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(54) Electrostatic ionizing system

(57) An electrostatic ionizing system for use in connection with a sprayer (10) for spraying conductive liquid particles, having a conductive needle (20) positioned near the centre of the sprayer (10), sprayed particle pattern (24), the needle (20) having a diameter of less than about 250 micrometers and a needle tip sharpened to have a radius of curvature (R) of less than about 50 micrometers, and a second electrode (12) spaced approximately four inches (10.16cm) from the needle (20) and being formed as a part of said sprayer (10).

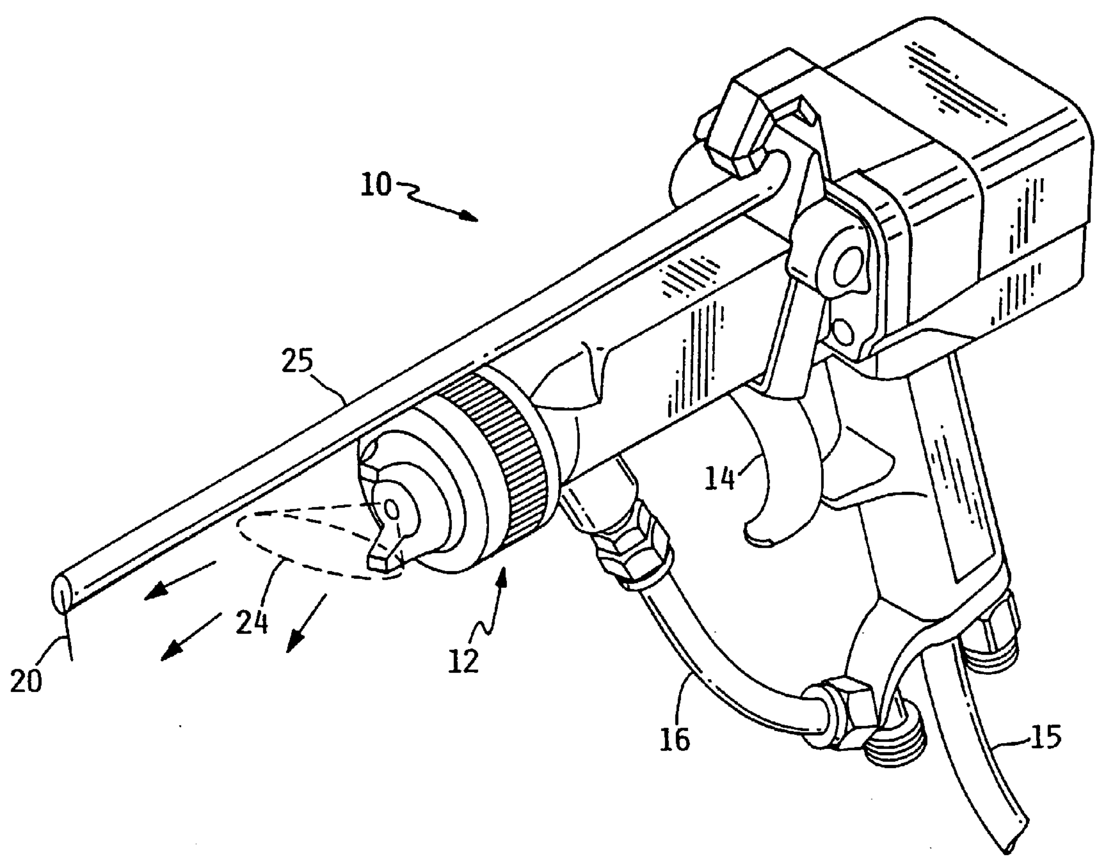

FIG. I

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Description

The present invention relates to an electrostatic charging system for atomizers and coating applicators; more particularly, the invention relates to an ionizing system adapted for use in connection with an electrostatic paint applicator. Moreover, it relates to a system wherein the paint is electrically conductive. The electrostatic paint applicator may be either a hand-held spray gun or may be an automatic spray gun which is operable by remote control connections.

This invention is related to United States Patent Application Serial No. 08/380,970, filed January 31, 1995, and corresponding British Patent Application No. 9601938.5, by the present applicant. A copy of the latter is annexed to the description, and the subject matter disclosed therein is incorporated by reference. The prior patent applications are primarily directed to the same inventive concept as applied to the spraying of non-conductive liquid particles, whereas the present invention is primarily, but not exclusively, directed to applying the inventive concept to a sprayer for spraying conductive liquid particles.

In the field of electrostatic spraying, it is desirable to create an electrostatic field in the vicinity between the spray gun and the target or article to be sprayed. The sprayed particles are propagated through this field, and the respective particles pick up voltage charges as they pass through the field. The charged particles are thereby attracted to the article to be coated, which is typically maintained at a ground or zero voltage potential so as to create an attractive force between the grounded article and the charged particles. By this process, it is possible to direct a much higher percentage of sprayed particles to the actual article to be sprayed, and thereby the efficiency of coating is vastly improved over conventional methods.

In a typical electrostatic spraying system, an ionizing electrode is placed in the vicinity of the spray gun spray orifice, the article to be painted is held at ground potential, and an electrostatic field is developed between the ionizing electrode and the article. The distance between the two electrodes may be on the order of about one foot (30.48 cm) therefore, the voltage applied to the spray gun electrode must necessarily be quite high in order to develop an electrostatic field of sufficient intensity to create a large number of ion/particle interactions so as to develop a sufficient attractive force between the paint particles and the target. It is not unusual to apply electrostatic voltages on the order of 60,000-100,000 volts (60-100 kV) to the sprayer electrode in order to achieve a proper degree of efficiency in the spraying operation. An ionizing current on the order of 50 microamps typically flows between the grounded article and the sprayer electrode.

Electrostatic systems of the foregoing type are frequently referred to as corona charging systems, because the field intensity creates a corona current from the electrode which ionizes the air in the vicinity, and the atomized paint particles which pass through the region of ionized air pick up the ionized charges and become more readily attracted to a grounded or neutral article to be coated. The efficiency of this process can be determined by the number of ions n which are applied to a typical particle as it passes between the spray gun and the target, according to the relationship

$$n = k*E*t*I;$$

where:

- n = number of ion charges per droplet;
- k = constant
- E = electrical field strength in the charging zone;
- t = time the droplet is in the charging zone;
- I = ion concentration in the charging zone.

The electrical field strength in the charging zone must be sufficiently intensive as to ionize the air in the vicinity of the electrode (in the charging zone) in order to create the corona current described above.

Electrostatic voltage charging systems can be utilized in connection with sprays whether the primary atomizing forces are created by pressurized air, hydraulic forces, or centrifugal forces. In each case, it is preferable that the ionizing electrode be placed at or proximate to the point where atomization occurs so as to cause the greatest number of atomized particles to pass through the ionizing field. Electrostatic ionizing systems can also be used with conductive or non-conductive paint; but in the case of conductive paint, the placement of the electrostatic ionizing electrode may have to be more carefully positioned so as to avoid developing a conductive path through the liquid paint column prior to the point of atomization.

