United States Patent [19]

Nord et al.

[11] **3,747,852**

[45] **July 24, 1973**

[54] **PAINT SPRAYING METHOD**

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[73] Assignee: **Nordson Corporation,** Amherst, Ohio

[22] Filed: **Sept. 2, 1971**

[21] Appl. No.: **177,432**

Related U.S. Application Data

[62] Division of Ser. No. 23,227, March 27, 1970, Pat. No. 3,635,400.

[52] **U.S. Cl.** **239/8**

[51] **Int. Cl.** **A01n 17/02,** A62c 1/12

[58] **Field of Search** 239/422, 8, 3, 10, 239/292, 300

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Primary Examiner—Lloyd L. King

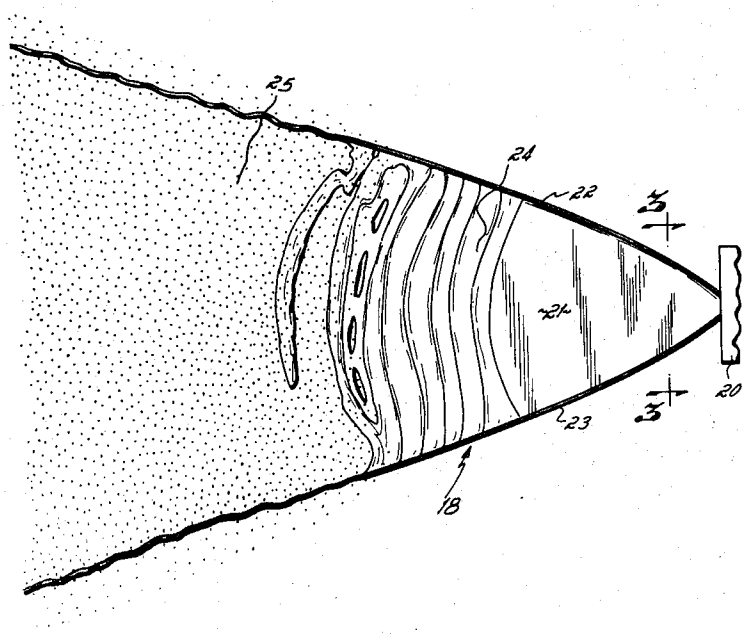
Attorney—Wood, Brinkman, Jr. et al.

[57] **ABSTRACT**

A method and apparatus for spraying paint and similar coatings. In one form the paint is sprayed at low pressure from a flat fan nozzle. A flat fan of air impinges upon the fan of paint at an angle of from 30°–70°. The air atomizes the paint to form a soft spray with low forward velocity. In another form of the method, two fans of paint are projected toward one another at an angle and an air fan is directed along the bisector toward the zone of intersection. The air fan atomizes both streams of paint. An electrode can be placed in the air stream to ionize the air stream which in turn charges the paint particles. The width of the paint spray pattern is varied by varying the included angle of the air fan.

A spray gun is disclosed having two tubular paint nozzles for projecting two fan-shaped fans of paint. An air nozzle is mounted between the paint nozzles for projecting a fan of air against the paint fans to atomize the paint. The air nozzle is adjustable to provide air fans of different angles for varying the width of the paint spray pattern. An electrode is disposed in the air nozzle for ionizing the air stream. This electrode is energized through a resistor and flexible cable. The cable is spring-urged toward the resistor so that when the resistor is removed, the cable shifts causing a safety switch to open deenergizing the gun. When a nozzle mounting member is removed, the cable and surrounding tube are shifted forwardly to automatically close a valve to seal off the air and electrical conduits. Removable caps are provided on the ends of the tubular paint nozzles for facilitating cleaning of the nozzles.

