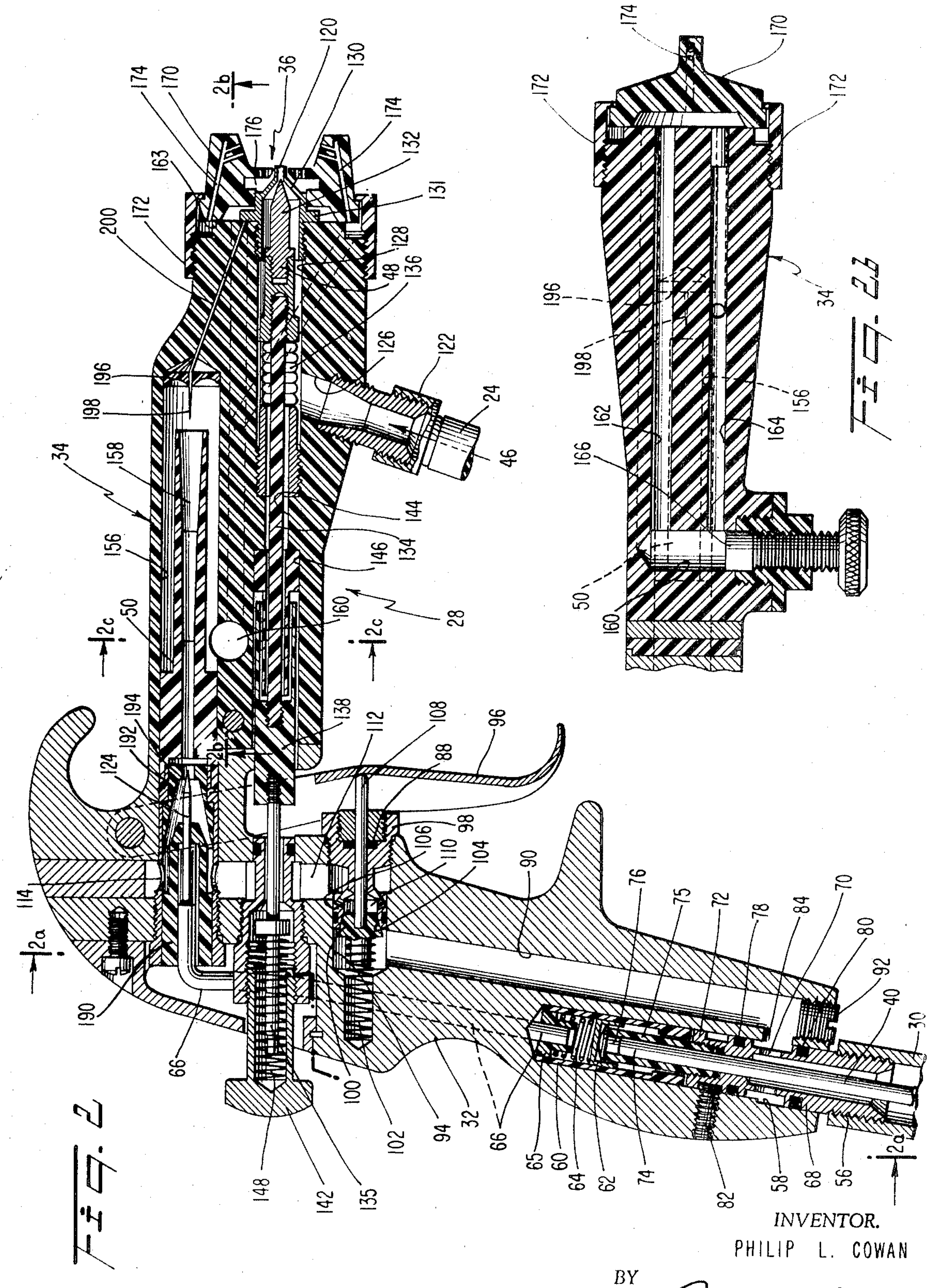

FIG. 2

FIG. 2b

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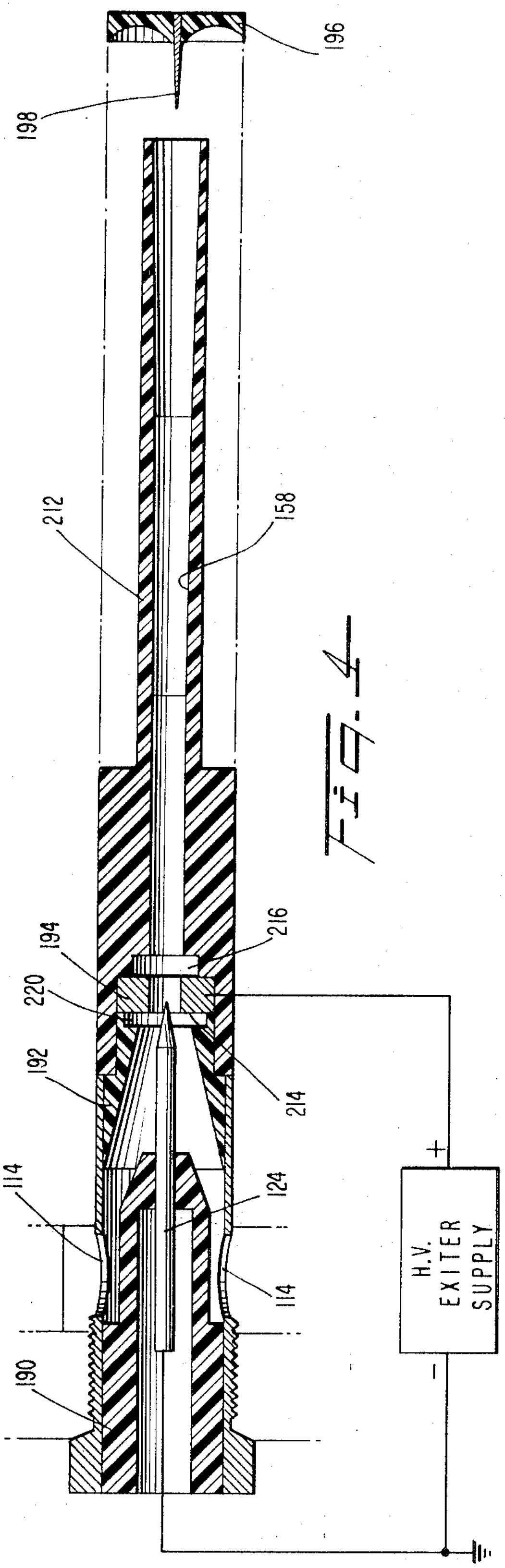