In the prior art, the electrostatic electrode configuration most often used for satisfactory performance is a needle configuration, which permits a high intensity field to develop at the needle tip, wherein the needle is positioned at or proximate to the zone of atomization. In the prior art, these needles are typically made from hardened steel material, frequently stainless steel, typically having a diameter of about 0.5 millimetres (mm) and projecting forwardly from the nozzle a distance sufficiently far to avoid electrical contact with the conductive paint column in the sprayer. These needles are typically formed from wire material which is cut to length, and no attempt is made to provide a sharpened point on the needle. In some cases the needle end is rounded. The voltage as applied to such needles is usually in the range of 60-100 kV, which develops a relatively high intensity electrostatic field in the vicinity of the needle, wherein the electrostatic field lines are formed between the needle and usually a grounded article to be painted. The field gradient in volts per centimetre (V/cm) is determined by dividing the voltage applied to the needle by the distance in centimeters to the second electrode, usually the article, where the field is developed.

It would be a distinct advantage in the field of electrostatic spraying to provide a construction having a very high electrostatic field intensity with an electrode positioned so as to avoid short-circuiting the high voltage through the liquid column. The factors that can influence the design of an appropriate electrostatic system include the distance between the respective electrodes, the geometry of the electrodes, the position of the electrodes relative to the atomized spray, and the type of material sprayed by the system.

It is an object of the present invention to provide an electrostatic system, for direct charging of coating materials which may be conductive in sprayers which avoids the use of any mechanical voltage isolation devices.

It is another object of the present invention to provide an electrostatic system wherein a high intensity field is developed from the sharp point of an electrode such that large numbers of ions can be generated around and in the atomization zone of the sprayer.µ

It is a further object of the present invention to provide a controlled high intensity electrostatic field with a needle electrode having a diameter of less than about 250 micrometers (µm) and having a sharpened needle tip.

According to one aspect of the present invention there is provided an electrostatic ionising system for use with a sprayer for emitting a pattern of atomised particles of otherwise conductive liquid, the system comprising:

an electrode having a sharpened edge with a radius of curvature of less than 50 µm, which, in use, is positioned such that the sharpened edge is outside the pattern of atomised particles, and remote from the sprayer; and a further electrode which is formed as part of the sprayer; the sharpened electrode operable in conjunction with the further electrode such that a voltage differential can be developed therebetween to provide an electrostatic field and corona discharge for charging particles emitted through the field.

According to another aspect of the present invention, there is provided an electronic atomizer having an ionizing electrode operable in conjunction with a second electrode, with a voltage differential developed therebetween, for providing an electrostatic field and corona discharge for charging a pattern of conductive liquid particles emitted through the field by the sprayer, the improvement in an ionizing system comprising:

(a) said ionizing electrode positioned outside the pattern of particles emitted from the atomizer, but remotely from the atomizer, and said ionizing electrode having a sharpened edge with a radius of curvature less than about fifty micrometers (50µm) and
(b) said atomizer comprising said second electrode, said ionising electrode being positioned about 10.16 cm (four inches) from said atomizer.

According to a further aspect of the present invention, there is provided an electrostatic ionizing system for attachment to a sprayer proximate the atomizing nozzle which emits a pattern of atomized particles of otherwise conductive liquid, comprising:

(a) a sharpened tip electrode positioned to place the tip of said electrode outside the pattern of atomized particles, and remote from the sprayer, said electrode having a sharpened tip with a radius of curvature of less than 50 micrometers;
(b) said sprayer comprising a second electrode; and
(c) means for applying a voltage potential difference between said sharpened tip electrode and said second electrode.

According to a still further aspect of the present invention, there is provided an electrostatic sprayer having an ionizing needle operable in conjunction with a second grounded electrode, with a voltage differential developed therebetween, for providing an electrostatic field and corona discharge for charging liquid particles from an otherwise conductive liquid, emitted through the field by the sprayer, the improvement in an ionizing system comprising:

(a) said ionizing needle positioned outside the pattern of particles emitted from the sprayer, but remotely positioned from the sprayer, said ionizing needle having a sharpened point with a radius of curvature less than about fifty micrometers and
(b) said second electrode forming a part of said sprayer.

According to yet another aspect of the present invention, there is provided an electrostatic ionising system for attachment to an atomiser for emitting a pattern of atomised particles, the system comprising:

an electrode (12);

an ionising electrode (20) operable in conjunction with the electrode (12), such that a voltage differential can be developed therebetween to provide an electrostatic field and corona discharge for charging particles emitted through the field; whereby the ionising electrode has a sharpened edge with a radius of curvature less than about 50µm.

In a system for use with an atomiser for conductive liquids, the ionising electrode is preferably positioned outside the particles emitted from the atomiser and the other electrode forms part of the atomiser.

In a system for use with an atomiser for non-conductive liquids, the ionising electrode is preferably positioned proximate the pattern of particles and the other electrode is preferably positioned outside the pattern of particles, about 2.54 cm (1") from the ionising electrode.

The invention provides a construction which achieves a satisfactory field intensity E for electrostatic spraying of conductive liquids by controlling the geometry of the needle and by controlling the placement of the needle electrode relative to a second grounded electrode. The needle diameter is selected to be less than about 250 micrometers (µm), the needle tip is sharpened to have a tip radius of curvature less than about 50 micrometers (µm). The needle is positioned to be relatively near the atomization zone for the particular spray gun to which it is applied. The electrostatic system will develop an ionizing current in the range of 20-80 microamp (µa) with an applied voltage in the range of 50-80 kV.

Embodiments of the present invention will now be described with reference to the accompanying drawings, of which:

Figure 1 shows an isometric view of an electrostatic sprayer having a preferred embodiment of the invention;

Figure 2 shows a partial elevation view of a prior art electrostatic needle; and

Figure 3 shows a partial elevation of the electrostatic needle of the present invention.

Figure 1 shows an isometric view of a typical electrostatic sprayer in conjunction with the present invention. The electrostatic sprayer 10 has a manually-operable trigger 14 for spraying liquid delivered through delivery tube 16 through a spray nozzle 12. The electrostatic high voltage is either developed internally by a high voltage supply in the sprayer, or delivered to sprayer 10 via a cable 15 which ultimately places a high voltage on needle 20. The atomized spray is ejected from an orifice at the front of nozzle 12 and is shaped into a spray pattern 24. The particles forming the spray pattern 24 are respectively ionized by the electrostatic field through which they pass as they are emitted from the orifice in the spray nozzle 12.

This invention is primarily directed to a sprayer for spraying particles of liquid, which liquid is electrically conductive. Therefore, a column of the liquid will conduct electricity in much the same manner as an electrical wire. Spraying such liquids under electrostatic field conditions requires extreme care in the design of the equipment in order to avoid short circuiting the electrostatic high voltage directly to ground in cases where the liquid column flowing to the sprayer is grounded. In some cases in the prior art, the sprayer and its associated components have all been isolated from ground; and therefore, attain a voltage level equal to the electrostatic high voltage. In the present case, the sprayer and its associated equipment is maintained at ground potential; and therefore, isolation must be maintained between the high voltage components and the sprayer and its associated conductive liquid column. This is achieved in the present invention by placing the needle 20 at the forward end of an insulated rod 25, and voltage isolating a conductor through the insulated rod 25 to contact the conductor in cable 15. The needle 20 is spaced away from the front of nozzle 12 by a distance of approximately 4-5 inches to provide the requisite voltage isolation needed for this application. By this technique, the electrostatic high voltage emitted at the tip of needle 20 is always placed into the atomization zone, i.e. the zone where liquid particles pass but not in the zone where a liquid column is present.