37 Claims, 19 Drawing Figures



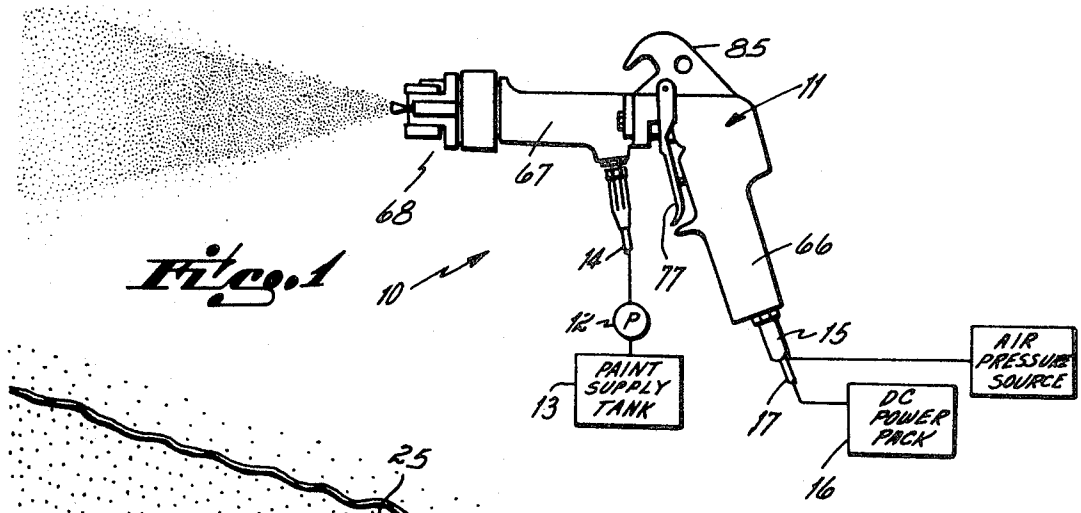


Fig. 1

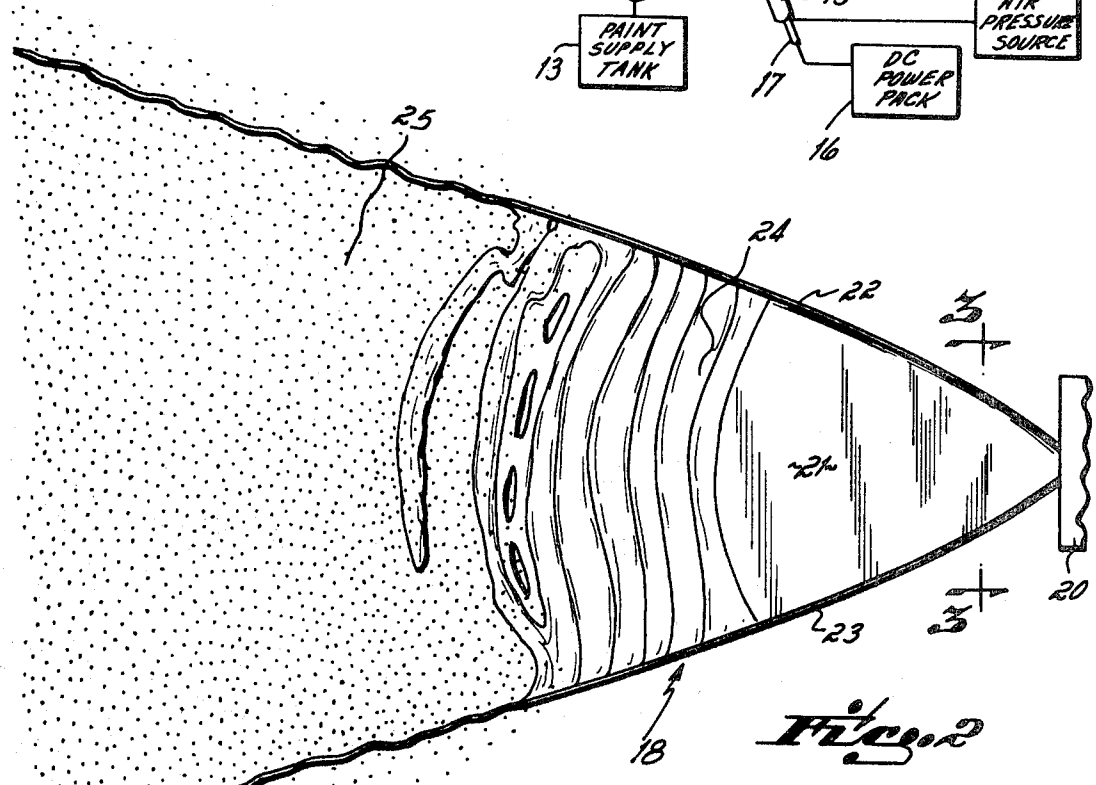


Fig. 2

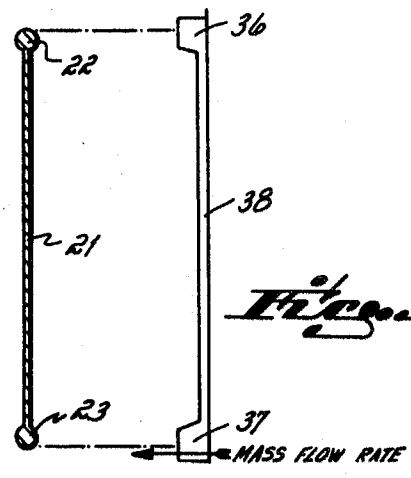


Fig. 3A

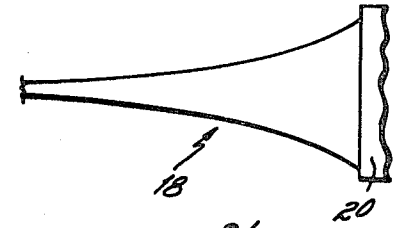


Fig. 4

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Fig. 3

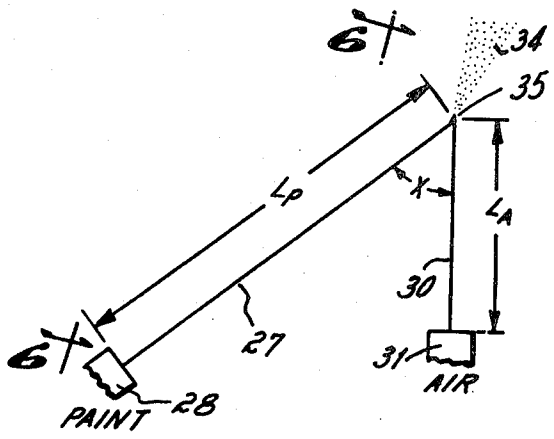


Fig. 5

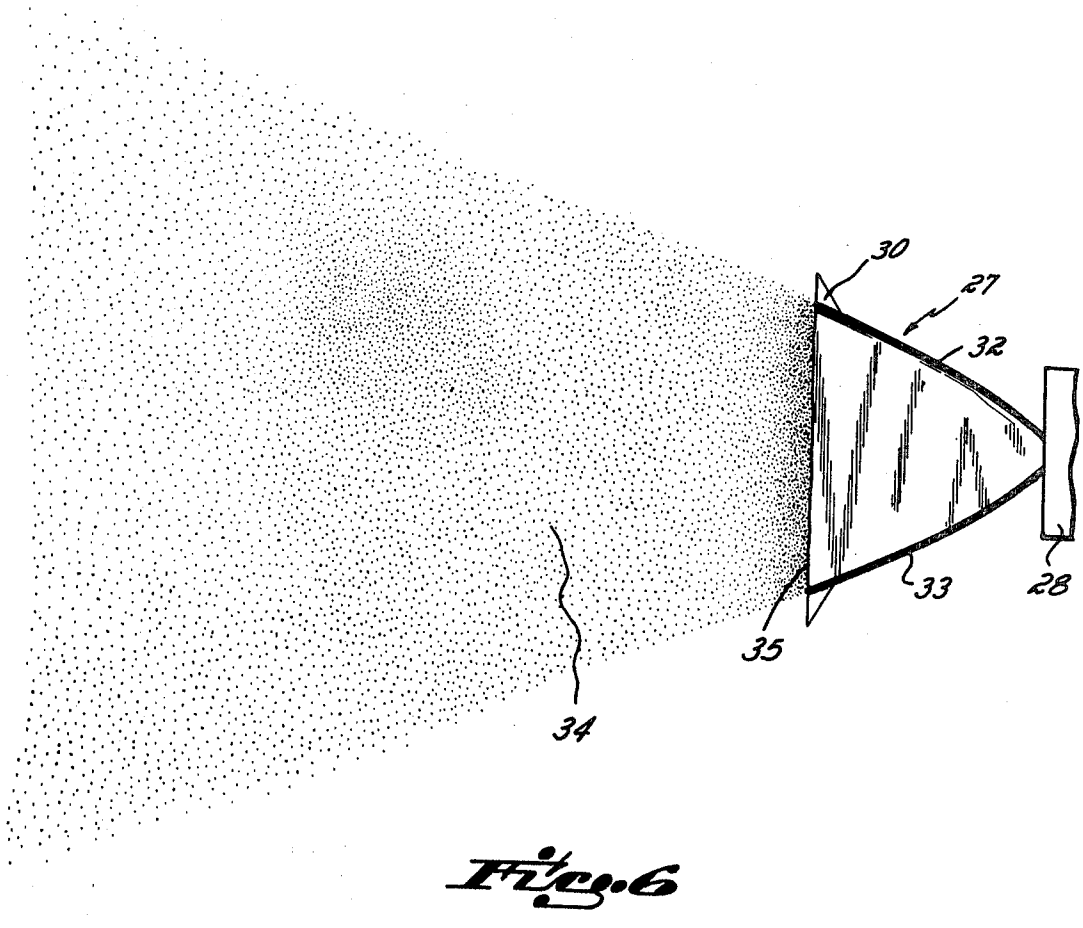


Fig. 6

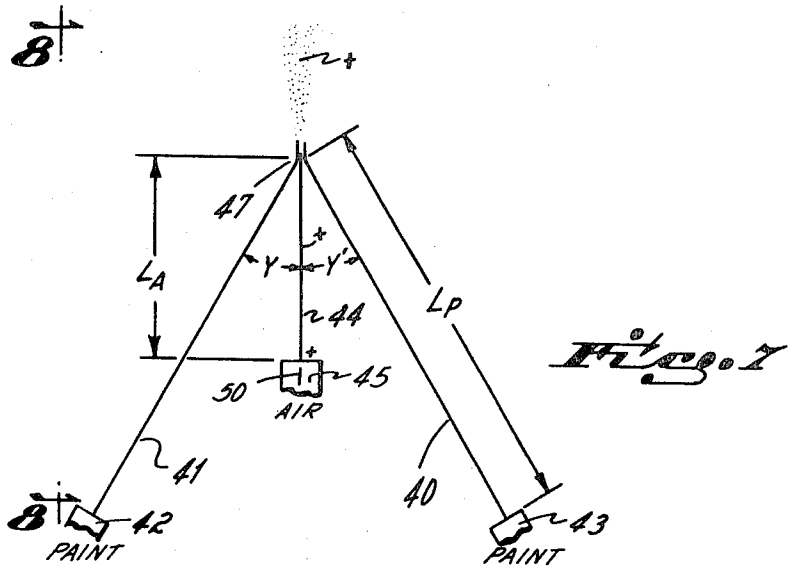


Fig. 1

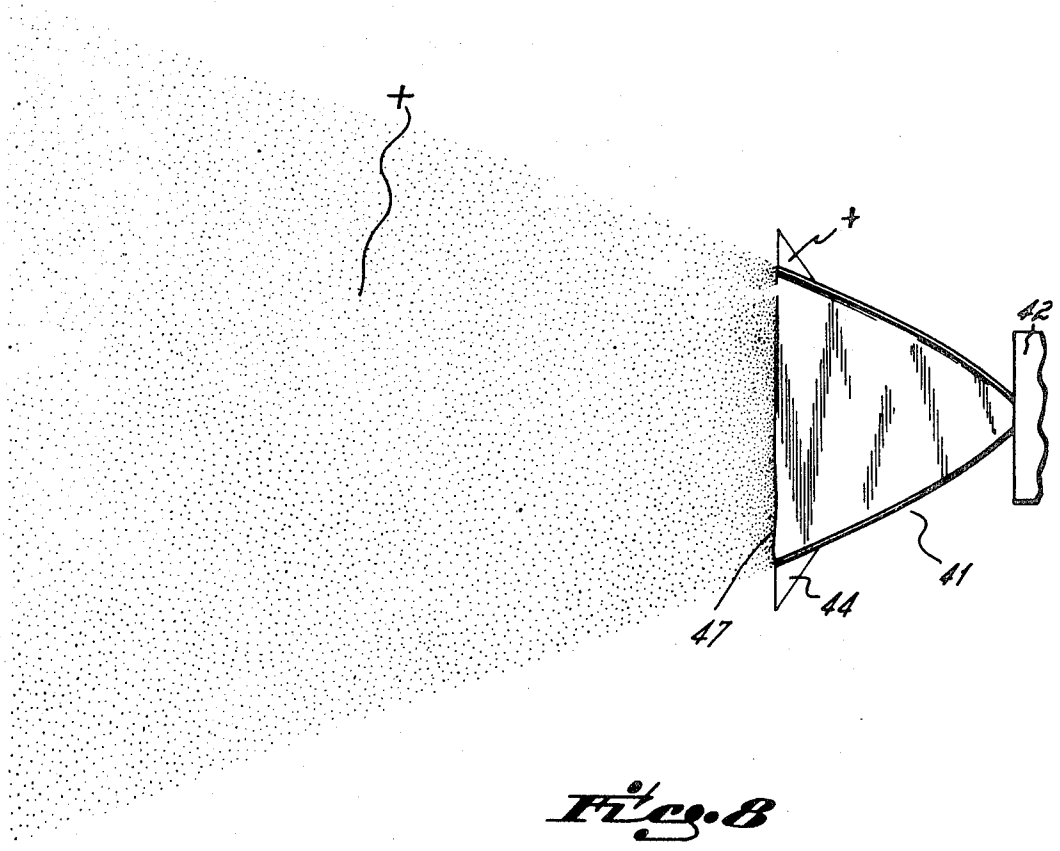
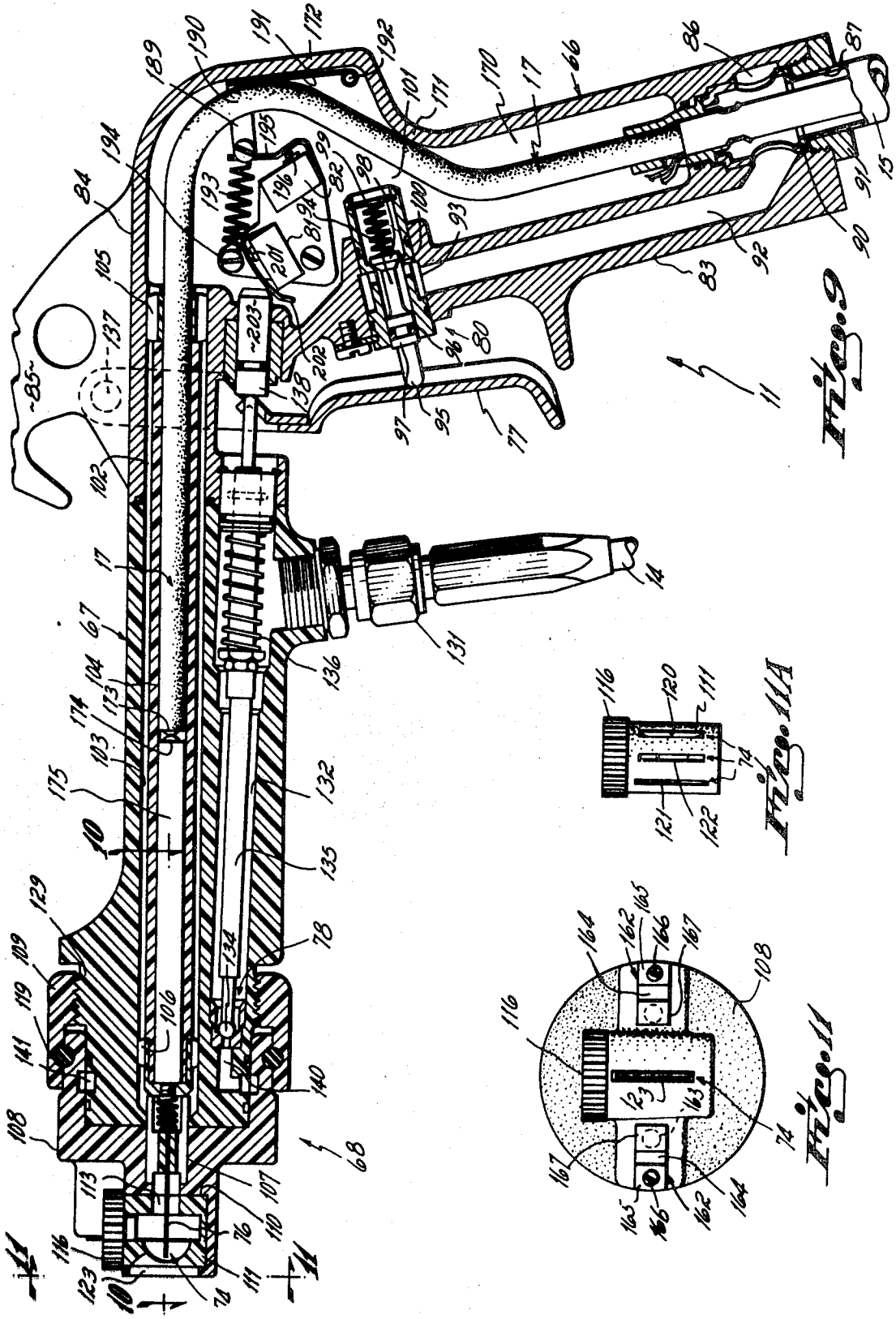


Fig. 8


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Fig. 9
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Fig. 11A
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Fig. 11