FIG. 4

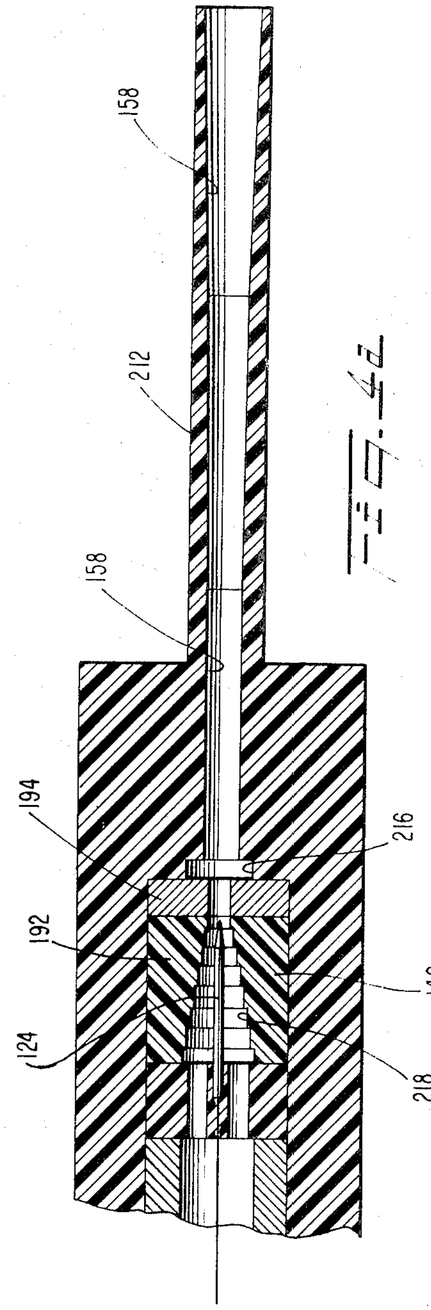

FIG. 4a

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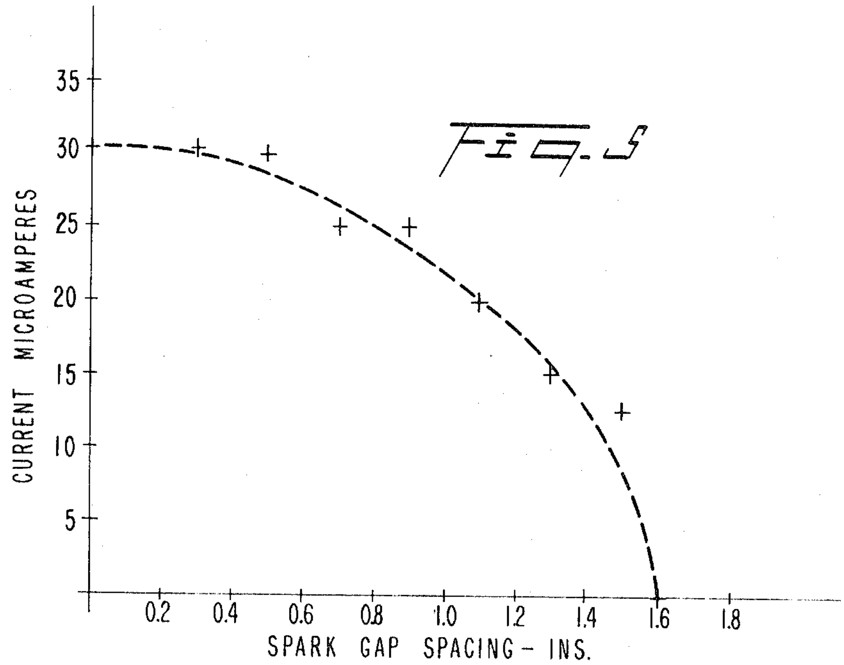

FIG. 5

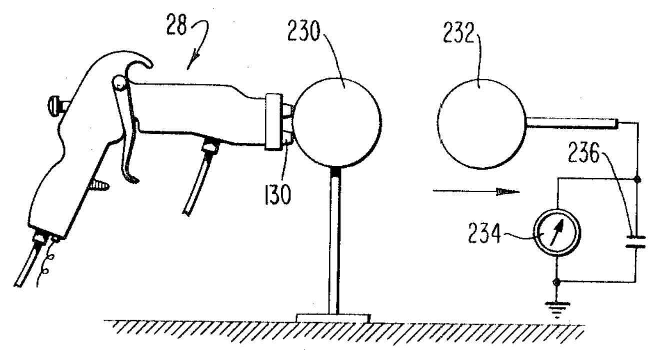

FIG. 6

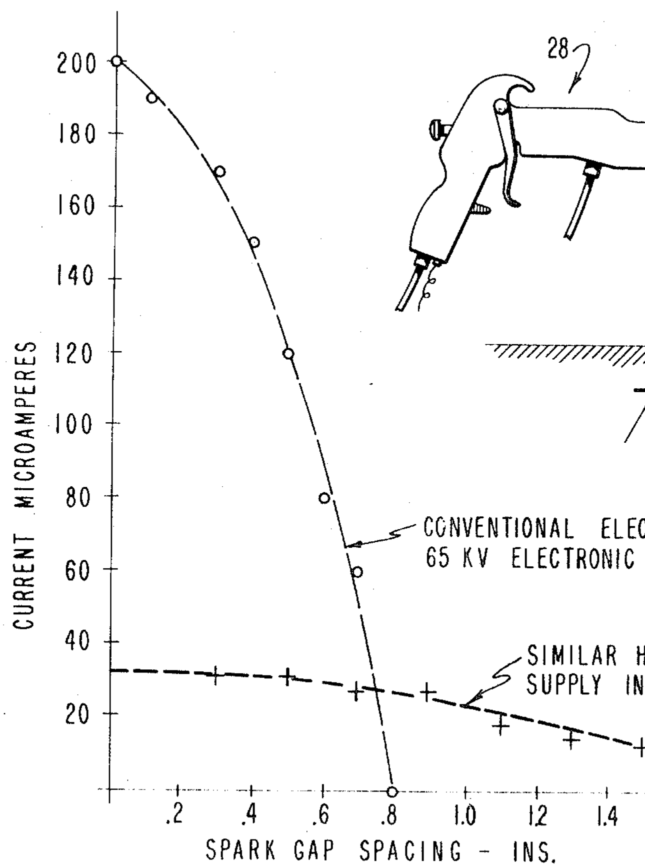

FIG. 7

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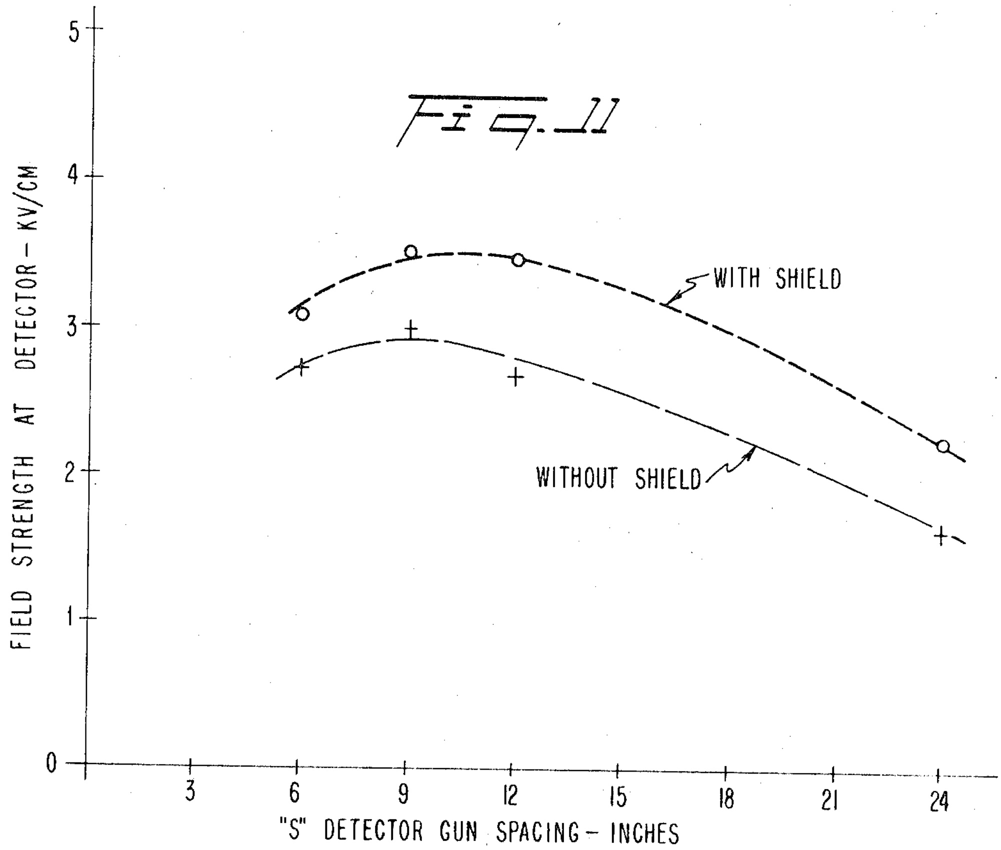