An important realization of the present invention is the discovery of the improved ionizing system which can produce a highly efficient coating process without contaminating the electrode by coating it with the sprayed material. This results from a construction which causes the voltage electrode to have an extremely sharp ionizing tip or edge outside the atomization zone, but still providing a sufficient number of ions in the atomization zone. This evolves from the recognition that the requisite ionizing field intensity is inversely proportional to the square root of the radius of curvature of the electrode from which the field emanates; i.e. with the same voltage potential applied between the needle and ground, a sharp tip can create a much higher local field intensity around the tip than can a more rounded configuration. A higher intensity field causes higher electron emissions from the tip, which in turn generates an increased number of ions via a stronger corona current, to increase the charge accumulation on liquid droplets passing through the ionization zone, even though the tip is outside the atomization zone. The spacing of the voltage electrode and the grounded electrode creates a very highly intense ionizing zone, and when this ionizing zone is positioned in or close to the zone of atomization the number of droplets which accumulate higher charges is also increased. The net result, with about 20-80 kV applied to the needle electrode of the present invention, produces a droplet charge accumulation equivalent to a conventional isolated electrostatic system, using comparable voltages.

The corona current produced by the improved ionizing system can range from 50-100 microamperes (50-100 µA), and can produce a heating effect at the point of emanation from the sharpened tip or edge. Therefore, it is important that a material having a relatively high melting point be selected for the needle construction.

Figure 2 shows an enlarged partial elevation view of a typical needle as known in the prior art. Such a needle is typically formed of a hardened steel such as stainless steel, and the diameter D_1 is usually about 0.5 mm.

Figure 3 shows an enlarged partial elevation view of the needle of the present invention which is preferably formed of an alloy having a high melting point, preferably above 2,300° Celsius (°C). A preferred material for forming needle 20 is tungsten, which has a melting point of 3,410°C. Needle 20 has a diameter of D_1, which is preferably less than about 250 micrometers (µm). Needle 20 is sharpened to a point having a radius of curvature "R". Radius "R" is less than 50µm and is preferably less than 25 µm.

In operation, the high voltage supply to the electrostatic needle of the sprayer shown in the preferred embodiment is approximately 40-80 kV. This voltage will create a stable corona current at least in the range of 20-80 microamps (µA) wherein the entire corona current flows from the extremely sharpened tip of the electrostatic needle. This relatively high corona current put together with the sharpened needle point tends to create heat in the vicinity of the needle point; and therefore, it is important that the needle be made from a material which has a high melting point in order to maintain the sharpness of the needle point when heated. The preferred material for use in connection with this invention is tungsten, although carbon, osmium and rhenium also have melting points in excess of 3,000° C. Other materials with high melting points which might be suitable for use in connection with the invention include boron, molybdenum, niobium, tantalum and ruthenium, but other factors such as cost may limit the choices of material. In operation, the intensely high electrostatic field which emanates from the sharpened point of the needle is distributed to the grounded liquid column in the sprayer in such a manner that the electrostatic field is relatively centered in the flow of the atomized particles emanating from the sprayer. Therefore, a high proportion of the atomized particles become ionized and are electrostatically attracted to the article to be coated, which itself is held at ground potential.

The magnitude of high voltage which must be applied to the needle in the present invention is determined by a number of factors including the type of liquid material being sprayed, the distance between the needle and the spray nozzle, the distance between the needle and the article to be sprayed, the velocity of the sprayed particles through the atomization zone and environmental factors such as humidity and temperature. It is preferred that the high voltage applied to the sprayer of the present invention be adjustable so as to enable the operator to select the electrostatic voltage value which best suits the particular operating conditions in circumstances. The electrostatic ionizing field will be developed between the needle and the grounded sprayer and also between the needle and the grounded article to be coated.

The present invention may be embodied in other specific forms without departing from the essential attributes thereof; and it is, therefore, desired that the present embodiment be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention. For example, the principles of the present invention could be achieved with an electrode having a sharpened edge, even though not in the form of a needle if the teachings herein and in the annex were applied to its construction.

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Annex comprising GB Patent Application No. 9601938.5

The present invention relates to an electrostatic charging system for atomisers and coating applicators; more particularly, the invention relates to an ionising system adapted for use in connection with an electrostatic paint applicator. The electrostatic paint applicator may be either a hand-held spray gun or may be an automatic spray gun which is operable by remote control connections, or a paint powder applicator. The invention is primarily useful for applying non-conductive liquids and powders, although the principles of the invention also find use in connection with spraying conductive liquids.

In the field of electrostatic spraying, it is desirable to create an electrostatic field in the vicinity between the spray gun and the target or article to be sprayed. The sprayed particles are propagated through this field, and the respective particles pick up voltage charges as they pass through the field. The charged particles are thereby attracted to the article to be sprayed, which is typically maintained at a ground or zero voltage potential so as to create an attractive force between the grounded article and the charged particles. By this process, it is possible to direct a much higher percentage of sprayed particles to the actual article to be sprayed, and thereby the efficiency of spraying is vastly improved over conventional methods.

In a typical electrostatic spraying system, an ionising electrode is placed in the vicinity of the spray gun spay orifice, the article to be painted is held at ground potential, and an electrostatic field is developed between the ionising electrode and the article. The distance between the two electrodes may be of the order of about one foot (30.5cm); therefore, the voltage applied to the spray gun electrode must necessarily be quite high in order to develop an electrostatic field of sufficient intensity to create a large number of ion/particle interactions so as to develop a sufficient attractive force between the paint particles and the target. It is not unusual to apply electrostatic voltages of the order of 60,000-100,000 volts (60-100 kV) to the spray gun electrode in order to achieve a proper degree of efficiency in the spraying operation. An ionising current of the order of 50 microamps typically flows between the grounded article and the spray gun electrode.

Electrostatic systems of the foregoing type are frequently referred to as corona charging systems, because the field intensity creates a corona current from the electrode which ionises the air in the vicinity, and the atomised paint particles which pass through the region of ionised air pick up the ionised charges and become more readily attracted to a grounded or neutral article to be coated. The efficiency of this process can be determined by the number of ions n which are applied to a typical particle as it passes between the spray gun and the target, according to the relationship

$$n = k*E*t*I;$$

where:

n = number of ion charges per droplet;

k = constant

E = electrical field strength in the charging zone;

t = time the droplet is in the charging zone;

I = ion concentration in the charging zone.

The electrical field strength in the charging zone must be sufficiently intensive as to ionise the air in the vicinity of the electrode (in the charging zone) in order to create the corona current described above.

Electrostatic voltage charging systems can be utilised in connection with spray guns whether the primary atomising forces are created by pressurised air, hydraulic forces, or centrifugal forces. In each case, it is preferable that the ionising electrode be placed at or proximate to the point where atomisation occurs so as to cause the greatest number of atomised particles to pass through the ionising field. Electrostatic ionising systems can also be used with conductive or non-conductive paint; but in the case of conductive paint, the placement of the electrostatic ionising electrode may have to be more carefully positioned so as to avoid developing a conductive path through the liquid paint column prior to the point of atomisation. In the prior art, the electrostatic electrode configuration most often used for satisfactory performance is a needle configuration, which permits a high intensity field to develop at the needle tip, wherein the needle is positioned at or proximate to the zone of atomisation. In the prior art, these needles are typically made from hardened steel material, frequently stainless steel, typically having a diameter of about 0.5 millimetres (mm) and projecting forwardly from the nozzle a distance of about 2-6 mm. These needles are typically formed from wire material which is cut to length, and no attempt is made to provide a sharpened point on the needle. In some cases the needle end is rounded. The voltage as applied to such needles is usually in the range of 40-100 kV, which develops a relatively high intensity electrostatic field in the vicinity of the needle, wherein the electrostatic field lines are formed between the needle and usually a grounded article to be painted. The field gradient in volts per centimetre (v/cm) is determined by dividing the voltage applied to the needle by the distance in centimetres to the second electrode, usually the article, where the field is developed.