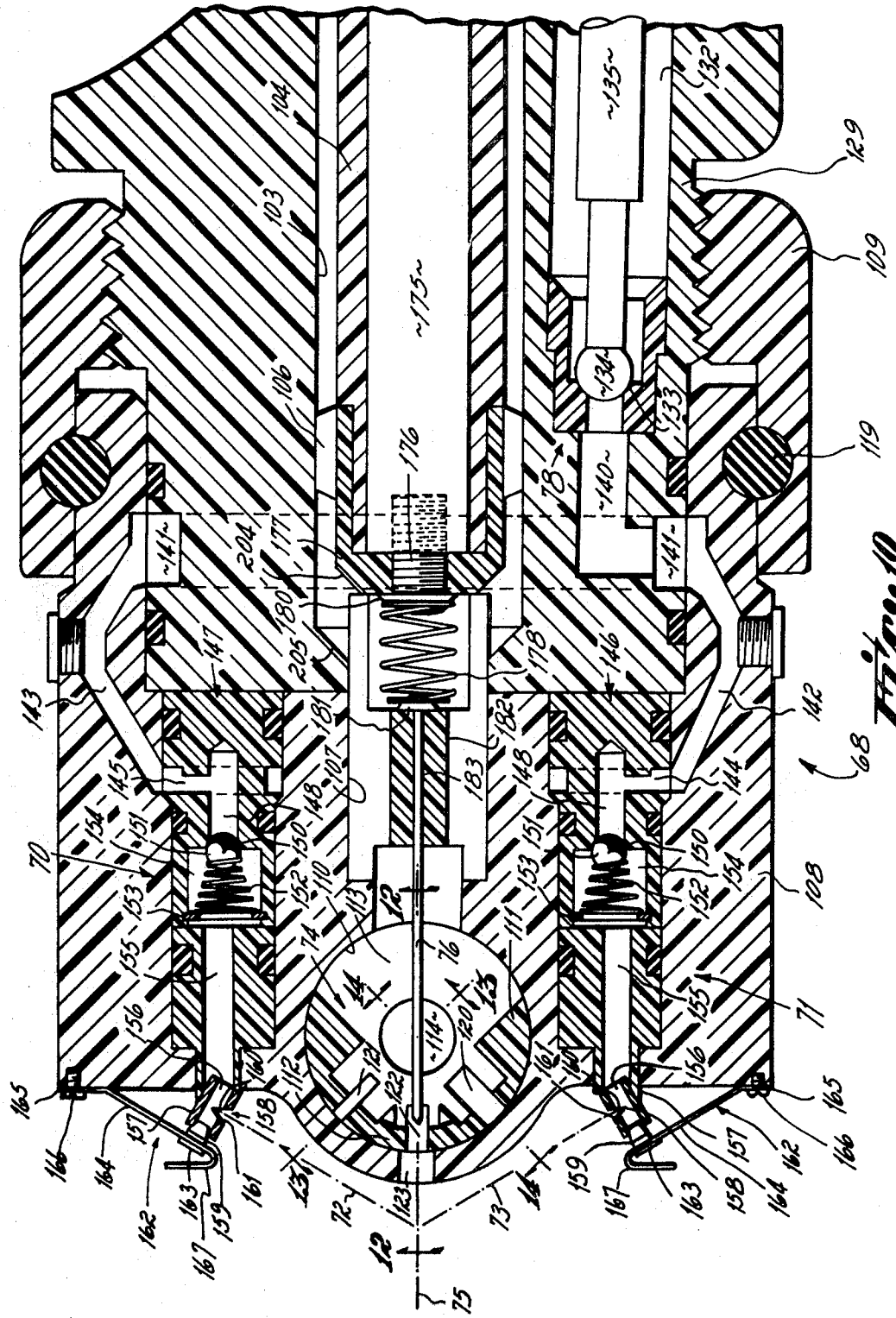
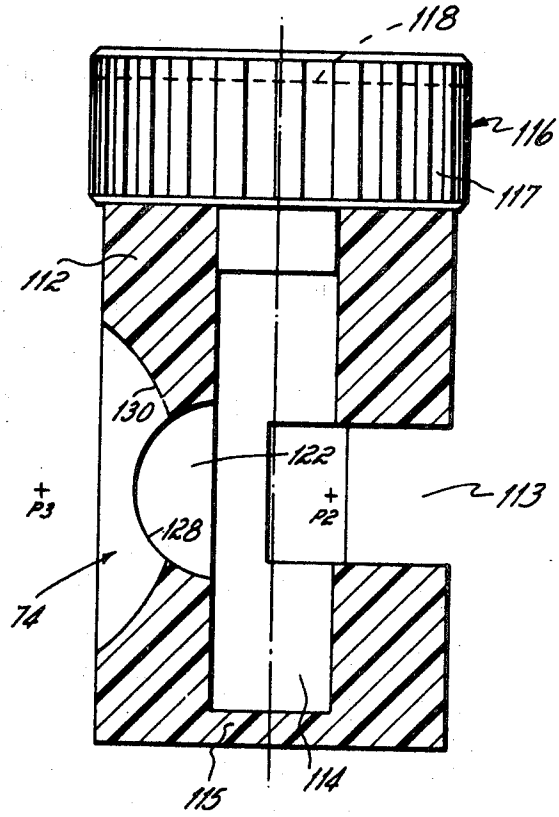


Fig. 10

Fig. 12



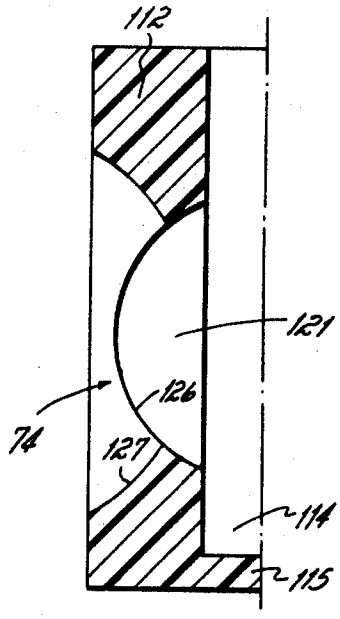


Fig. 13

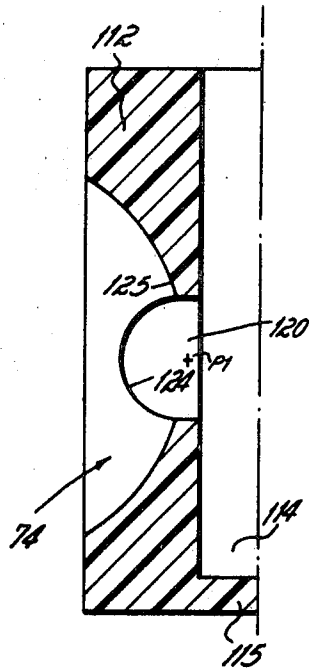


Fig. 14

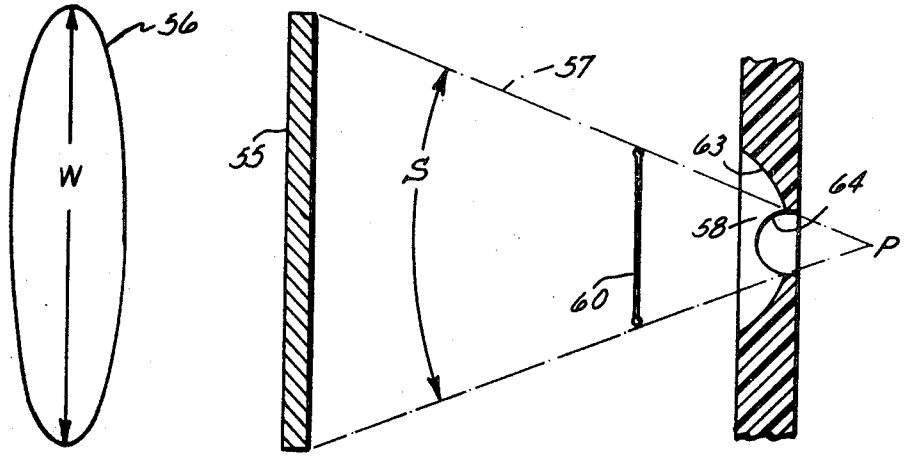


Fig. 15

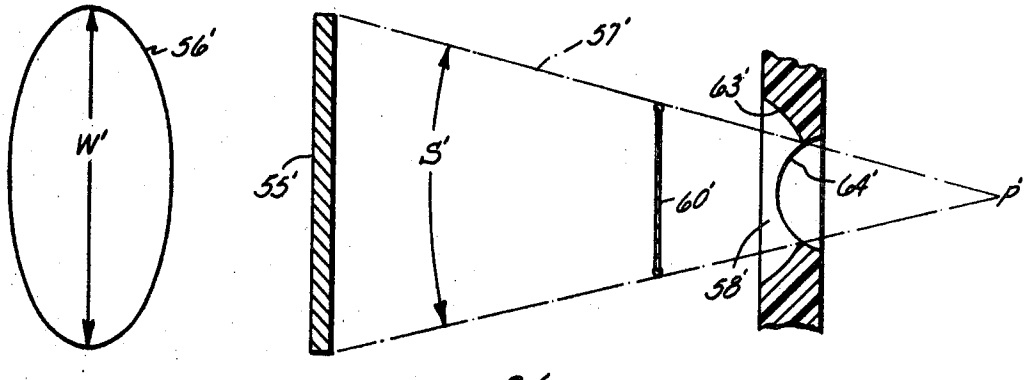


Fig. 16

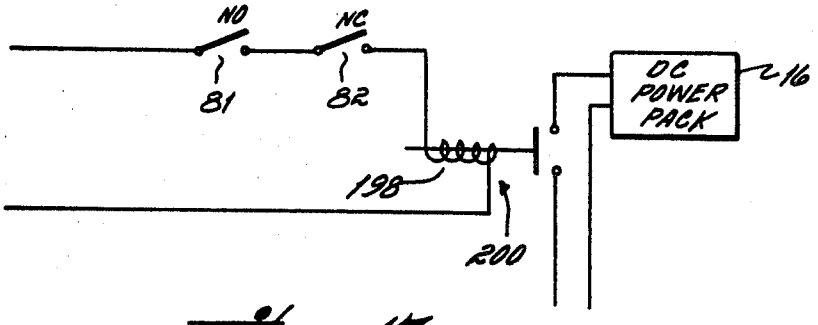


Fig. 17

PAINT SPRAYING METHOD

This application is a division of parent patent application Ser. No. 23,227, filed Mar. 27, 1970, now U.S. Pat. No. 3,635,400, issued Jan. 18, 1972 in the names of Eric T. Nord et al.

BACKGROUND OF THE INVENTION

This invention relates to methods and apparatus of spraying paints, lacquers and similar coating materials and is particularly directed to a novel method and apparatus for effecting air atomization of the paint and for electrostatically charging the paint if desired so that the electrostatic field forces can be utilized to increase the effectiveness of paint deposition.

In the past there have evolved two distinct types of paint spraying equipment. The first type can be characterized as "airless" spraying equipment. In an airless type of spraying apparatus, a paint stream is forced through an orifice under a relatively high pressure, for example, a pressure of the order of 300–1,000 pounds. As the paint is propelled through the small orifice it is broken up, or atomized, into very fine droplets. The paint spray formed from the gun moves at a relatively low velocity toward the article to be painted. In many cases the paint spraying operation is carried out in the presence of a high voltage electrostatic field in which the work to be coated is kept at, or close to, ground potential while the atomized paint particles are charged to a relatively high potential. These particles are then urged toward the work by the forces of the electrostatic field.

This type of system has the recognized advantage of providing a very high deposition efficiency, i.e. a large portion of the paint spray emitted from the gun is effectively deposited on the article to be coated. On the other hand, in some installations the airless spray-type apparatus has certain inherent shortcomings. One such objectionable characteristic is that the system requires a paint supply system operated at a relatively high pressure. As a result, it is not feasible to disconnect a gun from one high pressure paint line and quickly connect it to another high pressure paint line when, for example, it is desired to change the color of coating being sprayed.

The second general type of spray equipment does not require a high pressure paint source. This second type of spray system, which is known as "air spray" equipment, relies upon a stream of air to break up the paint into particle size suitable for spraying. In conventional air spray equipment, the paint is extruded from a nozzle in a generally rod-like form and is subjected to a high pressure blast of air. In a typical air spray installation, the air pressure at the gun is under a pressure of approximately the order of 75 pounds per square inch. The air is used in large quantities; for example, it is common practice to utilize an air flow of 14 or 15 standard cubic feet of air per minute to carry out atomization.

Air spray systems of this type do present certain advantages in that they can be utilized to atomize particularly difficult types of paint and can more readily be provided with quick disconnect couplings to the paint line since the paint line is maintained at a relatively low pressure of, for example, 50 psi. At the same time, however, prior art paint spray guns are subject to several disadvantages.

In the first place, the large quantity of high velocity air used to atomize the paint together with the air flow it induces causes a substantial portion of the paint spray to be carried past the workpiece and wasted even when an electrostatic charge is applied to the paint. Moreover, the rapidly moving air has a high kinetic energy which causes it to bounce back or rebound from the surface being coated carrying with it entrained paint particles. Consequently, an appreciable portion of the paint which is directed toward the workpiece is wasted due to rebound.