Fig. 11

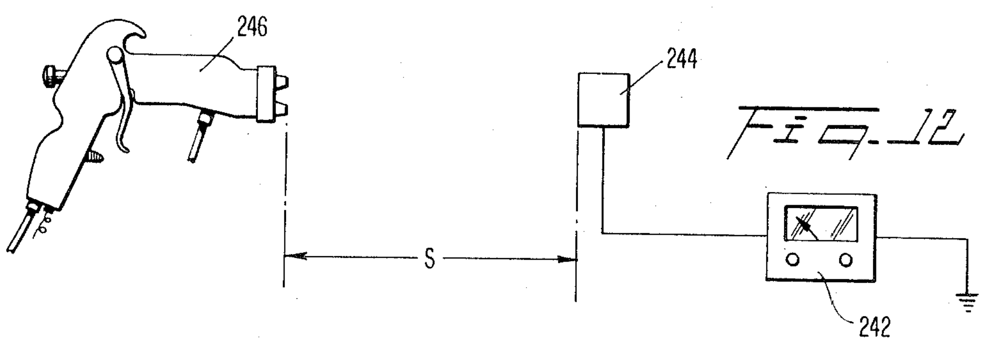

Fig. 12

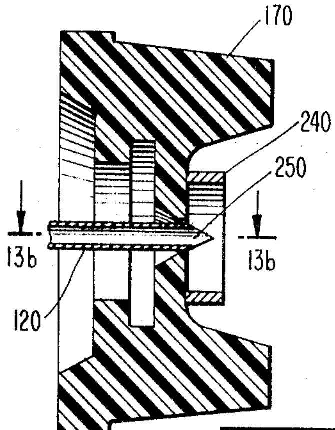

Fig. 13a

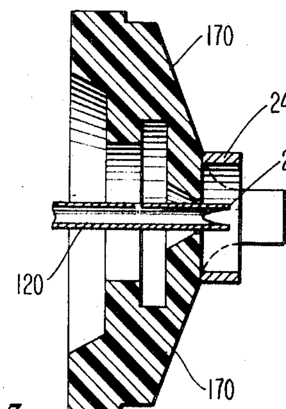

Fig. 13b

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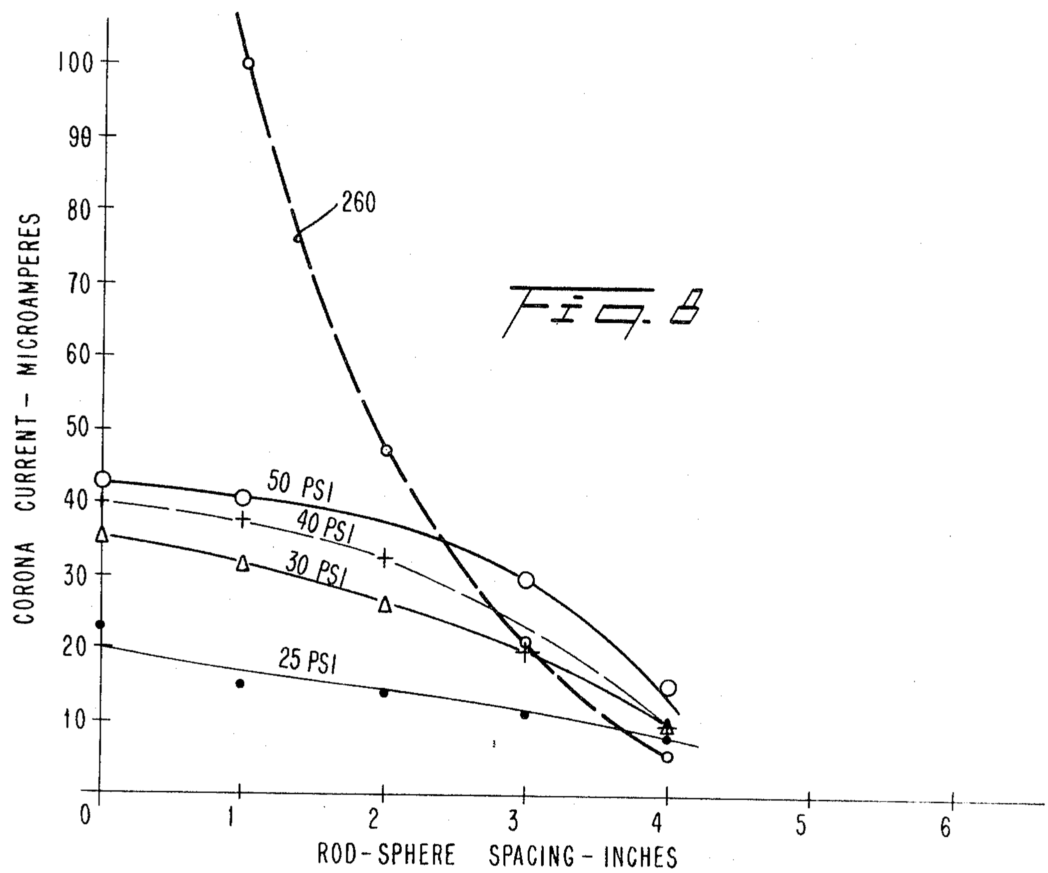

Fig. 8

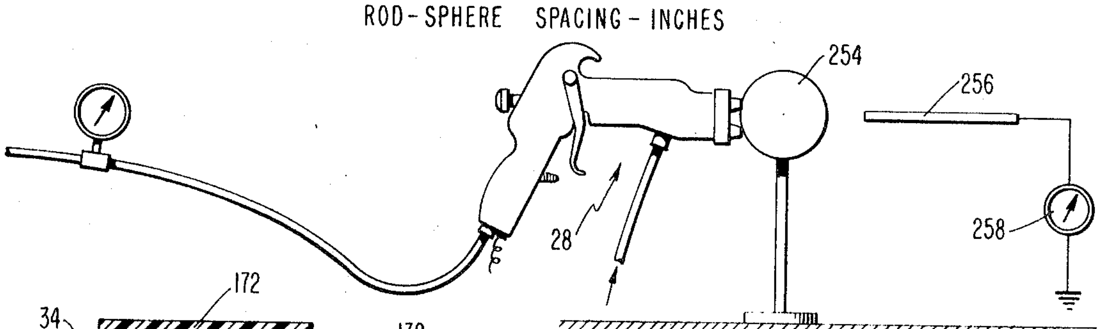

Fig. 9

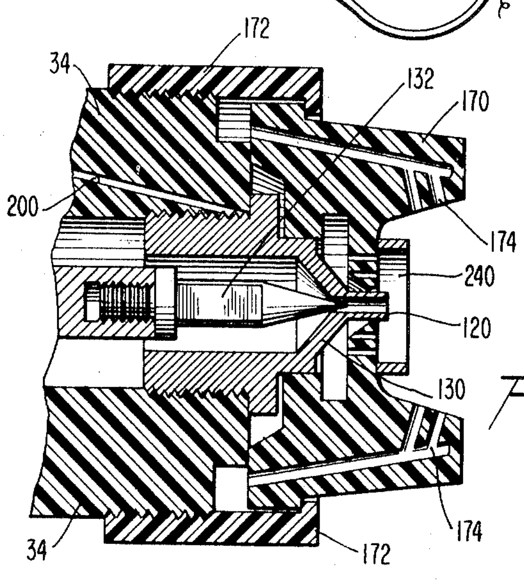

Fig. 10

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ELECTROSTATIC PAINT SPRAY SYSTEM

This invention relates to electrostatic spray coating systems and particularly to improved electrostatic spray coating methods and spraying apparatus employing air as an atomizing medium for liquid coating material.

Electrostatic spray coating systems employing air atomization of the coating liquid are widely utilized in paint spraying. Spray gun apparatus conventionally employed therein is generally constituted by an insulating barrel member having a grounded handle or mount disposed at one end thereof and a selectively sized and shaped high voltage electrode extending from the other end thereof disposed adjacent to the locus of atomization and usually charged to a potential in the neighborhood of from 50 to 85 kilovolts, and in certain installations as high as 150 kilovolts, to create a corona discharge condition and a concomitant electric field of appreciable magnitude. Under such conditions, the corona discharge current flowing from the high voltage electrode creates a region adjacent to the locus of atomization rich in unipolar ions that attach themselves to and charge the paint spray droplets. Alternatively, for conductive coating materials contact charging of the spray droplets will occur in the high field strength region around the fluid orifice. The charged droplets are then displaced, under the conjoint influence of their own inertial forces, the aerodynamic forces of the atomizing air and the electrostatic field extant in the spray region, toward a grounded workpiece. In the vicinity of the spray gun, the inertia and aerodynamic forces are usually dominant but as the particles recede therefrom and approach the grounded workpiece, the forces on the charged particles due to the electrostatic field extant between the charging electrode and the workpiece become more significant and operate to selectively drive the spray particles toward the workpiece to reduce undesired and wasteful "blowby" of paint.

In accord with conventional practice, maximum paint savings are generally effected by maintaining the charging voltage as high as possible and of such magnitude as to produce an average depositing field strength of at least 5,000 volts/inch, and preferably as high as 10,000 volts/inch, between the gun and the workpiece. As a concomitant thereto, the spray velocity in the vicinity of the workpiece should be of minimal magnitude consistent with the demands of adequate atomization and paint flow. Airflow rates above about 2,000 feet/minute in the vicinity of the workpiece are likely to result in operational override by the aerodynamic forces and in increased "blowby" of paint. Conventionally employed electrostatic air atomized coating systems are generally characterized by a rapid falloff in depositing efficiency as the fluid, i.e., paint, and atomizing airflow rates are increased. Such problems are accentuated when high airflow rates are necessarily utilized to effect a required very fine atomization of the coating material or to effect the required atomization of difficult to atomize materials. The requisite charging voltages are conventionally obtained through the utilization of standard electronic high voltage power supplies which are relatively large, heavy and expensive and are so constituted as to inherently function with essentially "constant voltage" type characteristics. In addition thereto and because of the magnitude of the potentials involved, the high voltage cable interconnecting such power supply with the spray gun is heavy, bulky and relatively inflexible, adding undesired weight to the gun assembly which, because of the concomitant high voltage insulation requirements is rendered unduly large, complex and, in most instances not field serviceable.

The utilization of such conventional power supplied has led to the inclusion of auxiliary, large magnitude resistive elements within the gun body to provide a limiting effect upon the current output. Such resistive elements function, as disclosed in U.S. Pat. No. 3,048,498, in the nature of a voltage divider to suppress the tendency for arcs to occur when the gun to workpiece distance varies and thus provides a useful safety feature, both against the hazards of fire and for the protection of the operator should he inadvertently touch the high voltage electrode. Such resistance elements additionally inherently function to effectively vary the magnitude of the potential of the charging electrode in relation with the distance between the gun and workpiece to provide a more or less constant strength of depositing field. In such systems, however, and apart from the dangers that are always inherent in the event of failure of the limiting resistors, operations are always characterized by the drawing of inordinately high ionic currents from the charging electrodes, as for example, in the order of from 100 to 200 microamperes, whereas less than 10 microamperes are needed to effectively charge the paint. Such excess current normally flows in the form of ions to nearby objects resulting in an undesired charge buildup on all such objects that are not adequately grounded. As is well known, the hazard of sparkling and consequent possible fire exists when the operator ro some other grounded object is brought close to such a charged and poorly grounded object. The presence of such high currents also requires that the workpieces being coated are well grounded for the reasons set forth above.