It would be a distinct advantage in the field of electrostatic spraying to provide a construction having a very high electrostatic field intensity with a considerably lower applied voltage than as used in the prior art. For example, reducing the applied voltage from 60 kV to 15 kV greatly simplifies the technical design of the voltage-producing circuitry, reduces the complexity of shielding the electrostatic field from adverse outside influences, and increases the overall safety in operating the system.

It is therefore an object of the present invention is to provide an electrostatic system for spray guns, which provides an electrostatic ionising field with considerably lower applied voltage than is known in the prior art.

It is a further object of the present invention to provide an electrostatic system wherein a high intensity field is developed over a relatively short distance and in the atomisation zone of the spray gun.

It is a further object of the present invention to provide a controlled high intensity electrostatic field with a needle electrode having a diameter of less than about 250 micrometers (μm) and having a sharpened needle tip.

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The factors that can influence the design of an appropriate electrostatic system include the distance between the respective electrodes, the geometry of the electrodes, the position of the electrodes relative to the atomised spray, and the type of material sprayed by the system.

The invention provides a construction which achieves a satisfactory field intensity E for electrostatic spraying. This is achieved in a preferred embodiment by controlling the geometry of the needle and by controlling the placement of the needle electrode relative to the second electrode. The needle diameter is selected to be less than about 250 micrometers (μm), the needle tip is sharpened to have a tip radius of curvature less than about 50 micrometers (μm), and the electrode spacing is preferably set to approximately about 1.5 centimetre (c). The needle is positioned to be relatively near the centre of the atomisation zone for the particular spray gun to which it is applied. The electrostatic system will develop an ionising current in the range of 20-50 microamp (μA) with about an applied voltage of 15 kV.

More generally, according to the present invention, there is provided an electrostatic ionising system for attachment to an atomiser for emitting a pattern of atomised particles, the system comprising:

an ionising electrode operable in conjunction with a second electrode, such that a voltage differential can be developed therebetween to provide an electrostatic field and corona discharge for charging particles emitted through the field; whereby:

the ionising electrode is positioned proximate the pattern of particles and has a sharpened edge with a radius of curvature less than about 50μm; and

the system is arranged such that the second electrode is positioned outside the pattern of particles and less than about 2.54 cm from the ionising electrode.

In one embodiment, the invention is in an electrostatic spray gun having an ionis ing needle operable in conjunction with a second electrode, with a voltage differential developed therebetween, for providing an electrostatic field and corona discharge for charging particles emitted through the field by the spray gun, the improvement in an ionising system comprising:

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(a) said ionizing needle positioned proximate the pattern of particles emitted from the spray gun, and said ionising needle having a sharpened point with a radius of curvature less than about fifty micrometers (50 μm); and

(b) said second electrode positioned outside the pattern of particles emitted from the spray gun and within about 1.5 centimetres from said ionising needle.

The ionising needle may further comprise a diameter of less than 250 μm. It may also comprise a metallic member having a melting point above 2,300°C, which is preferably made from tungsten material.

The second electrode may comprise a metallic ring positioned about the axis of the needle. Alternatively, it may comprise at least one metal sphere positioned along an axis passing through and transverse to the axis of the needle. The at least one metal sphere preferably has a diameter of at least ten times the diameter of said needle.

The voltage differential is preferably about 15 kilovolts.

In another embodiment of the present invention, there is provided an electrostatic ionising system for attachment to a spray gun proximate the atomising nozzle which emits a pattern of atomised particles, comprising:

(a) a needle electrode positioned to place a tip of said needle proximate the pattern of atomised particles, said needle having a diameter of less than 250 micrometers and having a sharpened tip with a radius of curvature of less than 50 micrometers.

(b) a second electrode positioned proximate the pattern of atomised particles and within about 1.5 centimetres from said sharpened tip; whereby said pattern is between said needle electrode and said second electrode; and

(c) means for applying a voltage potential difference between said needle electrode and said second electrode.

Preferably, the ionising needle is made from a material having a melting point of at least 2,300°C.

Optionally, the second electrode comprises a metallic ring concentrically positioned about the needle. Alternatively, it may comprise at least two metal spheres respectively oppositely positioned along an axis passing through the ionising needle.

Preferably, the voltage potential difference is about 15 kilovolts.

In a further embodiment of the present invention, there is provided an electrostatic ionising system for attachment to a spray gun proximate a nozzle for emitting a pattern of atomised particles, comprising:

(a) a plurality of ionising wires positioned proximate said pattern of atomised particles, each of said plurality of wires having a diameter less than 50 micrometers;

(b) a second electrode positioned proximate said pattern of atomised particles and within about one centimetre of said plurality of ionising wires; and

(c) means for applying a voltage potential difference between said plurality of ionising wires and said second electrode.

Preferably, the plurality of ionising wires are each made from a material having a melting point of at least 1,500° C.

In a still further embodiment, the invention is in an electrostatic atomiser having an ionising electrode operable in conjunction with a second electrode, with a voltage differential developed therebetween, for providing an electrostatic field of corona discharge for charging particles emitted through the field by the spray gun, the improvement in an ionising system comprising:

(a) said ionising electrode positioned proximate the pattern of particles emitted from the atomiser, and said ionising electrode having a sharpened edge with a radius of curvature less than about fifty micrometers (50μm); and

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(b) said second electrode positioned outside the pattern of particles emitted from, the atomiser and within about 1.5 centimetres from said ionising electrode.

The ionising electrode may comprise a metallic member having a melting point about 2,300^{o} C, which is preferably made from tungsten material.

Optionally, the second electrode comprises a metallic ring positioned about the ionising electrode or at least one metal sphere positioned along an axis passing through and transverse to the axis of said ionising electrode.

Such a metal sphere preferably has a diameter of at least ten times the radius of curvature of the edge.

Embodiments of the present invention will now be described with reference to the accompanying drawings, of which:

Figure 1 shows an isometric view of an electrostatic spray gun having a preferred embodiment of the invention;

Figure 2 shows an isometric view of an electrostatic spray gun having a second preferred embodiment of the invention;

Figure 3 shows a partial cross-section view of the spray gun of Figure 1;

Figure 4 shows a partial cross-section view of the spray gun of Figure 2;

Figure 5 shows a partial elevation view of a prior art electrostatic needle;

Figure 6 shows a partial elevation view of the electrostatic needle of the present invention;

Figure 7 shows a diagrammatic view of one form of placement of the needle of the present invention;

Figure 8 shows a diagram of a second form of the present invention;

Figure 9 shows a diagram of a third form of the invention; and

Figure 10 shows a diagram of a fourth form of the invention.