Another inherent disadvantage of conventional air spray equipment is the problem of ventilation. Specifically, because of the high volume of air emitted by each spray gun, and in many installations there are several guns operating simultaneously, a ventilation system must be provided having a high capacity for capture of paint particles entrained in the large mass of high-speed air, for example, capture velocities of 150 feet per minute.

Also, because of paint entrained in the large amount of over-spray and rebound, water curtains or other types of filters must be provided for preventing sizable quantities of paint from escaping and polluting the atmosphere.

SUMMARY OF THE INVENTION

The principal object of the present invention is to provide a novel method and apparatus for spraying paint in which relatively small quantities of air at a relatively low pressure are utilized to atomize the paint in a very effective manner so that the resultant paint spray is a soft, finely divided spray not unlike that which could heretofore be produced only by an airless gun.

At the same time, the present method and apparatus are effective to retain the advantages inherent in any air-type of spray gun, i.e. the ability to atomize various difficult types of coating material and the facile interconnectability to various paint lines so that the spary gun can be converted quickly from spraying one color or type of coating to another.

More particularly, the present invention is predicated in part upon the concept of spraying paint by emitting a thin, flat fan-shaped stream of paint from one nozzle and a fan-shaped stream of air from a second nozzle. The paint fan in most cases is initially in the form of a continuous sheet. However, the fan can be in the form of a thin, substantially planar discontinuous spray; for example, one which is already partially atomized. The fan-shaped stream of paint and air impinge upon one another at a substantial angle of from approximately 30°–70°. The air thus exerts an optimum shearing force upon the paint fan and breaks the paint down into small particles of a low mean particle size with substantially no particles of an objectionably large size.

This invention is further predicated in part upon the empirical discovery and determination of various physical relatioships and values of certain parameters which make it possible to obtain an atomization suitable for fine finishing purposes utilizing as one starting component a low pressure fan of paint. A flat stream of paint from any presently known form of fan nozzle operated at low pressure is inherently in a very difficult form to atomize into small particles with the uniformity required for producing satisfactory painted surfaces.

The difficulties involved are due to the fact that the paint stream is not a uniformly thin flat sheet. Rather,

the sheet in cross-section is somewhat like a dumbbell with a thin center web and two enlarged portions, one at each edge. These enlarged portions are in fact longitudinal beads or "streamers." These two streamers are several times the thickness of the central web portion and tend to remain integral and resist atomization even when the rest of the sheet is broken up into particles. It will readily be appreciated that no matter how finely most of the paint is atomized, if the streamers are not broken up into particles of generally the same fineness, the quality of the applied coating will suffer and may well become totally unacceptable. The present paint spray method is effective to cause effective break-up of all parts of the paint stream, including the streamers, into small particles while using only a relatively small quantity of air.

In accordance with the present invention, the air stream is projected under a relatively low pressure, for example, of the order of 9 to 45 pounds per square inch at the gun, while the paint is sprayed under a low pressure of, for example from 30–80 pounds per square inch. This method of atomization is so effective that the quantity of air required to deposit a relatively large quantity of paint, for example, 22–25 fluid ounces per minute of a typical baking enamel, is approximately 7–8 standard cubic feet per minute. As a result of this small volume of low pressure air and the fine atomization of the paint, the resultant spray is in the nature of a soft spray, or slowly moving fog, having a low forward velocity.

One of the principal advantages of this method of spraying is that it results in a substantially higher deposition efficiency than conventional air spraying methods. There is substantially less paint waste due to overspray and rebound which is minimized or practically eliminated.

Another advantage of the present spray method is that the relatively small quantity of air involved and the smaller quantity of paint entrapped in the exhausted air greatly simplifies the problem of ventilation and prevention of atmospheric contamination.

Another object of the present invention is to provide a novel method for readily changing the width of the paint spray pattern. This aspect of the present invention is predicated upon our determination that the width of the paint spray can be controlled by changing the included angle of the air fan without in any way changing the paint fan.

In accordance with the present invention, the air fan is selectively emitted from one of a series of nozzle openings constructed so that the nozzle openings not only simultaneously produce air fans of different included angles, but also produce air fans which behave much as though they are emitted from a point pressure source, the distance from the nozzle opening of which is varied in an inverse relationship to the angular size of the nozzle opening. By virtue of this relationship, the height of the air fan along its line of impingement with the paint stream is maintained substantially constant so that all portions of the paint stream are effectively atomized with a minimum air usage.

In addition to the method concepts disclosed above, the present invention also comprehends a preferred spray painting method utilizing in part the method described. More particularly, in the preferred method a fan of air is in effect "enveloped" between two fans of paint. The fans of paint are directed toward each other with the air fan bisecting the angle so that it impinges upon both paint streams in substantially the same zone. This method results in an even better atomization than the single spray method, apparently due to the fact that in order to escape, a major portion of the air must pass through one or the other paint streams or through the paint particles being separated from the streams. Thus, the kinetic energy of the air is more effectively utilized to shear the paint and cause its break up into particles of a small mean particle size.

The present two-paint stream method of spraying is also particularly advantageous when employed in conjunction with the present novel method of electrostatic charging. More particularly, in accordance with the present charging method, the paint is not charged directly or by an electrode in close proximity to the paint stream. Rather, it is our concept to ionize the air fan prior to its impingement upon the paint streams by passing the air fan through a corona discharge surrounding an electrode at a high potential. As explained above, the air fan then impinges upon the paint streams and causes the atomization of the paint streams.

The ions present in this air stream have a high mobility and are subjected to the forces of the surrounding electrostatic field. Specifically, these ions, which are charged and exist in a field of high potential, move toward the paint streams and fog of paint droplets existing in regions of a lower potential. The ions attach themselves to the paint particles which are of substantially lower mobility. These charged paint particles are propelled forward by the air stream and under the additional influence of the electrostatic field forces are brought into contact with the surface to be coated which is normally maintained at ground potential.

We have determined that the two-paint stream method results in substantially more effective charging of paint particles than the one-spray method and believe that this is due to the fact that the ions are to a large degree surrounded by the paint streams and particles and do not have a free path to one side of the paint as is the case when only a single paint spray is utilized.

The present method of charging paint is not only advantageous because of its high efficiency, but is further advantageous because the entire paint supply system, including the tube supplying paint to the gun, the paint pump and the paint reservoir, or tank, remain at or near ground potential.

In contrast, in prior art electrostatic spraying systems, particularly when a conductive paint or coating, such as one of the metallic-containing finishes utilized in the automobile industry, is used, the entire paint system became charged to the same order of potential as the electrode, e.g. 75,000 volts. This necessitated careful insulation of the entire paint system including the paint reservoir. In the event of insulation failure, for example in the paint supply tube, the high potential present could, and not infrequently did, result in fires, electrical shock hazards, and other operational difficulties. All of these problems are completely eliminated by the present charging method in which no charge is applied directly to the paint either by an electrode in contact with the paint or by an electrode in close promximity to the paint stream.

In addition to the method aspects of the present invention, the invention is directed to the provision of a novel spray gun for carrying out the method. More particularly, the present spray gun includes a handle, a for-

wardly extending barrl and a nozzl assmbly mountd at the forward nd of the barrl.

The nozzle assembly comprises two tubular paint nozzles effective to direct thin flat fan-shaped paint sheets toward the axis of the gun, and an air nozzle mounted between the paint nozzles and effective to direct a flat fan-shaped stream of air along the axis of the gun toward the zone of intersection of the two paint fans. In accordance with the present invention the air nozzle and paint nozzles are located so that the distance of the air nozzle from the zone of air-paint impingement is only a fraction of the distance of the paint nozzles from the zone of air-paint impingement. As a result, the velocity of the air issuing from the nozzle is attenuated only minimally prior to its impingement with the paint fans. Each of the paint fans and air fan meet at a substantial angle of the order of 30° to 70°. As a result, the air fan exerts an optimum shearing force on the paint fans and breaks up both fans simultaneously into a spray of particles of small mean particle size free from inordinately large particles.

One of the advantages of the present gun is that it is quite compact and maneuverable. Despite the fact that the gun utilizes three separate nozzles it is as small and easy to handle as previous spray guns of the air or airless type.

It is another objective of the present invention to provide a spray gun incorporating paint charging means of a substantially increased efficiency. In fact, the present electrostatic charging system is so efficient that when operated at 50,000 volts or even less, it provides the same deposition efficiency as is attained using a conventional electrostatic charging mechanism operating at a potential of 75,000 volts.

More particularly, in accordance with the present invention the gun includes an electrode mounted within the center air nozzle in alignment with the nozzle discharge opening. This electrode is effective to establish a corona through which the air passes prior to its discharge from the nozzle. As the air passes through the corona the gas molecules are ionized and dust particles charged. These charged particles move under the electrostatic field forces toward the paint which is at a low potential and are subsequently deposited on the low mobility paint particles.

As indicated above, one of the principal advantages of this invention is that the paint stream itself does not become charged so that there is at most a negligible charge build-up in any portion of the paint supply system.

Another objective of the present invention is to provide a charging circuit which is substantially safer to use than the prior art. More particularly, in many conventional prior art charging systems the charging electrode projects forwardly from the end of the spray gun. This high potential electrode is thus in an exposed position in which it can be touched accidentally by a workman or can be shorted by accidental contact with a grounded conductor. In contrast, the electrode of the present invention is buried within the air nozzle where it is effectively shielded from any contact with either the person using the gun or a grounded surface.

The present gun also embodies a second important safety feature which automatically prevents the application of a high potential to the gun in the event that the current-limiting safety resistor is left out. More particularly, it is common practice to provide a resistor in series with the electrode and the cable connecting the power pack to the gun. When a spray gun is overhauled, the resistor is often removed and at times a workman may neglect to replace it when reassembling the gun. When such a resistor is omitted the full potential from the power pack can be capacitively discharged across the void and applied to the gun electrode. In such a case, if a gun is brought too close to a grounded article, a spark may occur which might cause an ignition of the paint material or cause a painful electrical shock to the operator.

In accordance with the present invention, this is prevented by a novel safety switch arrangement in which the main power is automatically cut off whenever the resistor is removed from the gun.

Another objective of the present invention is to provide a construction in which the air and electrical conduits are automatically sealed off when the gun is disassembled by removing the nozzle assembly. In accordance with the present invention, this is accomplished by providing a valve seat at the forward end of the air and electrical conduit in the gun barrel and by providing a shiftable sleeve having a valve-closing plug at its forward end. When the gun is disassembled, this sleeve is spring-urged to the valve closing position to seal off the entrance to the air and electrical conduit. In so moving, it alao cuts off the power supply.

A still further objective of the present invention is to provide a novel form of air nozzle for selectively varying the air spray to change the size of the paint spray pattern.

In a preferred form of nozzle, the angle of air spray is changed by selectively emitting the air through one of a series of openings in a nozzle plug. The plug is provided with internal arcuate surfaces of different radii adjacent to each nozzle opening. We have made the empirical discovery and determination that air projected from such a nozzle appears to have somewhat the same properties as air emitted from a point source which is displaced from the nozzle opening a distance correlated with the radius of the internal nozzle surface.

To obtain a fan spray having a smaller included angle, the plug is shifted to present an opening in which the radius of this internal surface is greater so that a smaller segment of its periphery is cut away. This results in an air fan of smaller included angle and at the same time results in a shifting of the point source away from the nozzle opening. The net effect, as far as matching the width of the paint fans, is thus similar to shifting the nozzle away from the paint film. As a result, although its angle is smaller, the height of the air fan along the line of impingement of the paint film remains unchanged. Consequently, neither a large portion of the air stream is wasted by passing outside the confines of the paint film, nor are portions of the film improperly atomized due to the fact that they are not impinged upon by the air stream. At the same time the distance the air has to travel to reach the zone of impingement is minimized.