This invention may, in its broad aspects, be briefly described as an improved construction for air atomized electrostatic spray devices in which the air supply to the device is utilized for the purposes of atomizing the liquid and shaping the spray of atomized material and also for operating a self-contained electrogasdynamic power generator for charging the atomized coating material and for maintaining an electrostatic depositing field having one terminus adjacent the locus of atomization. Also in such broad aspects, the subject invention includes the provision of a diminutive electrogasdynamic power generator disposed within an air atomizing spray device that is operatively responsive to the flow of at least a portion of the seeded air supplied to the gun therethrough and has a voltage and current output of a magnitude dependent upon the magnitude of the delivery rate of the atomizing air for effecting proportional variations in the magnitude of the average depositing field strength of the electrostatic field engendered thereby and is characterized by field currents that are substantially independent of the potential gradient of the depositing field. In its more narrow aspects, the subject invention includes the provision of improved air atomized spray gun constructions utilizing cartridge-type electrogasdynamic power generators removably mounted in the spray gun and electrically connectable therewithin to ionizing electrode means constituting a portion of the atomizing spray nozzle assembly and associated external shielding means for the charging electrode to negate the influences of the grounded handle or mount portions thereof and permit operations of charging potentials and at effective field strengths markedly in excess of those usually employed and at minimal current flow levels.

Among the advantages of the subject invention is the provision of field serviceable, lightweight, diminutively sized and readily manipulatable air atomized spray gun construction for use in electrostatic spray coating systems that dispenses with the conventional large and bulky high voltage power supplies and associated heavy insulated cables and the like and derives its electric power from self-contained electrogasdynamic power generator means that is operably responsive to the gun air supply and functions to provide very high voltages at low current levels by direct conversion of the kinetic energy of portions of the moving atomizing air supply into electrical power. Still other advantages include the provision of an air atomized electrostatic spray gun system capable of operating at charging potentials as high as 150 kilovolts and with inherently current limited characteristics wherein high currents cannot be drawn even under short circuit conditions. Further advantages include the provision of a system wherein the kinetic energy of the air utilized for paint atomization is utilized for electric power generation to thereby dispense with auxiliary high voltage cables and auxiliary air lines; wherein the electrogasdynamic power generating means operates efficiently over a relatively wide pressure range, as for example from 20 p.s.i.g. to 100 p.s.i.g., with a small pressure drop so as to be fully compatible with normally available compressed air pressures and delivery rates; wherein the electrogasdynamic power generator operates essentially dry and requires only reduced quantities of conventional and inexpensive paint solvent seed materials that are compatible with the emitted atomized paint sprays and which are introduceable into the systems in a simple and inexpensive manner; wherein the magnitude of the average depositing field strength is proportionally related to the delivery rate of the atomizing air and wherein the actual output capacitance of the electrogasdynamic power supply is so low that no additional precautions need be taken, other than when highly conducting paints are being utilized, to limit the maximum spark energy drawable from the charging electrode to minimal values irrespective of the rates of approach thereof to grounded objects.

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 accordance with the mandates of the patent statutes, the principles of the invention as embodied in a presently preferred construction of an electrostatic spray painting system and air atomization-type spray gun assembly for use therein.

Referring to the drawings:

FIG. **1** is a schematic representation of the components of an electrostatic paint spray system incorporating the principles of this invention;

FIG. **2** is a vertical section through an air atomized spray gun constructed in accord with the principles of this invention and constituting a presently preferred embodiment thereof;

FIG. **2A** is a sectional view as taken on the line **2A—2A** of FIG. **2**;

FIG. **2B** is a sectional view as taken on the line **2B—2B** of FIG. **2**;

FIG. **2C** is a sectional view as taken on the line **2C—2C** of FIG. **2**;

FIG. **3** is a front elevation of the spray gun illustrated in FIG. **2**;

FIG. **4** is a vertical section of an alternative construction for an electrogasdynamic power generator cartridge;

FIG. **4A** is a sectional view of certain constructional details of an alternate configuration for the transition section configuration for an electrogasdynamic power generator;

FIG. **5** is a generalized graphical representation of the current-voltage characteristics of an electrogasdynamic powered spray gun assembly constructed in accord with the principles of this invention;

FIG. **6** is a schematic representation of the test apparatus employed in obtaining the data for the plot of FIG. **5**;

FIG. **7** is a generalized graphical representation of the output characteristics of an electrogasdynamically powered spray gun constructed in accord with the principles of this invention as compared with those of a commercially available electrostatic-type air atomized hand gun of generally conventional construction;

FIG. **8** is a generalized graphical representation illustrating the magnitude of the corona currents drawable from a spray gun constructed in accord with the principles of this invention for various pressures of atomizing air;

FIG. **9** is a schematic representation of the test apparatus employed in obtaining the data for the plot of FIG. **8**;

FIG. **10** is a sectional view illustrating the incorporation of a shielding electrode in the atomizing nozzle-charging electrode assembly;

FIG. **11** is a generalized graphical representation showing the effects of inclusion of a shielding electrode in the atomizing nozzle-charging electrode assembly on the strength of the electrostatic depositing field.

FIG. **12** is a schematic representation of the test apparatus employed in obtaining the data for the plot of FIG. **11**;

FIG. **13A** is a vertical section illustrating a presently preferred configuration for a charging electrode.

FIG. **13B** is a section taken on the line **13B—13B** of FIG. **13A**.

Referring to the drawings and initially to FIG. **1** there is generally illustrated the components of a hand-manipulable type of air atomized electrostatic paint spraying system embodying the principles of this invention. As there shown, such system conventionally includes a compressed air supply hose **10** connectable to a remote source of compressed air (not shown) suitably of a pressure of about 20 p.s.i.g. or greater and capable of supplying the requisite flow rates, that serves to conjointly supply fluid paint delivery pressure through a T-type fitting **12** and associated regulator and gauge assembly **14** to a paint supply pot **16** and to supply the necessary air alternately utilizable for atomization and electric power generation through line **18** to a vapor seed pot assembly **26**. The line **18** is desirably provided with an independent regulator and gauge assembly, generally designated **20**, to provide discrete and independent operational control over the pressure the flow rate of the air conveyed to the air atomized paint spraying device, generally designated **28** and suitably constituting a hand manipulatable air atomized spray gun, as hereinafter described. The paint supply pot **16**, which is also of conventional character, is desirably supported on an insulating stand **22** and fluid paint is conveyed therefrom to the insulated barrel portion of the spray gun **28** through an insulated paint supply hose **24** so as to insure when conducting paints are being utilized against possible shorting to the voltage carrying spray gun components to ground through the above-described components of the paint supply system.

As noted above, a common supply of air is introduced into the vapor seed pot assembly **26** wherein small quantities of seed material, here suitably an inexpensive and conventionally employed paint solvent of a character compatible with the fluid paint being employed, is selectively introduced thereinto in the form of vapor. Upon exiting from the vapor seed pot assembly the now seeded air is transported via the single supply hose **30** to the air atomized spray device **28** for utilization therein for the conjoint purposes of effecting atomization of the liquid coating material, shaping of the spray of atomized material if desired and for the generation of electric power for effecting electrostatic deposition of the atomized liquid. For the purposes of this application, the seeded air conveyed via the common supply line **30** from the locus of seed material introduction to the spray device will be hereinafter termed as the "seeded atomizing air" irrespective of the particular utilization or disposition thereof that is made or effected after its introduction into the spray device. As will become more apparent from what hereinafter follows, some or all of said "-seeded atomizing air" is, in accord with the principles of this invention, passed through the electrogasdynamic power generator to generate the power required for electrostatic deposition of the atomized material in addition to being utilized for effecting atomization of the liquid coating material either by direct interaction therewith or indirectly by powering a mechanical device such as a high-speed turbine that drives an atomizing device as well as being utilizable as fan air emittable from orifices adjacent the locus of atomization for the purposes of shaping the spray of atomized liquid coating material.

The compressed air supply hose **10**, the paint supply hose **24** and the atomizing air supply hose **18** are suitably constructed of electrically insulating material, as is the seeded atomizing air supply hose **30**, with the latter desirably containing a metallic conductor element, suitably in the form of a sheath or strand, which serves to ground the conducting handle portion **32** of the air atomized spray device **28** through the grounded vapor seed pot assembly **26**.