Figure 1 shows an isometric view of a typical electrostatic spray gun in conjunction with the present invention. An electrostatic spray gun 10 has a manually-operable trigger 14 for spraying liquid delivered through delivery tube 16 through a spray nozzle 12. The electrostatic high voltage is either developed internally by a high voltage supply in the spray gun, or delivered to spray gun 10 via a cable 15 which ultimately places a high voltage on needle 20 in nozzle 12. A pair of grounded spherical electrodes 18 are affixed to nozzle 12, and a high intensity electrostatic voltage field is developed between needle 20 and spherical electrodes 18. The diameter of each spherical electrode 18 should be at least about ten times the diameter of the needle 20. The atomised spray is ejected from an orifice at the front of nozzle 12 and is shaped into a spray pattern 24. The particles forming the spray pattern 24 are respectively ionised by the electrostatic field through which they pass as they are emitted from the orifice in the spray nozzle 12.

Figure 2 shows an alternative embodiment of the electrostatic ionising system affixed to spray gun 12. In this example, a grounded ring electrode 22 is affixed to nozzle 12 and surrounds the atomising orifice in nozzle 12. The needle 20 develops a high intensity electrostatic field to the ring electrode, and the atomised spray particles which form spray pattern 24 pass through the ionising field as they are propagated forwardly from the spray gun 10.

Figure 3 shows a partial cross-section view of the spray gun illustrated in Figure 1. The needle 20 projects forwardly from a liquid valve 19 which is interposed into the liquid flow path of the spray gun. Needle 20 has a slidable electrical contact 20A which is movable within a tubular resistor 23. Tubular resistor 23 is electrically connected via a conductor 17 to a high volume coupler 15. High voltage coupler 15 is connected to a high voltage source. Therefore, the high voltage is conveyed to needle 20 via the high voltage coupler 15, conductor 17, tubular resistor 23, and slidable tab 20A. The liquid flow path through spray gun 10 proceeds from liquid delivery tube 16 into the nozzle chamber 25 and through the spray orifice 27. Pressurised air is delivered through passages to air cap chamber 37, and outwardly to impinge upon the liquid emanating from orifice 27 to cause the liquid to become atomised. Further pressurised air is delivered through passages 33 in air cap 35 to impinge upon the atomised particles, and thereby tends to "flatten" or shape the atomised particles into a narrowed spray pattern.

The high voltage electrostatic field developed at the point of needle 20 is developed between needle 20 and the grounded spherical electrodes 18. Therefore, a very high intensity electrostatic field is found in the vicinity of the sharpened point of needle 20 to ionise the liquid particles which generally pass about needle 20 in a forward path.

Figure 4 shows a partial cross-section view of the spray gun of Figure 2, wherein like components have been numbered identically to the components shown in Figure 3. In all respects, spray gun 10 of Figure 4 operates identically to spray gun 10 of Figure 3, the only difference being the arrangement of the electrostatic ionising system of Figure 4 versus Figure 3. In Figure 4, electrostatic needle 20 develops a high intensity field with the grounded ring electrode 22. This electrostatic field is uniformly dispersed about the axis of the atomised particles emanating from orifice 27, thereby ensuring that the atomised particles become fully ionised as they are propagated past needle 20. The ring electrode 22 shown in Figure 4 is electrically connected to ground potential, as are the spherical conductors 18 shown in Figure 3, according to techniques which are well known in the art.

An important realisation of the present invention is the discovery of the improved ionising system which can produce a highly efficient coating process without the need for electrostatic voltage potentials in the range of 40-100 kV as was heretofore believed necessary. This results from a construction which places the voltage electrode within less than about one inch (2.54 cm) from the grounded electrode, together with constructing the voltage electrode to have an extremely sharp ionising tip or edge. This evolves from the recognition that the requisite ionising field intensity is inversely proportional to the square root of the radius of curvature of the electrode from which the field emanates; i.e. with the same voltage potential applied between the needle and ground, a sharp tip can create a much higher local field intensity around the tip than can a more rounded configuration. A higher intensity field causes higher electron emissions from the tip, which in turn generates an increased number of ions via a stronger corona current, to increase the charge accumulation on paint droplets passing through the ionisation zone. The relatively close spacing of the voltage electrode and the grounded electrode creates a very highly intense ionising zone, and if this ionising zone is positioned in or close to the zone of atomisation the number of droplets which accumulate higher charges is also increased. The close spacing of the two electrodes does reduce the size of the ionising zone, and therefore the time that a typical droplet is in the ionising zone, but this disadvantage is apparently more than offset by the increased ionisation density in the ionising zone. The net result, with about 15 kV applied to the needle electrode of the present invention, produces a droplet charge accumulation equivalent to about 100 kV applied to a conventional electrostatic system.

The corona current produced by the improved ionising system can range from 50-100 microamperes (50-100 μA), and can produce a heating effect at the point of emanation from the sharpened tip or edge. Therefore, it is important that a material having a relatively high melting point be selected for the needle construction.

Figure 5 shows an enlarged partial elevation view of a typical needle as known in the prior art. Such a needle is typically formed of a hardened steel such as stainless steel, and the diameter D_1, is usually about 0.5 millimetres.

Figure 6 shows an enlarged partial elevation view of the needle of the present invention which is preferably formed of an alloy having a high melting point, preferably above 2,300^{o} Celsius (^{o}C). A preferred material for forming needle 20 is tungsten, which has a melting point of 3,410^{o} C. Needle 20 has a diameter of D_2, which is preferably less than about 250 micrometers (μm). Needle 20 is sharpened to a point having a radius of curvature "R". Radius "R" is less than 50 μm and is preferably less than 25 μm.

Figure 7 shows a cross-section diagrammatic view of an alternative embodiment of the invention. In the embodiment shown in Figure 7, the components are generally cylindrical in shape with a view taken along a diameter of the cylindrical array of components. An air cap 28 forms an outer cylindrical member enclosing a fluid nozzle 30. A pair of air passages 29 pass between fluid nozzle 30 and air cap 28. Fluid nozzle 30 has an annular air passage 31 surrounding a correspondingly annular liquid passage 32. Centred in liquid passage 32 is a grounded rod 34. A needle 36 is connected to a high voltage supply 38, the needle 36 having a sharpened point in the zone of atomisation of liquid particles which emanate from liquid passage 32. The liquid passing through passage 32 becomes atomised under the influence of pressurised air through passage 31. The atomised particles are "flattened" by air from passages 29 to form a shaped, atomised spray pattern in the vicinity proximate the point of needle 36. Figure 8 shows the same overall embodiment with a different form of high voltage electrode. In this case, a needle conductor 40 is connected to a high voltage supply 38; but the ends of needle conductor 40 are formed into a plurality of brush needle points 42. The brush needle points 42 are each extremely fine wires having individual sharpened points with radii of about 15 μm, wherein the points of the brush needle 42 are proximate the zone of atomisation for particles emanating from the spray nozzle 26.

Figure 9 shows a further alternate embodiment of a spray nozzle 44 which utilises the electrostatic ionising system described herein. An air cap 46 surrounds a fluid nozzle 48 which has an orifice 53 projecting through the centre of a grounded air cap face 50. Air cap face 50 is metallic and is electrically connected to ground (not shown). Air cap 46 has two air passages 47 which confine pressurised air for shaping the atomised pattern. Further, air passages 54 surround the fluid nozzle 48 and emit pressurised atomising air between the outer surface of fluid nozzle 48 and the air cap face 50, thereby to atomise liquid particles emanating from orifice 53. The liquid particles are admitted into fluid nozzle 48 via a liquid passage 49. A pair of electrostatic needles 52 are projecting from air cap 46 and are connected to a source of high voltage power (not shown). Needle electrodes 52 are of the type generally described in connection with this invention having a very narrow diameter and a sharpened point, the respective points of the needle electrodes 52 being positioned in the zone of atomisation of nozzle 44.