These and other objects and advantages of our invention will be more readily apparent from a consideration of the following detailed description of the drawings illustrating the principles involved in the present method of paint spraying and a preferred form of apparatus for carrying out the method.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagrammatic view of a paint spray system embodying the present invention.

FIG. 2 is a semi-diagrammatic elevational view of a paint spray issuing under relatively low pressure from a fan nozzle.

FIG. 3 is a cross-sectional view of the paint spray taken along line 3—3 of FIG. 2.

FIG. 3A is a diagrammatic view plotting the preferred distribution of mass flow rate from an air nozzle used to atomize a paint spray film.

FIG. 4 is an enlarged top plan view of a portion of the paint spray film shown in FIG. 2 illustrating the manner in which the paint spray film decreases in thickness as it travels away from the nozzle.

FIG. 5 is a diagrammatic view showing the cooperative relationship between a paint spray nozzle and an air spray nozzle in carrying out the present paint spray method.

FIG. 6 is a semi-diagrammatic view taken along line 6—6 of FIG. 5.

FIG. 7 is a diagrammatic view showing the relationship of two paint nozzles and an air nozzle to carry out a preferred method of paint spraying in accordance with the present invention.

FIG. 8 is a view taken along line 8—8 of FIG. 7.

FIG. 9 is a longitudinal sectional view of a preferred form of spray gun constructed in accordance with the present invention.

FIG. 10 is an enlarged cross-sectional view taken along line 10—10 of FIG. 9 and with portions rotated 90° for purposes of clarity.

FIG. 11 is a view taken along line 11—11 of FIG. 10.

FIG. 11A is a front elevational view of the air nozzle plug.

FIG. 12 is a cross-sectional view taken along line 12—12 of FIG. 10.

FIG. 13 is a cross-sectional view taken along line 13—13 of FIG. 10.

FIG. 14 is a cross-sectional view taken along line 14—14 of FIG. 10.

FIG. 15 is a semi-diagrammatic view showing the relationship of the air nozzle and paint film to a target.

FIG. 16 is a diagrammatic view similar to FIG. 15 showing the manner in which the air nozzle opening and spacing from the paint film are varied to decrease the width of paint spray.

FIG. 17 is a schematic circuit diagram of the safety circuit.

SYSTEM

FIG. 1 shows a paint spray system 10 for spraying paints and other coatings in accordance with this invention. As is well recognized in the art, coating systems of the general type shown are utilized to apply coatings to many different types of products, such as automobile parts, furniture, containers, and the like. The coating materials utilized include not only paints, but also enamels, lacquers, stains, varnishs, emulsions, waxes, adhesives, and the like. In the following dscription the word "paint" will b used in a very generic sense to encompass all of these various types of coating materials.

In almost all instances, it is desirable that the paint or other finish be applied in a smooth, even coating with the particles deposited on the workpiece being of a small and relatively uniform size. Paint systems for carrying out the present process include a spray gun 11 which is supplied with paint by means of a pump 12 which feeds paint under pressure to the gun from a paint supply tank 13 through a paint tube 14. (Alternatively pump 12 can be eliminated and tank 13 pressurized). The gun is also supplied with air under pressure from a conventional compressor or other air pressure source. The air is applied to the gun through an air tube 15.

As is well known in the art, when spraying some types of products, for example, the interiors of deep tubular structures, it is desirable to operate the system as a straight air spray system without applying any electrostatic field. However, in spraying other types of articles, it is desirable to charge the paint particles so that the deposition of the particles is aided by the presence of a high electrostatic field. In such instances, the article being sprayed is normally maintained at ground potential so that the electrostatically charged paint particles move toward the article under the influence of the electrostatic field forces and a high percentage of them are effectively deposited on the article to be painted.

The present system can be operated either as a straight air spray gun or as an electrostatic air spray gun. In the event that the gun 11 is to be operated as an electrostatic unit, it is connected to a power pack, or source of DC voltage, 16. The power pack is connected to the gun through an electrical cable 17.

Gun 11 may either be a hand-held gun or can be an automatic gun mounted on a suitable support normally positioned adjacent to a conveyor line by means of which the articles to be sprayed are moved past the gun. In either case, and particularly in the case of hand-held guns, it is desirable that the gun itself be compact and maneuverable. With either form of gun the paint particles are atomized by a low pressure stream of air and are porjected forwardly from the gun in a soft spray of fine particles. A typical spray pattern of the present system travels only about one-half of the travel of a conventional air spray gun operated under the same conditions.

PAINT SPRAYING METHOD

In order to understand various ramifications of the present paint spraying process, it is desirable to consider the nature of a fan-shaped paint spray film as it is sprayed from a nozzle under relatively low air pressure. The pattern of a typical paint film 18 is illustrated in FIG. 2. The film is being emitted from a nozzle of the flat fan spray-type. Such nozzles are conventionally utilized in airless spray guns and one form is disclosed in Bede U.S. Pat. No. 2,754,228. Another form of fan spray nozzle is disclosed in detail below. The paint film shown in FIG. 2 is being sprayed under a relatively low pressure, for example, a pressure of the order of 40–50 psi as opposed to the normal pressure used in airless spray guns of the order of 300–1,000 psi.

As shown in FIGS. 2–4, the paint film is discharged from the orifice in a generally fan-shaped pattern with the upper and lower edges of the film diverging. The angle of divergence of these upper and lower edges gradually decreases. The film is not uniform in cross section. Rather, for a short distance as it leaves the nozzle 20, the film includes a central, relatively uniform web 21 and two edge enlargements or streamers 22 and 23. These bead-like streamers run along the upper and

lower edges of the fan and are substantially thicker than the central web portion **21.**

When low hydraulic pressures are used, such a film of viscous coating material remains relatively stable for a distance of perhaps 1 inch to several inches after it leaves the nozzle. However, at the end of this stable region the film begins to form transverse ripples, or waves, **24.** As the sheet becomes more, more and more unstable, the waves **24** eventually disintegrate into ligaments and droplets **25.** However, the streamers persist and strongly resist disintegration.

In addition to these characteristics, the thickness of the film decreases progressively as the film leaves the nozzle. This decrease in film thickness is generally inversely proportional to the distance from the nozzle so that the most rapid diminution of sheet thickness occurs in the first fraction of an inch (e.g. one-fourth inch) of sheet travel from the nozzle and from that point on the rate of diminution is substantially smaller.

The broadest aspect of the present paint spraying method is illustrated in FIGS. **5** and **6.** Essentially, we have determined that very fine paint atomization characterized by low mean particle size and freedom from random large particles can be obtained by spraying a fan-shaped film of paint **27** under relatively low pressure, for example, a pressure of the order of 30–80 psi, from a nozzle **28** and impinging this fan-shaped paint spray with a fan-shaped stream of air **30** emitted under a very low pressure of the order of 9–45 psi by an air nozzle 21. When the air stream impinges upon the paint fan, it exerts a strong shearing force on the film and effectively atomizes all portions of the paint stream, including the streamers 32 and 33. The paint stream is deflected and continues outwardly as a soft spray pattern, or fog, 34 of suitably atomized paint particles.

In accordance with the present method, the paint is struck by a relatively small volume of air at a relatively high velocity. We have empirically determined that optimum atomization of particles for paint spraying is obtained when the angle x between the paint spray film and the air spray is made between approximately 30° and 70°. The line of impingement **35** between the air stream and paint stream is spaced far enough from the nozzle so that the paint stream has undergone a greater portion of the attenuation of its thickness. At the same time, the line of impingement **35** against a stream of the type shown in FIG. **2** should occur within the region in which the paint film is substantially planar, i.e. before the transverse waves **24** would commence in the absence of an air stream.

Next, the length L_A of the path of travel from the air nozzle **31** to the line of impingement **35** should be only a fraction of the corresponding length L_P of the paint film from the paint nozzle **28** to the line of impingement **35.** We have empirically determined that the preferred range of ratio of L_A/L_P is from one-sixth to three-fourths. In one preferred embodiment, the actual length of paint film L_P is approximately three-eighths to three-fourths inch, while the actual length of air film L_A is approximately one-eighth to three-eighth inch. The air stream is slightly wider (from edge-to-edge) along the line of impingement **35** of the paint film than is the paint film. This facilitates breaking up and effective atomization of the streamers **32** and **33** which is essential to obtaining a good quality paint spray.

To further improve the atomization of the streamers, the air spray itself is made non-uniform with the air stream having higher mass flow rates adjacent its edges, in the areas of the stream which impinge upon streamers **22** and **23.** This is shown diagrammatically in FIG. **3A** in which the mass flow rate of the air is shown as being substantially greater in the areas **36** and **37** in which the air stream impinges upon the streamers **22** and **23** than in the central area **38** of the air stream which impinges upon the thin web portion **21** of the paint film.

In practice, this non-uniform air stream can be obtained by emitting air from a thin slot which is not of rectangular configuration, but rather is wider adjacent to the ends. In many cases, however, the use of such a specially configurated nozzle is not necessary since we have found that the use of a flat fan nozzle made with a rectangular gash gives a sufficiently heavy edged air flow to atomize the heavy edges of the paint sheets.

In carrying out the present process, paint can be applied at a high rate without adversely affecting the highly effective atomization achieved. Moreover, this fine and uniform atomization is achieved while utilizing only a relatively low amount of air in relation to the quantity of paint. For example, on one typical operation an acrylic enamel having a viscosity of 22 seconds as measured by a Zahn No. 2 cup at room temperature was sprayed at a rate of 22 fluid ounces per minute. The paint pressure was approximately 40 psi and the air pressure was 20 psi at the gun. The air flow was at the rate of 8 standard cubic feet per minute so that the ratio of air-to-paint was 0.36 standard cubic feet of air per fluid ounce of paint sprayed per minute. Conventional air spray guns utilize an air-to-paint ratio approximately twice this large and an air pressure of approximately 75 psi. Consequently, the total energy of the air utilized in the present process is only a small fraction of that required in a conventional air gun. This same relatively low ratio of air volume-to-paint is utilized in the present method through the entire range of viscosities of coating materials which are normally applied using the present method.

For example, a very viscous vinyl coating having a viscosity of 40 seconds as measured on a Zahn No. 2 cup at room temperature was deposited at the rate of 17.2 fluid ounces per minute. The paint pressure was 45 psi and the air pressure was 26 psi at the gun. The volume of air employed was 9.5 standard cubic feet per minute. Thus, the ratio of air to ounces of paint was 0.55 standard cubic feet of air per minute per fluid ounce of paint per minute.

As another example, a stain having a very low viscosity of 16.5 seconds as measured on a Zahn No. 2 cup at room temperature was applied at a rate of 24 fluid ounces per minute. Again, the paint pressure was 45 psi and the air pressure was 9 psi at the gun. The amount of air employed to atomize this stain was 4.5 standard cubic feet per minute or approximately 0.18 standard cubic feet of air per minute per fluid ounce paint per minute. In each of the above two examples, the air utilized by a conventional spray gun was approximately twice the amount utilized in the present spray gun.

An even more advantageous version of the present paint spraying process is disclosed in FIGS. **7** and **8.** In this preferred method of spraying paint, two substantially identical fan-shaped sprays of paint **40** and **41** are emitted from fan spray nozzles **42** and **43.** A single fan or air **44** is emitted from an air nozzle **45.** The fan of air **44** is disposed so that it bisects the angle formed by

the two planar fans of apint **40** and **41**. The two fan streams of paint converge and are impinged by the air stream **44** in an area indicated generally at **47**. Both paint streams are broken up into a fine mist, or fog, of generally uniform paint particles as indicated in FIG. **8**. In fact, the atomization is even more efficient than in the embodiment disclosed in FIGS. **5** and **6** since the air stream is in effect trapped between the two fluid streams and its energy is more effectively utilized in breaking up the apint into minute droplets.