The workpiece or object **42** to be coated is suspended, in a manner conventional in electrostatic spray painting systems, from a grounded support assembly generally designated **44** and which may comprise a conveyor device or the like to sequentially present successive articles to be coated in predetermined spaced relation with the path of the emitted spray **46** from the spray device **28**.

As will be apparent to those skilled in this art the air-atomized spray device 28 may be of varying character in which the seeded atomizing air may directly or indirectly effect atomization as pointed out above. As schematically illustrated in FIG. 1, the spray gun device 28 may suitably comprise a hand manipulatable unit in the nature of a spray gun having a generally cylindrical barrel portion 34 with a conducting pistol grip-type handle portion 32 mounted at one end thereof and an atomizing nozzle-charging electrode assembly, generally designated 36, disposed at the other end thereof. Although one specific construction will be hereinafter described in detail, the spray gun 28 may broadly include other conventional fluid paint delivery systems and atomizing nozzle assemblies in conjunction with a self-contained cartridge-type electrogasdynamic power generating device disposed in the flow path of at least a portion of the seeded atomizing air and having its excitation voltage supplied from a remote source 38 thereof via a lead 40, suitably comprising an unshielded conductor wire fastened directly to or contained within the seeded atomizing air supply line 30.

As clearly delineated in FIG. 1, a spray gun 28 constructed in accordance with the principles of this invention differs in one aspect from those conventionally employed in air atomized electrostatic spray coating systems in that it has connected thereto only the paint supply line 24, the seeded atomizing air supply line 30 and, as noted earlier, a lightweight unshielded wire 40 for the electrogasdynamic power generator excitation voltage and which may be conveniently fastened to or disposed within the seeded atomizing air supply line 30. The subject construction thus completely dispenses with the heretofore required large and heavy floor supported power supply unit and the associated heavy and relatively inflexible insulated cable inherently required to transmit the charging potentials form the power supply to the spray gun.

By way of specific example, FIG. 2 illustrates the constructional details of an electrostatic air atomized type of spray gun that incorporates the principles of this invention and constitutes a presently preferred embodiment thereof. As previously noted the subject gun includes, in its broad aspects, a selectively configured insulating barrel portion 34 having a pistol grip type of conducting handle portion 32 mounted at one end thereof and an atomizing and charging assembly, generally designated 36, disposed at the other end thereof. Included therewithin and located in the lower portion of the barrel 34 is fluid paint delivery system, generally designated 46, a seeded atomizing air conveying system extending through the handle and barrel portions; an electrogasdynamic power generator, generally designated 50 and operably responsive to the flow of seeded atomizing air therethrough, disposed within the insulating barrel member 34 together with provision for introducing the necessary excitation voltages thereto through the handle member 32; and an atomizing nozzle and charging electrode assembly, generally designated 36, mounted at the terminal end of the barrel 34 wherein atomization of the fluid paint by the direct interaction with the seeded atomizing air and charging of the atomized spray particles is effected.

In order to desirably reduce the number of connecting conduits to two and thereby markedly add to the ease of manipulation of the subject gun, the seeded atomizing air and the electrogasdynamic power generator excitation voltages are conjointly supplied to the gun via a composite conduit and specialized entry fitting and connector unit. More specifically the external exciter voltage supply lead 40, suitably in the form of an insulated wire, is disposed within the seeded atomizing air supply line 30 which carries seeded atomizing air, suitably under pressures in the range of from 20 to 75 p.s.i.g. or even higher. The composite seeded atomizing air-excitation voltage supply conduit terminates in a selectively shaped connector assembly generally designated 56 that is removably insertable through an aperture in the base of the handle 32 into a bore 58 longitudinally disposed therein. Disposed within the upper reaches of the bore 58 is an elongate insulating sleeve 60 surrounding a spring-biased electrical contact receptacle-type assembly comprising a displaceable receptacle-type contact member 62 connected to one end of an internally disposed insulated excitation voltage lead 66 that leads to the electrogasdynamic voltage generator 50 as will be described in detail hereinafter. Biasing of the contact member 62 is effected by the spring member 64 having its remote end fixedly positioned by the insulating plug 65. The connector assembly 56 generally comprises a selectively shaped elongate sleeve assembly 68 incorporating a plurality of atomizing air escape apertures 70 adjacent its midlength and upwardly terminating in a guide portion 72 sized and shaped to coaxially position the extending end portion 74 of the insulated electrogasdynamic power generator excitation lead 40. Said end portion 74 of the lead 40 is encased in a rigid insulating sleeve 75 that is sized to be removably contained within the sleeve 60 and dependently terminating in an electrical contact element 76 that is adapted to be disposed in firm electrical contact with the spring-biased receptacle-type contact member 62 when the connector assembly 56 is properly located within the bore 58. Suitable O-ring seals 78 and 80 are disposed in the walls of the sleeve member 68 on either side of the seeded atomizing air escape apertures 70 for disposition in sealing relation with the walls of the bore 58 to prevent leakage of the compressed seeded atomizing air therepast and to direct such seeded atomizing air through aperture 84 into bore 90.

As will be now apparent, insertion of the connector 56 into the bore 58 serves to automatically effect proper interconnection of the gun to both the requisite supply of seeded atomizing air and to the requisite source of excitation voltage for the electrogasdynamic power generator. The desired proper positioning of the connector within the bore is maintained by the setscrew 82.

When the connector assembly 56 is properly positioned as described above, the seeded atomizing air escape apertures 70 are disposed in gaseous communication through the aperture 84 with an elongate bore 90 that longitudinally traverses the handle portion 32 and is adapted to be closed at its dependent end by a threaded plug member 92. The upper end of the seeded atomizing air transmitting bore 90 is disposed in fluid communication with a transverse bore generally designated 94, adapted to contain a valve assembly responsive to manual actuation of a trigger member 96 to control the admission of seeded atomizing air into the electrogasdynamic power generator and its ultimate transmission to the locus of atomization. Suitably included in the valve assembly is a valve body member 98 having a base portion fixedly mounted in the open end of the bore 94 and an extension 106 shaped to open end provide an annular seat 104 and a plurality of apertures 110 disposed adjacent thereto in gaseous communication with the bore 112. Associated therewith is displaceable valve plug member 100 that is normally biased, as by the spring 102, into hermetically sealed relation with the valve seat. Displacement of the valve plug member 100 is effected by the pushrod 108 that extends through the valve body member and associated plug and packing 88 and is longitudinally displaceable in response to rotative displacement of the trigger 96. Thus, rotative displacement of the trigger 96 in the clockwise direction as illustrated in FIG. 2 effects a rearward displacement of the pushrod 108 against the action of the biasing spring 102 and lifts valve plug 100 out of sealing engagement with the seat 104. Such lifting of the plug 100 off the seat 104 permits a flow of seeded atomizing air from the bore 90 through the apertures 110 and into the bore 112. The bore 112 is disposed in gaseous communication with the entry portion 114 of the electrogasdynamic power generator 50 and thus serves to effect the introduction of seeded atomizing air therein.

As will be apparent from the foregoing, the above-described structure operates to introduce both the seeded atomizing air and the excitation voltage to the electrogasdynamic power generator 50. Preparatory however to describing the structure and operation of the electrogasdynamic power generator 50 and the remainder of the seeded atomizing air conduit system, clarity and brevity will be served by digressing and describing the nature of the fluid paint delivery system components included in the subject gun.

The fluid pain delivery components of the illustrated spray gun serve to effect the controlled delivery of a flow of liquid coating material to the locus of atomization and are essentially of conventional character. The liquid coating material is adapted to be introduced into the gun from the paint supply line **24** through a suitable fitting **122** disposed on the underside of the barrel portion **34**. The fitting **122** is in fluid communication with a short bore **126** which in turn communicates with a elongate bore **128** running longitudinally of the barrel **34**. Mounted at one end of the bore **128** is a fluid tip nozzle member **130** having a conically shaped end portion terminating in a short cylindrical section **120** that defines a liquid paint emitting aperture. As best shown in FIG. 2 the fluid tip nozzle member **130** is formed of electrically conducting material and includes an extending flange portion **131** disposed in abutting engagement with the front end **163** of the barrel member **34**. Disposed in coaxial alignment with the liquid paint emitting aperture defined by the cylindrical section **120** and adapted to control the effective cross-sectional area thereof is a displaceable needle valve member **132**. The needle valve member **132** is mounted at one end of an elongate fluid flow control shaft member **134** having a bellows-type sealing assembly **136** disposed in encircling relation about the portion thereof disposed within the front or forward section of the bore **128** to limit the disposition of liquid paint under pressure to said front section of the bore **128**. The fluid flow control shaft **134** extends rearwardly through a reduced intermediate section **144** of the bore **128** and into a rear enlarged section **146** thereof. The rear end of the fluid flow control shaft **134** is supported in an insulated coupling member **138** sized to be closely contained within the bore **146**. The coupling member **138** is in turn connected to a shaft **135** included as a part of a spring biased and trigger displaceable actuating assembly generally designated **140**. Such assembly includes a sleeve-type adjusting stop screw **142** disposed about a biasing string **148** for limiting the degree of displacement of shaft **135** and for controlling the amount of biasing force applied by such spring to the shaft **135** to maintain the fluid flow needle member **132** in sealing engagement with the fluid emitting aperture in the fluid tip nozzle member **130**. In operation of the above-described structure, displacement of the trigger **96** in a clockwise direction effects a rearward displacement of the shaft **135**, coupling member **138** and fluid flow control shaft **134** against the opposition of the biasing spring **148**. Such retraction of the shaft **134** removes the needle valve member **132** from sealing relation within the fluid emitting aperture to permi the emission of a stream of liquid paint therefrom.