Figure 10 shows a further embodiment of a spray nozzle 58 utilising the principles of the present invention. In this case, an air cap 62 surrounds a fluid nozzle 60; and air passages 63 are formed therebetween. The liquid passing through fluid nozzle 60 is emitted via orifice 61, ad the pressurised air passing through air passages 63 are emitted through the annular orifice surrounding fluid nozzle 60, in the region

A12

between air cap 62 and fluid nozzle 60. A needle electrode 64 is inserted through the centre of fluid nozzle 60 and is connected to an electric ground connection. A metal ring 66, which can be part of the spray nozzle air cap, is formed on the forward periphery of air cap 62, and metal ring 66 is connected to a source of high voltage (not shown). In this example, the needle electrode 64 is of the type generally described in connection with this invention; and the forward point of needle 64 is placed into the atomisation zone for the liquid particles emanating from the nozzle 58. The ionising field is developed between the point of needle electrode 64 and the circumferential ring 66, thereby creating a uniform ionising field through which all of the atomised particles will pass.

In operation, the high voltage supply to the electrostatic needle of the spray gun shown in the various embodiments is approximately 15 kV. This voltage will create a stable corona current at least in the range of 20-50 microamps (μA) wherein the enter corona current flows from the extremely sharpened tip of the electrostatic needle. This relatively high corona current put together with the sharpened needle point tends to create heat in the vicinity of the needle point; and therefore, it is important that the needle be made from a material which has a high melting point in order to maintain the sharpness of the needle point when heated. The preferred material for use in connection with this invention is tungsten, although carbon, osmium and rhenium also have melting points in excess of 3,000^{o} C. Other materials with high melting points which might be suitable for use in connection with the invention include boron, molybdenum, niobium, tantalum and ruthenium, but other factors such as cost may limit the choices of material. In operation, the intensely high electrostatic field which emanates from the sharpened point of the needle is distributed to the grounded electrode in such a manner that the electrostatic field is relatively centred in the flow of the atomised particles emanating from the spray gun. Therefore, the high proportion of the atomised particles become ionised and are electrostatically attracted to the article to be painted, which itself is held at ground potential.

The present invention may be embodied in other specific forms without departing from the essential attributes thereof; and it is, therefore, desired that the present embodiment be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than to the foregoing description to indicate the scope of the invention. For example, the principles of the present invention could be achieved with an electrode having a sharpened edge, even though not in the form of a needle if the teachings herein were applied to its construction.

The aforegoing description has been given by way of example only and it will be appreciated by a person skilled in the art that modifications can be made without departing from the scope of the present invention.

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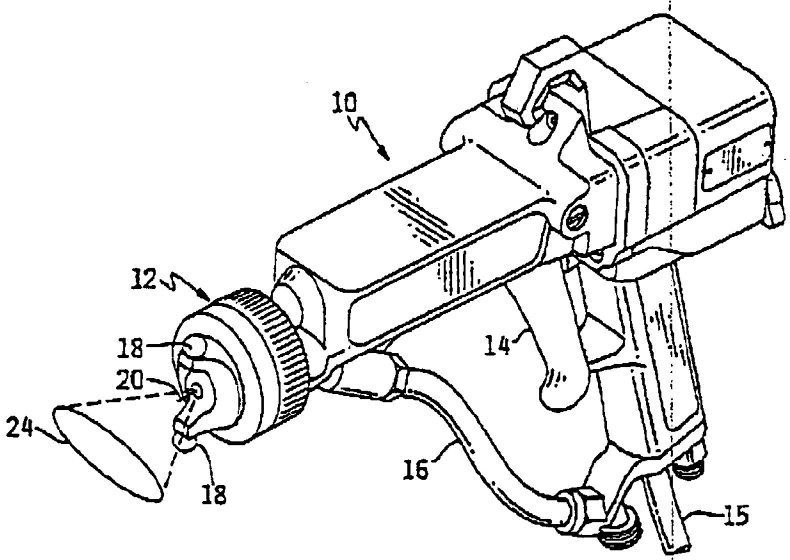

FIG. 1

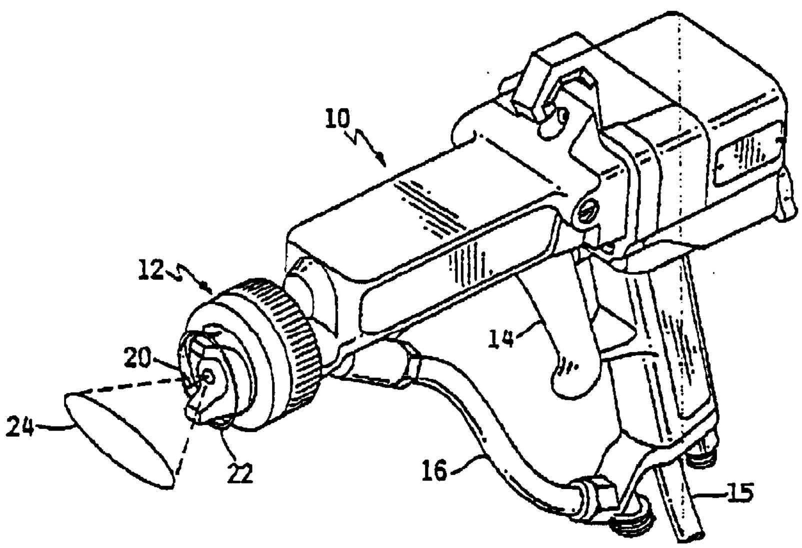

FIG. 2

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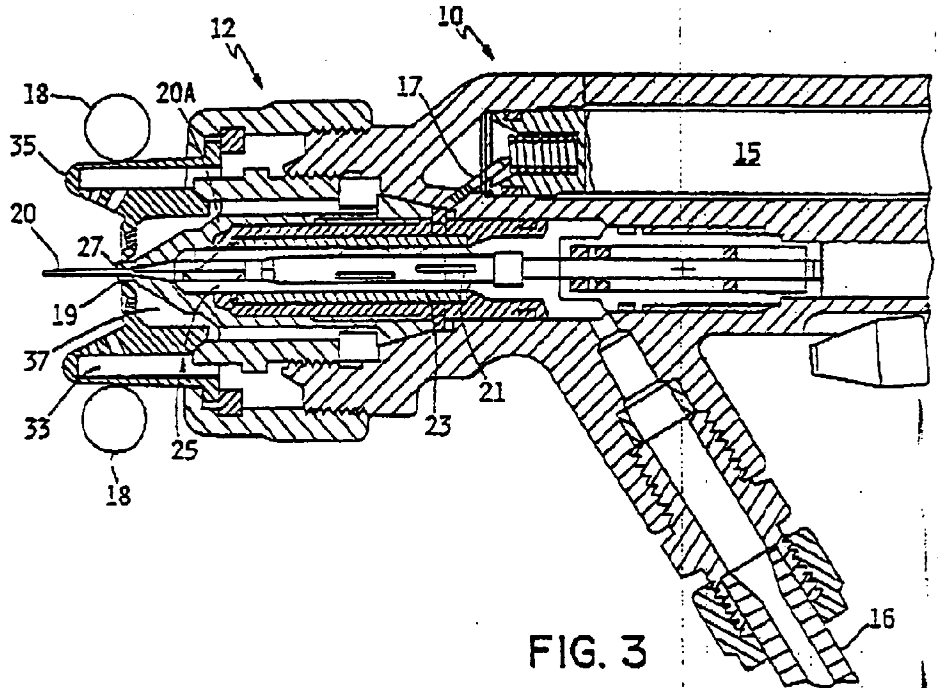