The same parameters described above in connection with the method illustrated in FIGS. **5** and **6** are also applicable to the method disclosed in FIGS. **7** and **8**. More particularly, the angles Y and Y' between the apint and air streams are in the range of from approximately 30° to approximately 70°. The paint pressure is from 30 to 80 psi, while the air pressure is from 9 to 45 psi at the gun. The ratio of the length of air travel L_A from the nozzle to the zone of impingement compared to the the length of paint travel from the nozzle to the zone of impingement is approximately in the range of one-sixth to three-fourths. Also, the actual length of paint travel L_P is of the range of approximately three-eighths to three-fourths inches, while the actual length of air film travel L_A is approximately one-eighth to three-eighth inches. Furthermore, the ratio of volume of air to quantity of paint applied is the same as that described above. This ratio is in the range of from 0.2 to 0.6 standard cubic feet of air per fluid ounce of paint.

The process described above can also be employed to effect a simultaneous atomizing, mixing and spraying of two different liquids for coating. More particularly, it has been determined that one type of liquid can be sprayed from one nozzle and a different type of liquid can be sprayed from the second nozzle with the result that the coating deposited on the work is of a uniform blend of the two coating liquids.

The process of atomization described thus far can be employed by itself to cause effective application of paint or a similar coating to a product. However, the atomization process can also be utilized in connection with a paint charging step to electrostatically spray paint. In accordance with the present invention, this charging operation is effected by utilizing the atomizing air as a charge carrier for transferring charges to the paint particles.

As is shown in FIG. **7**, an electrode **50** is disposed in the air stream preferably within the air nozzle **45**. This electrode is connected to a source of high DC potential, for example, a potential of the order of 50 Kv. It will, of course, be understood that the potential applied to the electrode **50** can be greater or less than this figure, depending upon such variables as the characteristics, e.g. resistivity of the paint being applied nature of the article being coated, distance of the gun from the article, etc.

The potential applied to electrode **50** causes a corona discharge to be formed surrounding the tip of the electrode. The air stream passes through this corona on its path through the nozzle and as a result large numbers of ions are formed in the stream. These ions, i.e. ionized gas molecules have relatively high mobility and move primarily under the influence of the electrostatic field toward the coating material at a relatively low potential. In practice, the ions thus move toward the paint which is at a low potential and ultimately attach themselves to the atomized paint particles.

The two paint stream method illustrated in FIGS. **7** and **8** results in an improved charging efficiency over the one paint stream method shown in FIG. **5**. One possible explanation for this is that the paint streams envelope the air stream, i.e. are disposed on both sides of it. Consequently, the ions must pass through a paint stream or a fog of paint particles in order to reach a ground surface. In this travel there is a high likelihood that they will attach themselves to one of the paint particles. In contrast, in the one paint stream method of FIG. **5**, the ions can escape to a grounded surface without passing either through a paint stream or a fog of particles, e.g. as shown in FIG. **5** the charged ions could be attracted to a grounded surface and move off to the right without ever contacting the paint.

In any event, empirical tests have shown that the two paint fan electrostatic paint spraying method of FIGS. **7** and **8** as compared to the one paint fan method of FIG. **5** (even when the air stream of the one paint fan method is ionized).

Another important facet of the present spraying method involves the control of the width of the spray pattern. More particularly, it will be appreciated that articles being sprayed vary in physical dimensions so that in order to minimize overspray, it is often desirable to alter the size of the paint spray pattern produced by the gun. The novel manner in which this is accomplished in the present invention is diagrammatically shown in FIGS. **15** and **16**.

FIG. **15** shows a paint spray directed against a target **55**. The actual pattern **56** of spray has a width W which in actual practice would be slightly longer than the target **55**. We have empirically determined that the width of the spray pattern can be varied by changing the included angle S of the air stream without changing the width of the paint stream.

As shown in FIG. **15**, a fan-shaped sheet of air **57** is emitted from a nozzle **58**. The air impinges upon a fan-shaped film of paint **60**. It will be appreciated that this film of paint may be a single film which is projected at an angle to the air fan as shown in FIGS. **5** and **6**, or may in fact be constituted by two paint films as shown in FIGS. **7** and **8**.

In either event, the air is projected from the nozzle in a fan-shaped stream which is shown as having upper and lower edges **61** and **62** including an angle S such that the air stream just intercepts the entire section of the film against which the air stream impinges. Again, it will be appreciated that in actual practice the angle S would be slightly greater than that shown so that the air stream passes slightly above and below the film. (This exact relationship is not shown, however, to simplify the present explanation.)

In practice, the spacing between the paint film **60** and the target **55** remains substantially constant. Accordingly, when it is desired to spray a smaller target **55'**, as shown in FIG. **16**, it is desirable to produce a paint pattern **56'** having a smaller width W' without requiring shifting of the gun. In accordance with the present invention, this change in the spray pattern is accomplished by projecting the air fan at a smaller angle S'. It will be appreciated that if the angle of the air fan in FIG. **15** were reduced with no further change, the air stream would intersect only a portion of the paint film **60**. This would result in substantially unatomized, or coarsely atomized, paint and, hence, a defective finish.

In accordance with the present method, this difficulty is avoided and the paint pattern width is varied without affecting the uniform atomization of all of the paint. Specifically, the size of the paint pattern is altered by making two changes in the air fan. In the first place, the included angle of the air stream is reduced from the angle S to the angle S'. In the second place, the internal configuration of the nozzle opening is changed so that the apparent focal point, or pressure source point, P of the air stream is shifted away from the nozzle opening and away from the paint film to a more remote point as indicated by P'.

More particularly, as shown in FIG. **15**, it is apparent that the nozzle opening is formed by the intersection of two segments of circular arcs, an external arc **63** and an internal arc **64**. In this example, the arcs are disposed relative to one another so that the nozzle opening encompasses approximately 180° of the inner arc **64**. This nozzle functions as though the air emanates from a point source P disposed relatively close to the nozzle opening.

The changed nozzle opening, as shown in FIG. **16**, is also formed by the intersection of outer arc **63'** and inner arc **64'**. In this case, the radius of the outer arc **63'** is the same as that of arc **63**. However, the radius of the inner arc **64'** is appreciably greater than the arc **64**. As a result, the nozzle opening intersects a much smaller portion of the inner arc **64'**. This nozzle functions as though the air emanates from a point pressure source P' spaced an appreciable distance from the nozzle opening and from film sheet **60'**.

As a result of these concomitant changes, i.e. lessening the included angle of the air fan while at the same time shifting the apparent focal point or apparent point source of the air stream away from the nozzle and paint film, the height of the air fan at its point of intersection with the film remains constant. Consequently, by changing the air fan in this manner without changing any other aspect of the operation of the gun, for example, the paint pressure or paint sheet size, the paint pattern can be compacted or enlarged. A preferred form of nozzle construction for effecting these changes in a simple manner is illustrated in FIGS. **10–14**, and the details of construction of this nozzle are explained below.

SPRAY GUN

The details of construction of a preferred form of spray gun for carrying out the present method of paint spraying are shown in FIGS. **9–14**. As there shown, the spray gun **11** comprises a hollow handle portion **66**, a barrel or extension portion **67** formed of a suitable insulating material and mounted forwardly of the handle and a nozzle assembly **68** mounted on the forward end of barrel **67**.

The nozzle assembly **68** includes two paint nozzles **70** and **71** effective to project flat fan-shaped sprays of paint toward the center line of the gun as indicated by dotted lines **72** and **73**. The gun further includes an air nozzle **74** effective to project a fan-shaped stream of air forwardly along the axis of the gun toward the area of intersection of the paint streams as indicated by line **75**. Additionally, the gun includes an electrostatic charging circuit including a needle electrode **76** for charging the atomizing air and ultimately causing a charge to be applied to the atomized paint particles.

Operation of the gun is controlled by a single trigger **77** which is effective to control flow of paint through a paint valve **78**, flow of air through air valve **80**, and application of electric potential to electrode **76** through actuation of switches **81** and **82**. The trigger functions to first open air valve **80**, then open paint valve **78** and finally close switch **81**. When the trigger is released this sequence is reversed.

More particularly, handle **66** is formed of a suitable conductive material, such as aluminum or the like. The handle is hollow and is configurated to form a hand grip portion **83**, a forwardly extending stock portion **84** and a suspension hook portion **85**. A transverse flange is formed at the forward end of the stock for abutment with a mating flange on the barrel. The barrel and stock flanges are bolted together in a conventional manner. Hand grip portion **83** is provided adjacent its lower end with an opening **86** for receiving the combined air and electrical input fitting **87**.

Air is introduced to the gun through an air tube **15** which surrounds electrical cable **17**, there being an annular space between the tube wall and cable for passage of air from the compressor to the inlet fitting of the gun. The hollow interior of the gun is sealed at the cable entrance in any suitable manner, such as by means of an O-ring **90** compressed between a shoulder in the gun housing and a threaded cap member **91**. Air passes through an inlet passageway **92** formed in the handle and enters a valve chamber **93** of air valve **80**.

This valve includes a reciprocating stem member **94** having an extension **95** disposed for abutment with trigger member **77**. An intermediate portion of the stem carries an O-ring **96** or similar packing member disposed between spaced shoulder **97**. The inner end of the stem carries a tapered plug **98** adapted to engage a tapered seat **100** to seal off the air flow. When the trigger is depressed, plug **98** is shifted against the force of spring **99** from engagement with seat **100** and air is free to flow into internal chamber **101** in the gun handle.

This chamber communicates with a longitudinal bore **102** in the stock and a continuation of this bore **103** formed in the barrel member. This chamber surrounds a sleeve **104** which is formed of insulating material and is supported in mounting spiders **105** and **106**. The forward end of bore **103** communicates with a longitudinal bore **107** formed in nozzle support member **108** which carries the paint and air nozzles. Nozzle support member **108** is preferably formed of an insulating material such as "Delrin." Support member **108** is mounted on the front end of barrel member **67** by means of a threaded cap **109** which is coupled to the mounting member by a retaining ring **119** fitted in opposed grooves in the cap and mounting member. Cap **109** engages threaded extension **129** on the barrel.

Support member **108** is provided with a circular plug-receiving opening **110**. This opening **110** houses a generally cylindrical air nozzle plug **111** which is preferably made of a plastic material, e.g. Delrin. Nozzle plug **111** includes an annular peripheral wall **112** having an arcuate inlet opening **113** which communicates with a vertical central chamber **114**. The lower end of the plug is closed by a solid circular wall **115**, while the top of the plug is closed by a cap **116** which is press fit or otherwise secured to the top of the plug. The cap seals off the upper end of chamber **114** and includes an outwardly extending peripheral flange **117** having a transverse slot **118** for rotating the cap and plug member.

The peripheral wall of the plug member opposite entrance slot **113** is provided with three parallel spaced, rectangular openings **120, 121** and **122.** The plug can be rotated to selectively align any one of these openings with front opening **123** in member **108.** The selection of the particular nozzle opening **120, 121** and **122** disposed in registry with front opening **123** of the stationary support member **108** provides the means for varying the air stream to vary the paint spray pattern in the manner shown diagrammatically in FIGS. **15** and **16.**

More particularly, opening **120** is effective to provide the widest angle of air spray fan and, hence, the widest paint spray pattern. Similarly, opening **121** is effective to provide the narrowest air spray fan and, hence the narrowest paint spray pattern. Nozzle opening **122** is effective to provide an air spray fan and paint spray pattern of intermediate size.