The upper portion of the insulating barrel **34** contains a relatively large elongate bore **156** which is adapted to removably receive an electrogasdynamic power generator assembly, generally designated **50**, which in the electric power necessary to charge the atomized paint spray particles and to create the electrostatic depositing field is derived from the direct conversion of the kinetic energy of the moving stream of seeded atomizing air. In the illustrated unit, the seeded atomizing air under pressure is introduced, in response to actuation of the trigger **96**, through the bore **112** into an annularly shaped entry section **114** of the elctrogasdynamic power generator which is of relatively large cross-sectional area so as to produce a relatively low flow velocity and minimal pressure drop therewithin. Disposed within the entry section **114** is the extending portion of an insulated mounting sleeve assembly **190** which serves to coaxially position an elongate ionizer needle electrode **124** relative to a surrounding converging transition section **192** and an annular attractor electrode **194**. Such sleeve assembly **190** also serves to provide a receiving support for the end of the excitation supply voltage lead **66** which, in the illustrated embodiment, is connected to the said ionizer needle electrode **124**. The ionizer electrode needle **124** extends axially downstream within the transition section **192** to the attractor electrode ring **194** which operatively effects a marked decrease in the cross-sectional flow area for the moving seeded atomizing airstream and serves to increase the speed thereof as it approaches the attractor ring. After passage through the attractor ring electrode **194**, the atomizing airstream passes through an elongate channel **158** of relatively small, and preferably slightly increasing in the direction of flow, cross-sectional area suitably sized so that, within which and under the pressure conditions extant, the flow velocity of the seeded atomizing air will be markedly higher than that extant in the entry section **114** and which, for good performance, should preferably be in the vicinity of the sonic velocity. After exiting from the channel **158** the seeded atomizing airstream impinges against the adjacent axially disposed collector needle electrode **198** mounted in a plug **196** and expands into the bore **156** and flows therewithin at reduced velocities toward the exit conduit **160** therefrom. As shown, the collector electrode **198** is directly connected, as by the lead **200**, to a conducting metallic fluid tip nozzle member **130** which latter serves as the charging electrode.

As best shown in FIGS. *2b* and *2c* the exit conduit **160** is disposed in gaseous communication with a discrete fan air transfer conduit **164** running longitudinally of the barrel portion **34** and terminating at the forward end **163** thereof. The atomizing air and fan air conduits **162** and **164** respectively are of reduced cross-sectional area and are selectively sized so as to permit delivery of the seeded atomizing air at the rates requisite to effect desired atomization under the range of ambient pressures available within the gun. Associated with the exit conduit **160** is a screw-type plug member **166** that is effectively longitudinally displaceable in response to rotative displacement thereof into selective overlying or closing relation with the end of the fan air transfer conduit **164** to thereby permit manual control of the amount of the seeded atomizing airstream diverted into the fan air transfer conduit **164**. As will now be apparent, the atomizing air transfer conduit **162** and the fan air transfer conduit **164** terminate at spaced locations on the front end of the barrel portion **34** of the gun radially outward of the flange portion **131** of the fluid tip nozzle member **10**, disposed in overlying relation therewith and removably secured in desired position by a threaded and removably secured in desired by a threaded retaining ring **172** is a selectively configured air cap member **170** formed insulating material. As is conventional, the air cap **170** is shaped to provide a first set of internal conduits, generally designated **174**, disposed in fluid communication with the end of the fan air transfer conduit **164** at the end **163** of the barrel portion of the gun and having the other ends thereof selectively terminating at one or more predesired locations downstream of the fluid tip nozzle member **130** and with a positional location and angular disposition that serves to selectively direct the emission of jets of fan air to modify the shape of the spray of atomized material. In addition thereto the surface of the air cap **170** disposed in abutting facing relation with the end portion **163** of the barrel is contoured to provide for the transfer of atomizing air emanating from the transfer conduit **162** to one or more apertures disposed in surrounding relation to the extending cylindrical section of the fluid tip nozzle **30** to effect, by direct interaction, atomization of the liquid paint stream being emitted therefrom.

In operation of the described unit, application of excitation voltage, suitably in the order of 5,000 volts, to the ionizer needle electrode **124** will initiate a corona discharge condition and cause a corona current to flow in the gap between the point of the ionizer needle electrode **124** and the adjacent ring electrode **194**. Concurrently therewith, the seeded atomizing air moving through the gun in the path described above will travel fro the bore **112** and entry section **114** into the converging inlet or transition section **192** and the attractor electrode ring **194** and through the corona discharge area with progressively increasing velocity. Under corona discharge conditions as described above, the passage of the seeded atomizing air therepast at progressively increasing speeds will result in condensation of at least a portion of the seed vapor therein in the form of extremely small particles or droplets around the unipolar ions present in the corona discharge area. The ions in the region where the seed material condenses are thereby degraded in mobility, become fixed or nearly so in the stream of moving atomizing air and are swept out of the corona discharge area, past the attractor ring electrode 194 and down the elongated insulating channel 158 at high velocity, as for example at speeds in the vicinity of the sonic velocity. The ions in the moving gas stream will then be collected at the collector electrode 198 and will raise the potential thereof to extremely high values, which such potential being applied by the conductor 200 to the fluid tip nozzle member 130.

As will now be apparent, in operation of the described device, clockwise displacement of the trigger 96 will conjointly effect emission of liquid paint through the aperture defined by the cylindrical nozzle portion 120 of the fluid tip nozzle member 130 and a flow of seeded atomizing air through the bore 90, the electrogasdynamic power generator 50, the atomizing air and fan air transfer conduits 162 and 164 respectively and through the various conduits of the air cap 170 to effect atomization of the emitted liquid paint and to selectively shape the spray patterns of the atomized fluid. As noted above, the passage of the stream of seeded atomizing air through the electrogasdynamic power generator 50 results in the generation of high DC voltages at the collector electrode 198 and in the direct application thereof, through conductor 200, to the fluid tip nozzle member 130, which thereby performs the dual function of serving as the charging electrode for the electrostatic deposition system. The application of such potentials to the fluid tip nozzle member 130 will create a corona discharge condition adjacent the terminus thereof and an area rich in unipolar ions closely adjacent to the locus of atomization, which ions attach themselves to the atomized paint particles and selectively charge the same. Under such conditions the fluid tip nozzle member 130, which charged in the manner described, will also serve as one terminus of an electrostatic depositing field with the other terminus thereof being constituted by the grounded object to be coated.

As pointed out earlier, the utilization of a self-contained electrogasdynamic power generator as the source of the necessary high potential not only eliminates the heretofore required large and bulky floor supported high voltage power supplies and associated heavy and inflexible cables necessary to the transmittal of such high voltages to the charging electrode on the gun, but also provides advantages operating characteristics that where heretofore unobtainable with conventional equipment. An understanding and appreciation of such advantageous operating characteristics requires a more detailed disclosure of the nature of the electrogasdynamic power generators and particularly of an improved character of generator that is preferably utilized herein.

In electrogasdynamic power generators of the general type described, the initiation of the requisite corona discharge at the entrance to channel 158 requires the application of only relatively low excitation voltages, as for example in the order of 5,000 volts, in order to effect the generation of very high voltage at the collector electrode 198. The load current and voltage can be much higher than that of the excitation supply, since the electrical power generated is derived from the kinetic energy of the moving gas stream which does the necessary work in driving the ions along the channel 158 from the attractor ring electrode 194 to the collector electrode 198 against the opposing electrical field. It should be noted that although convenience has here dictated application of the excitation voltage to the ionizer needle 124 and having the attractor ring electrode 194 grounded, such can be readily reversed and operations effected with a grounded needle electrode and a charged attractor electrode with the necessary constructional modification relative to insulation and the like. In the electrogasdynamic power generator, the maximum output voltage thereof is essentially determined by the voltage at which electric breakdown will occur between the collector electrode and ground, and in the unit shown in FIG. 2 such breakdown will most likely occur between the collector and attractor electrodes along the walls of the channel 158. As such, the length of the insulating channel 158 employed provides a convenient control of the magnitude of the maximum voltage obtainable from the system and different generator cartridges can be made available in accord with the exigencies of the desired use thereof.