FIG. 3

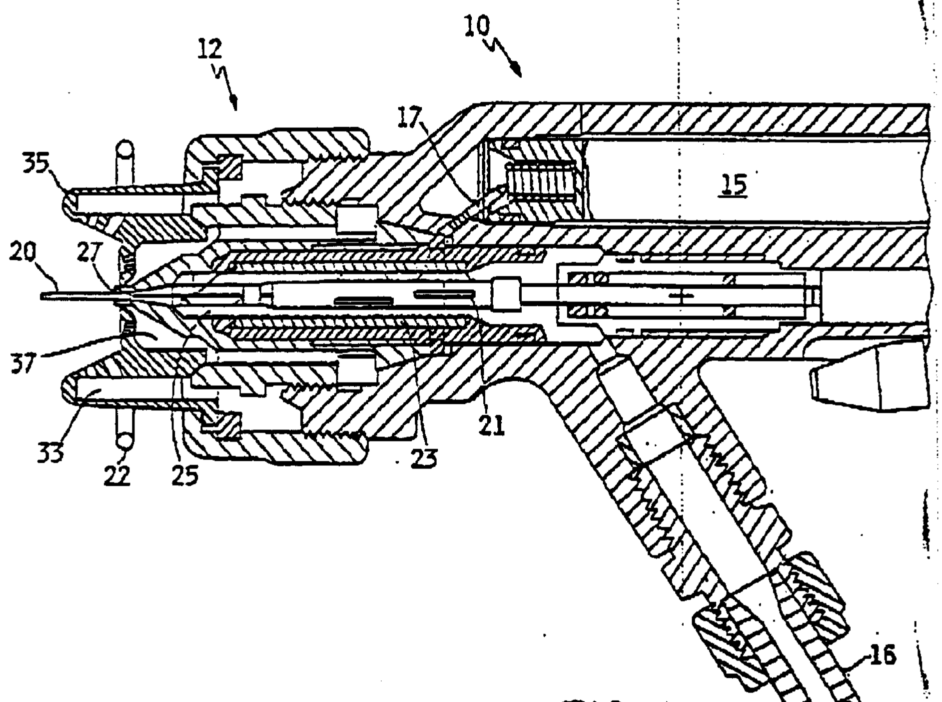
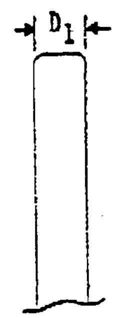


FIG. 4

A3/4



(PRIOR ART)
FIG. 5

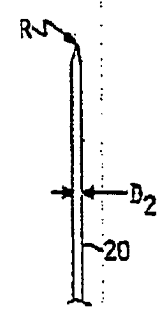


FIG. 6

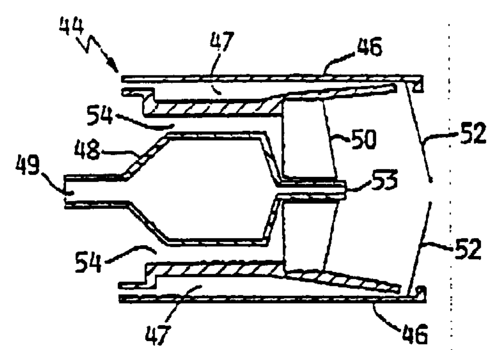


FIG. 9

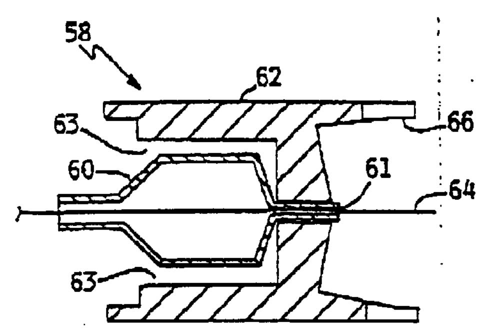


FIG. 10

A4/4

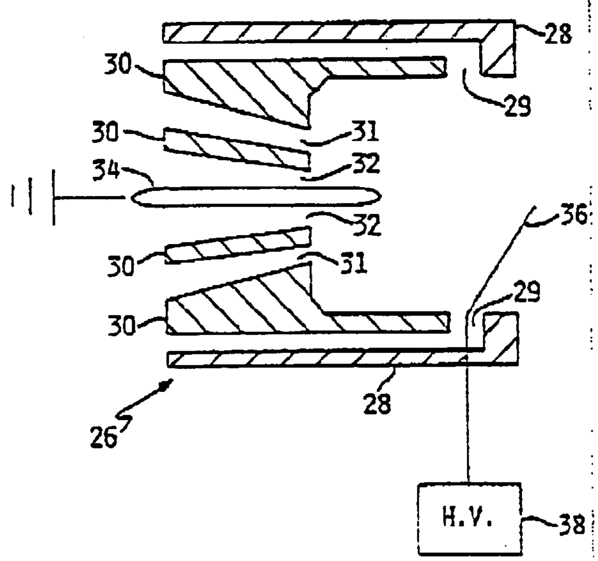


FIG. 7

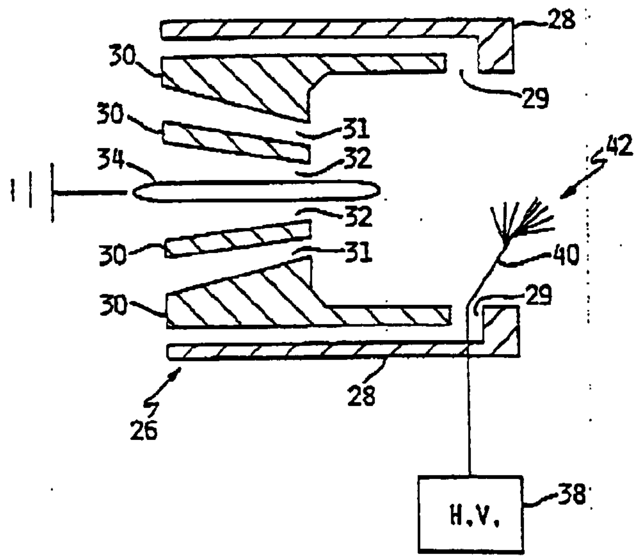


FIG. 8

Claims

1. An electrostatic ionising system for use with a sprayer (10) emitting a pattern of atomised particles (24) of otherwise conductive liquid, the system comprising:

   an electrode (20) having a sharpened edge with a radius of curvature (R) of less than 50µm, which, in use, is positioned such that the sharpened edge is outside the pattern of atomised particles (24) and remote from the sprayer (10); and
   a further electrode (12) which is formed as part of the sprayer (10);
   the sharpened electrode (20) operable in conjunction with the further electrode (12) such that a voltage differential can be developed therebetween to provide an electrostatic field and corona discharge for charging particles emitted through the field.

2. A system as claimed in claim 1, comprising means (15) for applying the voltage difference between the two electrodes (12,20).