It will be noted that nozzle opening **120** is formed by a semi-cylindrical internal cut **124** formed in peripheral wall **112,** the axis of cut **124** being horizontal. This cut is intersected by a segmental disc-like cut **125** oriented in a vertical plane and extending inwardly from the outer periphery of wall **112** internally along a radius of the plug member.

In one preferred embodiment of the plug member, the disc-like cut **125** has a 0.375 inch radius with a center located 0.178 inch outwardly from the periphery of the plug wall. Internal cut **124** has a seven-sixty-fourths inch radius located inwardly 0.169 inch from the periphery of the plug. This nozzle opening has been found effective to emit a fan-shaped stream of air having an included angle of approximately 94°. Hydraulically, this nozzle opening functions generally as though there were a point source of gas pressure located at point P1 approximately one-fourth inch inwardly from the periphery of the plug member.

Slot **121** is formed by an internal semi-cylindrical cut **126** formed in peripheral wall **112** along a horizontal axis. Cut **126** is intersected by a horizontal disc-like cut **127.** Disc-like cut **127** extends radially inwardly from the outer periphery of wall **112.** In one preferred embodiment of plug, the disc-like cut **127** has a 0.375 radius with the center located 0.219 inch outwardly from the periphery of the plug wall.

Internal cut **126** has a radius of 0.203 inch with the center of the cut being located 0.263 inch from the periphery of the plug. This nozzle opening has been found to emit a fan-shaped stream of air having an included angle of approximately 36°. This nozzle functions generally as though the air emitted from it emanated from a point source P3 disposed substantially further from the peripheral wall than point **P1** (e.g., approximately four times as far).

In order to maintain the volume of air emitted from nozzle openings **120** and **121** substantially equal, the width of nozzle opening **121** is made slightly narrower than the width of nozzle opening **120** so that the cross-sectional area of the opening is constant. Thus, in one preferred embodiment, the width of nozzle opening **120** is made equal to 0.074 inch, while the width of nozzle opening **121** is made equal to 0.065 inch.

The third, or intermediate size, nozzle opening **122** is similarly formed, i.e. this nozzle opening is formed from a segment of a cylindrically internal cut **128** intersected by a vertical disc-like cut **130,** disc-like cut **130** extending inwardly along a radius from the outer peripheral wall **112.** In one preferred embodiment, the cut **130** has a 0.375 radius with a center located 0.168 inch from the periphery of the plut. Inner cut **128** has a radius of 0.156 inch located 0.216 inch from the periphery of the disc. This nozzle opening emits a fan-shaped stream ofir having an included angle of approximately 64°. Air is emitted from this nozzle in generally the same manner as though the air flowed from a point source P2 located of the order of twice the distance from the periphery of the plug as point **P1.** In this preferred embodiment the pressure of the air applied to the gun is relatively low, for example, of the order of 9–45 psi at the gun. The exit velocity of the air is approximately sonic. The distance, in the preferred gun, of air travel L_A to the point of impingement of the air and paint streams is approximately three-sixteenth inch.

Paint is supplied to the gun from pump **12** through tube **14.** This tube is coupled to the gun through fitting **131** which communicates with a longitudinal paint passage **132** formed in extension member **67.** Passage **132** communicates with the seat area **133** of paint valve **78.** This seat area is engaged by a spherical head **134** of valve stem member **135.** This valve stem member reciprocates longitudinally to shift the head **134** toward and away from the seat member and is spring-urged toward the seat by means of a compression spring **136.**

The valve is adapted to be opened by pressure on trigger **77.** When the trigger is pivoted toward the handle member about pivot pin **137** which supports the upper end of the trigger, the trigger engages a shoulder **138** secured to stem **135,** forcing the stem rearwardly to open the paint valve. With paint valve **78** open, paint is free to flow through longitudinal conduit **140** into annular passageway **141** and from this passageway into axial angulated bores **142** and **143** formed in nozzle support member **108.** These bores communicate with paint nozzle assemblies **70** and **71.**

More particularly, bores **142** and **143** are aligned with inlets **144** and **145** in cylindrical members **146** and **147.** Each of these cylinders is formed with an internal passageway **148** and a seat **150** for a check valve formed by ball member **151.** Each of the balls **151** is spring-urged against the seat by means of a spring **152** bearing against a thrust washer **153** mounted within a chamber **154** in cylindrical members **146, 147.** Each of the chambers opens into an axial passageway **155** communicating with an axial bore **156** in tubular nozzle member **157.** Each of the nozzle members is preferably formed of a suitable plastic material, such as Delrin.

The fluid discharge passageway in each of the nozzles is formed by a V-shaped cut **158** extending inwardly from a periphery of the wall to approximately the center line of the tube. Each of the V-shaped cuts **158** includes a rearward wall **160** and a forward wall **161.** As shown in FIG. **10,** each nozzle **157** is angulated, or tilted, slightly outwardly relative to the axis of passageway **155.** This tilting enables the nozzle to direct the paint stream at the desired angle relative to the air fan.

More particularly, each nozzle **157** is effective to emit a thin substantially planar fan-shaped stream of paint at an angle of approximately **60°** to the axis of bore **155** which is parallel to the axis of the gun. Consequently, this fan-shaped paint stream is impinged by the fan-shaped air stream at approximately the same angle, i.e. at approximately 60°. In this preferred embodiment, the length of paint travel L_P from the nozzle to

the zone of impingement of the paint and air streams is approximately five-eighth inch.

In accordance with the present invention, the ends of axial bores **156** in each of the nozzle tubes **157** is closed by a spring-loaded plug **159.** These plugs are secured to angulated spring members **162** in any suitable manner; for example, as shown in FIG. **10,** plug **158** passes through a small bore in a portion of arm **162** and has an overturned head **163** effective to clamp the plug to the arm. Both plugs **159** and spring members **162** are preferably formed of a uitable plastic material. ARms **162** include a transverse section **164** and a foot portion **165** which is mounted upon the support member **108** in any suitable manner, such as by means of bolts **166.**

Each of the spring members **162** also includes an overturned flange portion **167** by means of which the spring arm can be pulled outwardly to disengage the plug from the seat formed in the end of the associated tube member **157.** In normal operation, the spring force is sufficient to maintain the plug in sealing engagement with the end of the tube **157.** However, in the event that the nozzle should become clogged, the passage can readily be cleared by grasping flange portion **163** to pull the spring arm and plug outwardly, opening the end of the tube. Trigger **77** is then depressed to cause paint to be discharged from the end of the tube removing whatever impediment had accumulated in the tube section.

The electrical input to the gun is preferably through a high resistance cable **17.** The details of construction of one preferred form of cable are disclosed in Rosen U.S. Pat. NO. 3,348,186. The remote end of this cable is connected to a power pack **16** effective to develop a high DC potential, for example, 50,000 volts. Cable **17** enters the gun through the interior of fitting **87** and passes upwardly through a hollow section **170** of the handle. The cable is flexible and is bent rearwardly around shoulder **171** at the junction of the hand grip portion **83** and the stock portion **84** toward the rear wall **172** of the stock. The cable is then bent forwardly and is inserted into insulating sleeve **104,** the cable being loosely received in the sleeve so that it is free to move relative thereto. The forward end of the cable is provided with a contact button **173** disposed for mating contact with a similar contact button **174** provided on the rear end of cylindrical resistor **175.**

This resistor is preferably sealed in the end of sleeve **104** and has an electrical resistance of the order of 75 megohms. The forward end of resistor **175** is in electrical contact with a bolt **176** passing inwardly through a cap member **177** enclosing the forward end of sleeve **104.**

The head **180** of bolt **176** is engaged by a contact spring **178** which is compressed between the head of the bolt and a head **181** formed on electrode **76.** Electrode **76** is in the form of an elongated pin supported in axial alignment with the air nozzle by means of a cruciform insulating member **182.** This cruciform insulating member includes a central bore **183** into which the pin is press fit. The cruciform member is rigidly mounted in the central opening **107** in support member **108.**

Electrode **76** extends forwardly through entrance opening **113** in the air nozzle member and extends forwardly to a position just inside the peripheral wall **112** carrying the three nozzle openings **120, 121,** and **122.** In normal operation, this electrode is charged to a suitable potential of the order, for example, of 40,000 volts. A corona is established surrounding the tip of the electrode. The stream of air flowing through the nozzle surrounds the electrode and passes through the corona prior to the time it is discharged from the nozzle opening. As the air passes through the corona gas molecules are ionized and dust particles are charged. These ions and charged particles move forwardly under the influence of the electrostatic field forces toward a lower potential region of the field constituted by the paint films and atomized particles. There the charges attach themselves to the paint particles to form the charged paint spray.

One of the advantages of this paint charging device is that the paint supply in conduit **14** does not become charged so that the entire paint supply system, including tube **14,** pump **12** and the paint supply tank **13,** remain at or very near ground potential. In fact, in the embodiment shown the paint supply system is grounded through needle **135** and handle member **66** which is conventionally grounded in use. This greatly simplifies the problem of insulating the paint supply system and eliminates the dangers common in many prior art systems due to charge accumulation in the paint supply system.

In addition to the elements described above, the electrical charging circuit includes a safety circuit for preventing application of power to the cable in the event that resistor **175** is removed from the gun and the gun reassembled without replacing the resistor.

More particularly, as is best shown in FIG. **9,** the cable **17** forms a rearwardly extending resilient bend **190** adjacent to rear wall **172** of the stock. An actuating arm **191** is pivoted about pin **192** in the stock portion of the gun and is interposed between cable bend **190** and rear wall **172.** This arm includes a forwardly extending link portion **189** which is attached to one end of tension spring **193,** the other end of the spring being secured to a stationary bracket **194.**

Bracket **194** carries snap-action microswitches **81** and **81.** Microswitch **82** is normally closed, while microswitch **81** is normally open. A spring arm **195** is disposed for engagement with actuating plunger **196** of microswitch **82.** This spring arm is adapted to be shifted with link **189,** for example, by engagement with a shoulder **197** carried by the link.

So long as the cable **17** is positioned rearwardly as shown in FIG. **9,** plunger **196** is not depressed and switch **82** remains closed. In normal operation of the gun, the cable is held in this position against forward movement by the presence of resistor **175.** However, if resistor **175** and sleeve **104** are not present in the gun, spring **193** acting upon arm **191** forces the cable forwardly within conduit **103.** This forward movement of arm **191** causes arm **195** to open switch **82.**

As is shown in FIG. **17,** switch **82** is connected in series with switch **81** and a coil **198** of relay **200.** Switch **81** is normally open switch adapted to be closed upon actuation of trigger **77.** More particularly, microswitch **81** includes an actuating plunger **201** adapted to be engaged by s spring arm **202.** This arm in turn is positioned for contact with a head **203** formed on the continuation of stem member **135.**

When trigger **77** is depressed, the stem and its extension are shifted rearwardly so that head **203** bends spring arm **202,** closing microswitch **81.** When both microswitch **81** and **82** are closed, relay **200** is energized

to complete a circuit to power pack **16.** This power pack is then effective to apply a potential to cable **17** and, hence, to electrode **76.**

The safety circuit just described is also effective to prevent application of power to the cable when the nozzle assembly is removed from the gun. More particularly, as is shown in FIG. **9,** tube **104** is supported in the surrounding bores in the stock member and barrel by means of low friction spiders **105** and **106.** The tube is normally retained in its retracted position shown in FIG. **9** by the abutment of spider **182** with the end of cap member **177.** However, when the nozzle mounting member **108** is removed by unthreading cap **109** from the threaded extension **129** on the barrel member, the restraint on forward movement of the sleeve is removed, The sleeve is then shifted forwardly under the influence of spring **193** acting on the cable member.