FIG. 4 illustrates certain improvements in construction of an electrogasdynamic power generator which provides, in a diminutive size unit adapted for cartridge-type utilization and employing velocities in the vicinity of the sonic velocity in the generator channel, high performance characteristics over a wide range of operating pressures and mass flow rates. As previously described in conjunction with FIG. 2, the subject generator includes an ionizer needle 124 coaxially disposed relative to the axis of the channel 158 formed by the insulating sleeve 212 by a mounting member 190 and sized to extend through a converging inlet or transition section to the attractor ring electrode 194 as defined by the conically bored insulating member 192. Preferably all such units are preassembled and permanently secured in desired position so as to facilitate unit replacement of the generator assembly when desired, thus making the spray gun readily field serviceable in the event of failure or deterioration. In this illustrated embodiment, the excitation voltage is connected to the attractor ring electrode 194 as an alternative to the previously described construction and the needle electrode 124 is operated at ground potential. With proper design almost all of the current flowing from the ionizer needle 124 can be caused to move with the atomizing air downstream to the collector electrode 198 which operates to effectively minimize the excitation power required since under such condition the current flowing in the excitation circuit approaches zero in value. As noted earlier, the subject electrogasdynamic power generator is proportioned so that the flow of atomizing air in the elongate channel 58 is near sonic in character which provides high performance at low-pressure drops of a magnitude that are essentially compatible with commercially available compressor delivery characteristics. In addition thereto, the portions of the generator disposed immediately adjacent to the attractor ring electrode 194 are selectively shaped to provide one or more relatively sharp edged surface discontinuities in the walls defining he atomizing airflow path. One suitable means for introducing such the surface discontinuity is to make the diameter of the downstream end of the converging inlet section 192 appreciably larger tan the diameter of the attractor ring electrode 194 to effectively provide an annular shoulder extending at right angles to the longitudinal axis of the flow path. A second means is to incorporate an annular recess 220 intermediate the attractor ring electrode 194 and the downstream end of the transition member 192. A third means is to incorporate a second annular recess 216 intermediate the attractor ring electrode 194 and the channel 158 which is of a transverse diameter effectively greater than the air passage defined by the ring and channel. A fourth means is to make the internal diameter of the channel 158 slightly larger than the diameter of the attractor ring electrode 194. Additionally the channel 158 diverges slightly in cross-sectional extent in the direction of airflow to insure maintenance of near sonic velocities in the vicinity of the attractor electrode 194.

All of the above means are desirably incorporated in the generator disclosed in FIG. 2. While the reasons for the improved performance obtained by the incorporation of such type of structure is not clearly understood, it is believed that the discontinuities in the defining walls of the system function to introduce a high degree of turbulence into the flow through the attractor ring electrode 194 and the channel 158 and serves to minimize, if not prevent, build up of a relatively slow moving gas layer along the wall portions within the attractor ring electrode 194 and within the channel 158.

FIG. 4A illustrates an alternative means whereby surface discontinuities may be introduced into the defining walls of the generator adjacent the attractor ring electrode 194. In this embodiment, the converging inlet or transition section **192** is shaped to provide a series of steps or shoulders facing the flow of seeded air that serve to introduce a plurality of sharp-edged surface discontinuities therein.

By way of specific example, markedly improved performance has been obtained with a spray gun incorporating an electrogasdynamic power generator of the type illustrated in FIGS. **2** and **4** having the following dimensions and operating with an airflow velocity in the vicinity of the sonic velocity in the channel **158** under the following operating parameters:

Atomizing Air delivery pressures of from	20 – 100 p.s.i.g.
Attractor ring electrode (194)	0.116" ID by 0.177" long
Converging or transition section (192)	0.260" ID at entry 0.150" ID at exit and 0.410" long
Recess (220)	0.035" deep by 0.300" diameter
Recess (216)	0.320" diameter by 0.060" deep
Channel (158)	0.120" ID by 3.0" long with 0.008"/" divergence

In general the materials of construction do not appear to be of prime importance although the insulating portion thereof i.e., the transition section **192** and the channel **158** and mounting member **190** (when the ionizer needle is subjected to the excitation voltage) should be formed of insulating material of high dielectric strength.

Such a generator configuration provides high voltage performance over a wide pressure range and readily delivers a current of up to about 60 microamperes. The approximate current-voltage relationship for such a generator has been determined experimentally using a spark gap as a load by means of the apparatus illustrated in FIG. **6**. As there shown, the fluid tip nozzle **130** of a spray gun generally designated **28** having a self-contained electrogasdynamic power generator as described above incorporated therein was placed in close physical proximity with an isolated 3-inch diameter sphere **230** having a grounded 3-inch diameter sphere **232** disposed in contact therewith. The grounded sphere **232** was then slowly moved away from the sphere **230**. As the two spheres are separated a spark forms in the gap therebetween and a meter **234** in the line connecting the sphere **232** to ground measures the current flowing across the gap. A capacitor **236** is desirably connected in parallel with the meter to smooth out the current surges and to prevent damage to the meter movement. Thus by measuring the magnitude of the current as a function of the spark gap length an approximate voltage-current curve as illustrated in FIG. **5**, was obtained for the subject generator. As reference thereto clearly shows, the current which is quite small even at maximum value, drops of relatively slowly with increasing voltage, as the latter is measured by the spark gap spacing. FIG. **7** serves to compare the output characteristics of a spray gun incorporating the above-described electrogasdynamic power generator means with the output characteristics of an air atomized electrostatic-type handgun manufactured by the Eclipse Equipment Company of Fairfield, N.J., utilizing a conventional 65 kilovolt electronic power supply and incorporating a limiting resistor as taught by U.S. Pat. No. 3,048,498.

As is readily apparent from FIG. **7**, the short circuit current of the handgun constructed in accord with the principles of this invention is markedly lower than the short circuit current for the conventionally employed unit and, the open circuit voltage (as again measured by spark gap spacing) is markedly higher for the device of this invention than that for the conventionally employed unit. FIG. **7** also clearly shows that the incorporation of an electrogasdynamic power generator operatively responsive to the flow of seeded atomizing air functions as an essentially "constant current" type of power source in direct contradistinction to the essentially "constant voltage" type characteristics inherent in the conventionally employed electronic power supplies in association with a series connected limiting resistor in the order of several megohms per kilovolt in the output thereof. Thus in the practice of this invention, the output current is limited by the inherent characteristics of the electrogasdynamic power generator and the actual output capacitance thereof is also so low that no additional specialized precautions or constructions need be taken to limit the maximum spark energy drawable from the charging electrode as the gun is brought close to a grounded object and irrespective of the rate of approach thereof as are characteristically required in conventional constructions.

One of the highly advantageous operating characteristics of spray devices incorporating the principles of this invention is the provision of a voltage and current output of the self-contained electrogasdynamic power generator having a magnitude that varies in accord with the rate of flow of seeded atomizing air which functions to minimize the dropoff in depositing efficiency characteristic in conventional systems as the liquid paint and airflow rates are increased. Thus in the spray gun devices of this invention, an increase in the rate of flow of the seeded atomizing air effects an increased flow through the generator and production of increased current and voltage output therefrom and a corresponding increase in the magnitude of the average depositing field strength of the electrostatic field engendered thereby. FIG. **8** graphically demonstrates the variation in measured corona currents at various gap spacings for various rates of flow of seeded atomizing air as evidenced by data obtained from the test arrangement illustrated in FIG. **9**. As shown in FIG. **9**, the fluid tip nozzle member of a handgun of the type illustrated and described herein is placed in close proximity with an insulated 6 inch diameter sphere **254** and the corona currents delivered to a grounded probe **256**, specifically a square cut brass rod of .048-inch diameter, over a gap of known geometry was measured by a suitable meter **258**. As clearly shown in FIG. **8**, the device of the subject invention provides increasing outputs, as evidenced by the increased corona currents at all spacings as the supply pressure of the seeded atomizing airstream is increased. FIG. **8** also shows, by curve **260**, the current drawn from the Eclipse air atomized electrostatic-type spray gun referred to earlier under similar test conditions. Such current is markedly higher at the smaller gap spacings but drops appreciably below that of the device of this invention at higher gap spacings, thus confirming the higher voltage capabilities of the subject construction.

It should be here noted that while the presently preferred construction illustrated in FIG. **2** and described above passes all of the seeded atomizing air through the electrogasdynamic power generator, practice of the invention also includes utilization of portions of such seeded atomizing air for power generating purposes. Thus the stream of seeded atomizing air may be preliminarily subdivided into atomizing and fan airstreams and the electrogasdynamic power generator selectively disposed in either of said streams. Likewise operation can be effected by preliminarily diverting a portion of the seeded atomizing air through an electrogasdynamic power generator that exhausts into the atmosphere at a location remote from the locus of atomization, as for example, to create a forwardly moving sheath of air over the gun barrel to prevent or minimize wrap-back of slowly moving charged particles to the handle.