3. In an electrostatic atomizer (10) having an ionizing electrode (20) operable in conjunction with a second electrode (12), with a voltage differential developed therebetween, for providing an electrostatic field and corona discharge for charging a pattern of conductive liquid particles emitted through the field by the sprayer (10), the improvement in an ionizing system comprising:

   (a) said ionizing electrode (20) positioned outside the pattern of particles emitted from the atomizer (10), but remotely from the atomizer, and said ionizing electrode (20) having a sharpened edge with a radius of curvature less than about fifty micrometers; and
   (b) said atomizer (10) comprising said second electrode (12), said ionising electrode being positioned about 10.16cm (four inches) from said atomizer (10).

4. An electrostatic ionizing system for attachment to a sprayer (10) proximate the atomizing nozzle (12) which emits a pattern of atomized particles of otherwise conductive liquid, comprising:

   (a) a sharpened tip electrode (20) positioned to place the tip of said electrode (20) outside the pattern of atomized particles, and remote from the sprayer (10), said electrode (20) having a sharpened tip with a radius of curvature (R) of less than 50 micrometers;
   (b) said sprayer (10) comprising a second electrode (12); and
   (c) means (15) for applying a voltage potential difference between said sharpened tip electrode (20) and said second electrode (12).

5. A system as claimed in any preceding claim, wherein the sharpened electrode (20) is a needle having a sharpened tip with a radius of curvature (R) of less than 50µm.

6. In an electrostatic sprayer (10) having an ionizing needle (20) operable in conjunction with a second grounded electrode (12), with a voltage differential developed therebetween, for providing an electrostatic field and corona discharge for charging liquid particles from an otherwise conductive liquid, emitted through the field by the sprayer (10), the improvement in an ionizing system comprising:

   (a) said ionizing needle (20) positioned outside the pattern of particles emitted from the sprayer (10), but remotely positioned from the sprayer (10), said ionizing needle (20) having a sharpened point with a radius of curvature (R) less than about fifty micrometers; and
   (b) said second electrode (12) forming a part of said sprayer (10).

7. An electrostatic ionizing system for use in connection with a sprayer (10) for spraying conductive liquid particles, having a conductive needle (20) positioned near the centre of the sprayer (10) sprayed particle pattern (24), the needle (20) having a diameter of less than about 250 micrometers and a needle tip sharpened to have a radius of curvature (R) of less than about 50 micrometers, and a second electrode (12) spaced approximately 10.16 cm (four inches) from the needle (20) and being formed as a part of said sprayer (10).

8. A system as claimed in any of claims 5 to 7, wherein the needle has a diameter of less than about 250µm.

9. A system as claimed in any preceding claim, wherein the sharpened electrode or needle (20) comprises a metallic member having a melting point of at least 2,300°C.

10. A system as claimed in any preceding claim, wherein the sharpened electrode or needle is of tungsten material.

11. A system as claimed in any preceding claim, wherein the voltage differential is greater than about 40kV.

12. An electrostatic ionising system for attachment to an atomiser for emitting a pattern of atomised particles, the system comprising:

an electrode (12);
an ionising electrode (20) operable in conjunction with the electrode (12) such that a voltage differential can be developed therebetween to provide an electrostatic field and corona discharge for charging particles emitted through the field; whereby
the ionising electrode (20) has a sharpened edge with a radius of curvature (R) less than about 50µm.

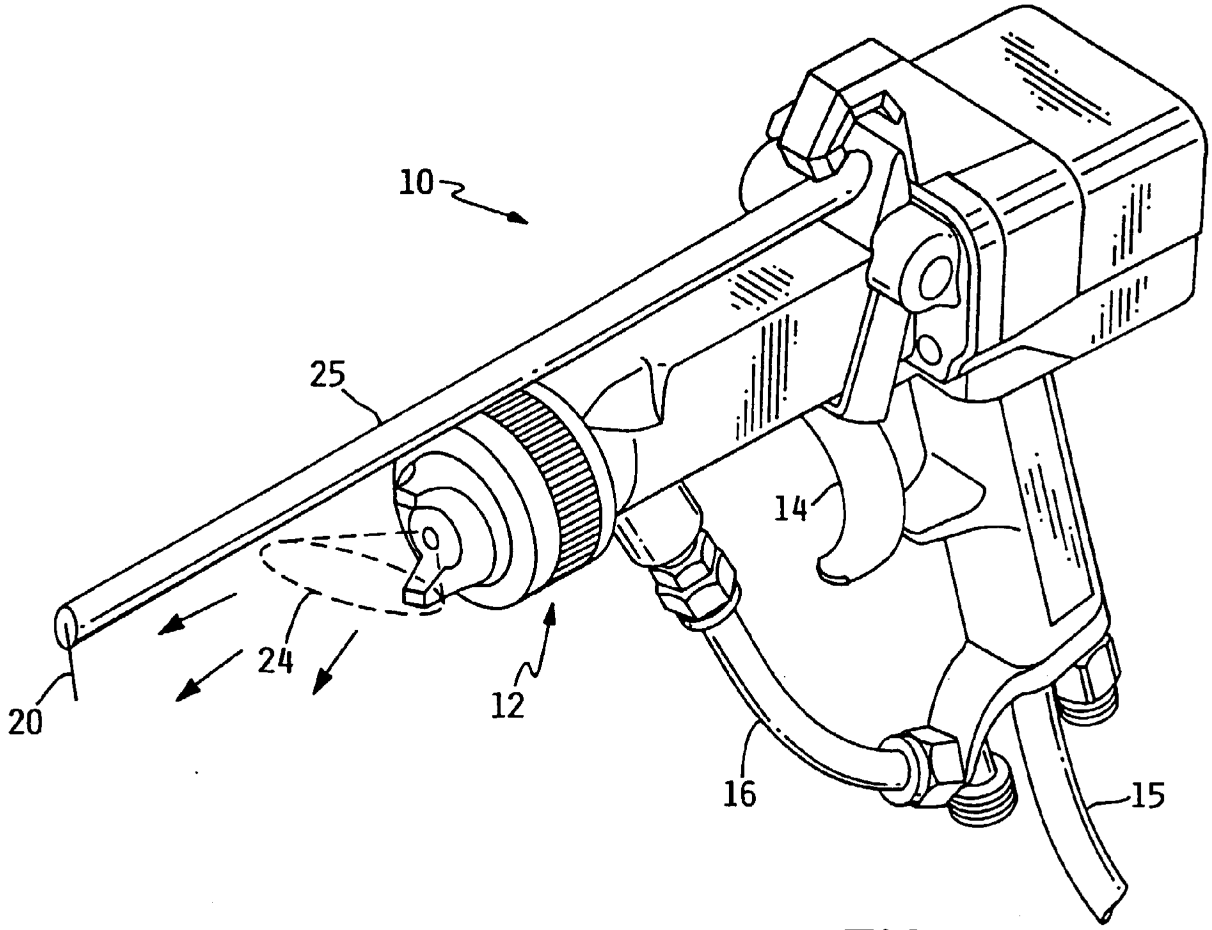
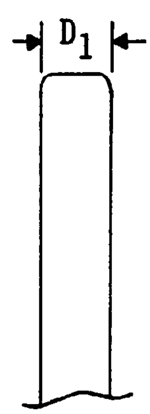


FIG. 1



(PRIOR ART)
FIG. 2

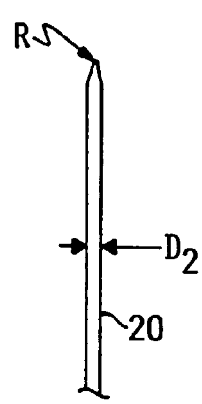


FIG. 3