As the cable member is shifted to the left, arm **191** is shifted forwardly causing arm **195** to open switch **82** preventing energization of the power pack and thereby preventing application of potential to cable **17.** At the same time, forward movement of sleeve **104** is effective to provide a second function in that it automatically seals the air chamber and end of the resistor or electrical conduit from contamination. More particularly, as best shown in FIGS. **9** and **10,** the forward end of cap **177** is tapered to form a seat **204.** This seat is effective to engage a mating tapered seat **205** formed in the barrel **67** when sleeve **104** is shifted forwardly, i.e. to the left in FIG. **10.**

When the nozzle is reassembled, spider **182** engages cap **177** forcing the cap away from the seat **205** to reopen the air conduit. At the same time, the cable **17** is shifted rearwardly so that ben **190** causes arm **191** to pivot, thereby reclosing switch **82** to permit reenergization of the powr pack and cable **17** when trigger **77** is depressed.

The construction of the gun as described above also incorporates two additional safety features. In the first place, switches **81** and **82** and the other electrical contacts such as those between the cable and resistor occur in an enclosed or pressurized explosive-proof chamber. Moreover, this chamber is continuously purged to remove any accumulated gases by the flow of the air utilized to atomize the paint.

From the foregoing disclosure of the general principles of the present invention and the above description of a preferred embodiment, those skilled in the art will readily comprehend various modifications to which this invention is susceptible.

For example, while the air fan and paint fan streams have been described as being substantially planar, it is contemplated that the paint fans may be slightly arcuate, i.e. in the form of thin bowed sheets. Moreover, if a gun is to be utilized for atomizing, mixing and spraying two different liquids by spraying one liquid from one nozzle and another liquid from the other nozzle, it is apparent that a separate supply line must be provided for each nozzle. This can readily be accomplished by essentially duplicating the liquid supply system shown while eliminating the conduit which now interconnects the two nozzles. Also while air has been described as the atomizing gas, it will be appreciated that in some particular installations other gases could be employed. Accordingly, the term "air" as used in the following claims should be interpreted as including other gases as well.

Accordingly, we desire to be limited only by the scope of the following claims in which it is to be understood that the term "paint" is used in the generic sense to cover fqnish coatings of the type described above and in which the term "gun" is used generically to cover either a hand spray gun or a mechanically-supported control spray device.

Having described our invention, we claim:

1. The method of spraying paint which comprises the steps of:

projecting a flat fan of paint,

projecting a fan of air,

causing the fan of air to impinge upon the fan of paint at a substantial angle of from approximately 30° to approximately 70°, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, whereby the air fan is effective to atomize the paint to form a spray,

and projecting said spray against a workpiece to be coated.

2. The method of claim **1** in which the air is projected from an air nozzle and the paint is projected from a paint nozzle, and the length of air travel from the air nozzle to the zone of paint — air impingement is from approximately one-sixth to three-fourths the length of paint travel from the paint nozzle to the zone of air-paint impingement.

3. The method of claim **1** in which air is projected from an air nozzle and paint is projected from a paint nozzle and the length of air flow from the nozzle to the zone of air-paint impingement is from approximately one-eighth inch to three-eighths inch and the length of paint travel from the paint nozzle to the zone of air-paint impingement is approximately three-eighths to three-fourths inches.

4. The method of claim **1** in which the air flows in a ratio of from approximately 0.2 standard cubic feet of air per minute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute.

5. The method of claim **1** in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun.

6. The method of claim **5** in which the paint pressure is approximately from 30 to 80 pounds per square inch.

7. The method of claim **4** in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun.

8. The method of claim **7** in which the paint pressure is approximately from 30 to 80 pounds per square inch.

9. The method of claim **1** in which the fan of paint is in the form of a continuous sheet having a thin center web and thickened streamer portions along both edges.

10. The method of claim **9** in which the fan of air is non-uniform and has mass higher flow rates in the areas of impingement upon the streamer portions than in the area impinging upon the center web of the paint fan.

11. The method of claim **10** in which the air flows in a ratio of from approximately 0.2 standard cubic feet of air per minute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute.

12. The method of claim **10** in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun and the paint pressure is approximately from 30 to 80 pounds per square inch.

13. The method of claim 12 in which air is projected from an air nozzle and paint is projected from a paint nozzle and the length of air flow from the nozzle to the zone of air-paint impingement is from approximately one-eighth inch to three-eighths inch and the length of paint travel from the paint nozzle to the zone of air-paint impingement is approximately three-eighths to three-fourths inches.

14. The method of spraying paint which comprises the steps of projecting a flat fan of air;
projecting two flat fans of paint,
fans of paint being projected toward the fan of air from opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle of from approximately 30° to approximately 70°,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray and,
projecting said spray against a workpiece to be coated.

15. The method of claim 14 in which air is projected from an air nozzle and each fan of paint is projected from a paint nozzle, and the length of air travel from the air nozzle to the zone of paint-air impingement is from approximately one-sixth to three-fourths the length of paint travel from the paint nozzle to the zone of air-paint impingement.

16. The method of claim 14 in which air is projected from an air nozzle and each fan of paint is projected from a paint nozzle and the length of air flow from the nozzle to the zone of air-paint impingement is from approximately one-eighth inch to three-eighths inch and the length of paint travel from the paint nozzle to the zone of air-paint impingement is approximately three-eighths to three-fourths inches.

17. The method of claim 14 in which the air flows in a ratio of from approximately 0.2 standard cubic feet of air per minute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute.

18. The method of claim 17 in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun and the paint pressure is approximately from 30 to 80 pounds per square inch.

19. The method of claim 14 in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun and the paint pressure is approximately from 30 to 80 pounds per square inch.

20. The method of claim 14 in which each fan of paint is in the form of a continuous sheet having a thin center web and thickened streamer portions along both edges.

21. The method of claim 20 in which the fan of air is non-uniform and has mass higher flow rates in the areas of impingement upon the streamer portions than in the area impinging upon the center web of the paint fans.

22. The method of claim 21 in which the air flows in a ratio of from approximately 0.2 standard cubic feet of air per minute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute.

23. The method of claim 21 in which the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun and the paint pressure is approximately from 30 to 80 pounds per square inch.

24. The method of claim 23 in which air is projected from an air nozzle and each fan of paint is projected from a paint nozzle and the length of air flow from the nozzle to the zone of air-paint impingement is from approximately one-eighth inch to three-eighths inch and the length of paint travel from the paint nozzle to the zone of air-paint impingement is approximately three-eighths to three-fourths inches.

25. The method of simultaneously mixing and spraying paint which comprises the step of projecting a flat fan of air, projecting two flat fans of paint, each of said flat fans of paint being of a different color,
the fans of paint being projected toward the fan of air from opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle of from approximately 30° to approximately 70°,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray and,
projecting said spray against a workpiece to be coated.

26. The method of spraying paint which comprises the steps of:
projecting a flat fan of paint from a paint nozzle,
projecting a fan of air from an air nozzle,
causing the fan of air to impinge upon the fan of paint at a substantial angle, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, and the length of air travel from the air nozzle to the zone of paint-air impingement is from approximately one-sixth to three-fourths the length of paint travel from the paint nozzle to the zone of air-paint impingement, whereby the air fan is effective to atomize the paint to form a spray,
and projecting said spray against a workpiece to be coated.

27. The method of spraying paint which comprises the steps of:
projecting a flat fan of paint from a paint nozzle,
projecting a fan of air from an air nozzle,
causing the fan of air to impinge upon the fan of paint at a substantial angle, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, and the length of air flow from the nozzle to the zone of air-paint impingement is from approximately one-eighth inch to three-eighths inch and the length of paint travel from the paint nozzle to the zone of air-paint impingement is approximately three-eighths to three-fourths inches, whereby the air fan is effective to atomize the paint to form a spray,
and projecting said spray against a workpiece to be coated.

28. The method of spraying paint which comprises the steps of:
projecting a flat fan of paint from a paint nozzle,
projecting a fan of air from an air nozzle,
causing the fan of air to impinge upon the fan of paint at a substantial angle, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, and the air flows in a ratio of from approximately 0.2 standard cubic feet of air per min-

ute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute, whereby the air fan is effective to atomize the paint to form a spray,
and projecting said spray against a workpiece to be coated.

29. The method of spraying paint which comprises the steps of:
projecting a flat fan of paint from a paint nozzle,
projecting a fan of air from an air nozzle,
causing the fan of air to impinge upon the fan of paint at a substantial angle, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, and the air pressure is from approximately 9 pounds to 45 pounds per square inch at the gun, whereby the air fan is effective to atomize the paint to form a spray,
and projecting said spray against a workpiece to be coated.

30. The method of varying the size of a paint spray pattern which comprises,
the steps of projecting a flat fan of paint,
projecting a fan of air from an air nozzle,
causing the fan of air to impinge upon the fan of paint at a substantial angle, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, whereby the air fan is effective to atomize the paint to form a spray pattern and,
selectively increasing or decreasing the included angle of the air fan to increase or decrease the width of the paint spray pattern.

31. The method of claim **30** in which the fan of air flows as though it emanates from a point pressure source and the point pressure source is shifted away from the zone of impingement of the air-paint when the included angle of the air fan is decreased, whereby the width of the air fan at the zone of impingement with the air-paint remains substantially consistent.

32. The method of spraying paint which comprises the steps of projecting a flat fan of air from an air nozzle,
projecting two flat fans of paint from two paint nozzles,
the fans of paint being projected toward the fan of air from opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray and,
the air pressure is from approximately **9** pounds to **45** pounds per square inch at the gun, and
projecting said spray against a workpiece to be coated.

33. The method of spraying paint which comprises the steps of:
projecting a flat fan of paint,
said fan of paint being in the form of a continuous sheet having a thin center web and thickened streamer portions along both edges,
projecting a fan of air,
causing the fan of air to impinge upon the fan of paint at a substantial angle, while said fan is substantially planar, the fan of air being at least as wide at the zone of air-paint impingement as the fan of paint, whereby the air fan is effective to atomize the paint to form a spray,
and projecting said spray against a workpiece to be coated.

34. The method of spraying paint which comprises the steps of projecting a flat fan of air from an air nozzle,
projecting two flat fans of paint from two paint nozzles,
the fans of paint being projected toward the fan of air from opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray,
each fan of paint being in the form of a continuous sheet having a thin center web and thickened streamer portions along both edges, and
projecting said spray against a workpiece to be coated.

35. The method of spraying paint which comprises the steps of projecting a flat fan of air from an air nozzle,
projecting two flat fans of paint from two paint nozzles,
each fan of paint being in the form of a continuous sheet having a thin center web and thickened streamer portions along both edges,
the fans of paint being projected toward the fan of air from opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray,
the fan of air being non-uniform and having higher flow rates in the areas of impingement upon the streamer portions than in the area impinging upon the center web of the paint fans, and
projecting said spray against a workpiece to be coated.

36. The method of spraying paint which comprises the steps of projecting a flat fan of air from an air nozzle,
projecting two flat fans of paint from two paint nozzles,
the fans of paint being projected toward the fan of air from the opposite sides thereof and impinging the fan of air in substantially the same area,
each of the fans of paint impinging upon the fan of air at a substantial angle,
the fan of air being at least as wide at the zone of air-paint impingement as the fans of paint, whereby the air fan is effective to atomize both fans of paint to form a spray,
the air flowing in a ratio of from approximately 0.2 standard cubic feet of air per minute per fluid ounce of paint per minute to approximately 0.6 standard cubic feet of air per minute per fluid ounce of paint per minute, and
projecting said spray against a workpiece to be coated.

37. The method of claim **33** in which the paint pressure is from approximately 30 to 80 pounds per square inch.

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