In each of these instances however the power output of the generator will have a magnitude dependent upon the delivery rate of the incoming seeded atomizing air for effecting proportional variations in the magnitude of the average depositing field strength of an electrostatic field engendered thereby and will provide the other desirable characteristics described above.

In addition to the foregoing advantageous characteristics, practice of the subject invention also effectively dispenses with the need for any "counter electrode" function oftentimes conventionally employed for the purposes of maintaining higher field strengths in the region of the paint charging electrode with lower charging potentials and particularly when the charging electrode is spaced at a relatively large distance from the workpiece. While the functioning of such "counter electrode" systems may have some degree of utility in hand guns powered by conventional electronic power supplies and wherein the maximum practicably useable voltages are not much in excess of 60 kilovolts, its utilization in the electrogasdynamically powered handgun of the subject invention with its higher voltage capability and lower current capacity is distinctly disadvantageous. Such "counter electrode" may be constituted by a grounded handle for the spray gun and since the subject spray gun described above desirably includes a grounded handle for the purpose of protection of the operator, charging electrode shielding means are desirably included to minimize, if not negate, the possible deleterious effects of the presence thereof. It has been found that the utilization of such a shield electrode permits operation of a compact electrogasdynamically powered hand or automatic gun incorporating the principles of this invention at voltages that are appreciably higher than those conventionally employed. FIG. 10 (and also FIGS. 13*a* and 13*b*) schematically illustrates the incorporation of such a shield electrode to the atomizing nozzle-charging electrode assembly of the spray gun of FIG. 2. As there shown, the shield electrode suitably comprises an annular ring of conducting material 240 mounted on the surface of the air cap 170 surrounding the cylindrically shaped terminal portion 120 of the fluid tip nozzle member 130 serving as the charging electrode. Such shield electrode 240 is electrically "-floating," in that it is neither connected electrically to the charging electrode or to ground, and will thereby collect current from the charging electrode when the latter is at high potential and rise to a potential that is slightly below that of the charging electrode. As the shield electrode rises in potential it tends to extinguish the corona discharge around the charging electrode, but since the system herein disclosed is essentially possessed of "constant-current" characteristics, the shielding electrode acts to cause the voltage on the charging electrode to increase to maintain the same current flow.

The influence of the shielding electrode on the strength of the depositing field between the gun and the workpiece can be readily observed from FIG. 11. FIG. 11 presents measured values of depositing field strengths at various gun-target spacings as determined by an electrostatic field meter 242 (manufactured by Munroe Electronics Co. of Middleport, N.Y.) connected intermediate a probe 244 and ground and a spray gun 246 constructed in accord with the principles of this invention and of the type described above. The two curves shown on FIG. 11 clearly show the marked increase in operating voltage and hence field strength when a shield electrode is employed. Variations in size shape and location of the shield electrode may be made to effect even greater increases in the strength of the depositing field. In general, the configuration of such electrode is largely determined by the configuration of the charging electrode and by the geometry of the system adjacent to the locus of atomization with limitation thereof being dictated by practical considerations such as avoidance of interference with the flow of fan or atomizing air or with the emitted spray pattern.

As described in detail at an earlier point in this specification the fluid tip nozzle member 130 and particularly the cylindrically shaped terminal sleeve portion 130 constituting the paint emitting aperture therein serves as the charging electrode. Other configurations of charging electrodes well known in the art as, for example, elongate needle members or the like, may be employed. As well as the direct application of the output of the electrogasdynamic power generator to the liquid paint prior to its discharge through a nozzle member. A particularly simple and effective electrode configuration for providing a high charge to the atomized spray particles and which at the same time provides the proper loading for the electrogasdynamic power generator is shown in FIGS. 13A and 13B. As there shown the dependent end of the sleeve portion 120 of the fluid tip nozzle member 130 is sharpened into a "V" configuration to provide a plurality of relatively sharp edged surface discontinuities 250 at the terminal portion thereof. A shielding electrode 240 is again disposed in encircling relationship around the charging electrode.

While I have shown and described certain presently preferred embodiments incorporating the principles of my invention, it should be understood that the same is capable of modification. Changes, therefore, in both constructions may be made without departure from the spirit and scope of the invention as disclosed in the appended claims.

I claim:

1. A spray device for use in an electrostatic spray coating system wherein grounded articles are coated by having charged atomized spray particles electrostatically attracted toward and deposited thereon while still in the liquid state, comprising

a source of pressurized air,

means for selectively introducing seed material into the pressurized air,

electrogasdynamic power generating means,

first conduit means for directing at least a portion of the pressurized seeded air to said electrogasdynamic power generating means for passage therethrough for charging the atomized spray particles and for maintaining an electrostatic depositing field having one terminus adjacent the locus of atomization,

means for atomizing liquid coating material by interaction with a high velocity gaseous stream and for projecting the atomized coating material as a spray of fine coating material particles, and

second conduit means for directing at least a portion of the seeded air discharged from said electrogasdynamic power generating means to said atomizing means.

2. A spray device according to claim 1 further comprising body means for carrying said electrogasdynamic power generating means.

3. A spray device according to claim 2 wherein said body means includes a forward portion formed substantially of insulating material.

4. A spray device according to claim 2 wherein said body means includes a bore and said generating means is selectively dimensioned for removable disposition within said bore.

5. A spray device as set forth in claim 1 wherein said electrogasdynamic power generating means has a voltage and current output of a magnitude dependent upon the magnitude of the delivery rate of said seeded atomizing air for effecting proportional variations in the magnitude of the average depositing field strength of said electrostatic depositing field engendered thereby.

6. A spray gun as set forth in claim 5, wherein said electrogasdynamic power generating means generates direct current and voltage.

7. A device as set forth in claim 3 including

spray charging discharge electrode means mounted at one end of said forward body portion and comprising at least a portion of said atomizing means electrically connected to the output of said electrogasdynamic power generating means for maintaining said ionized atmosphere in proximity to said atomized coating material.

8. The device as set forth in claim 7 including electrically isolated shielding electrode means disposed in spaced relation to said spray charging discharge electrode means for increasing the operating potential of the latter.

9. The device as set forth in claim 7 wherein said spray including charging discharge electrode means is selectively contoured to provide at least one corona inducing projection at the terminus thereof.

10. The device as set forth in claim 7 wherein said spray charging discharge electrode means is selectively contoured to provide at least one corona inducing projection at the terminus thereof and including electrically isolated shielding

electrode means disposed in spaced relation thereto for increasing operating potential thereof.

11. The device as set forth in claim 8 wherein said shielding electrode means comprises a sleeve of conducting material disposed in surrounding spaced relation with said discharge electrode and having its forwardly directed end extending beyond the forward terminus of said discharge electrode.

12. The device as set forth in claim 10 wherein said shielding electrode means comprises a sleeve of conducting material disposed in surrounding spaced relation with said discharge electrode and having its forwardly directed end extending beyond the forward terminus of said discharge electrode.

13. The device as set forth in claim 7 wherein said spray charging discharge electrode means comprises liquid emitting nozzle portions of said atomizing means selectively contoured to provide at least one corona inducing surface discontinuity at the terminus thereof.

14. The device as set forth in claim 3 comprising an elongate needlelike member extending forwardly of said atomizing means.

15. The device as set forth in claim 14 including electrically isolated shielding electrode means disposed in spaced relation to said spray charging discharge electrode means for increasing the operating potential of the latter.

16. A device as set forth in claim 2 wherein said electrogasdynamic power generating means comprises a removably insertable cartridge.

17. The device as set forth in claim 2 including manually graspable support means mounted on the end of said body portion formed of conductive material and adapted to be grounded during operation of said electrogasdynamic voltage generating means.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,645,447 Dated February 29, 1972

Inventor(s) Philip L. Cowan

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

IN THE SPECIFICATION

Column 1, line 67, "supplied" should read -- supplies --

Column 2, line 15, "ro" should read -- or --

Column 4, line 19, after "designated" should be inserted -- 20, to provide discrete and independent operational control over the pressure and the flow rate of the air conveyed to the air atomized paint spraying device generally designated --

Column 5, line 46, after "is" should be inserted -- a --

Column 6, line 48, "open" (second occurance) should be deleted

Column 6, line 49, "end" should be deleted

Column 7, line 3 "pain" should read -- paint --

Column 7, line 11, "a" should read -- an --

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,645,447 Dated February 29, 1972

Inventor(s) Philip L. Cowan

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 51, "perm" should read -- permit --

Column 8, line 40, "10, disposed" should read -- 130. Disposed --

Column 8, lines 41, 42, "and...threaded" should be deleted

Column 8, line 43, after "formed" should be inserted -- of --

Column 8, line 69, "fro" should read -- from --

Column 10, line 43 "he" should read -- the --

Column 10, line 47, "tan" should read -- than --

Column 11, line 54, "of" should read -- off --

Column 13, line 65, "130" should read -- 120 --

Signed and sealed this 10th day of October 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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