Oct. 9, 1962 R. J. VERBA ETAL 3,057,558

ELECTROSTATIC ATOMIZING HEAD

Filed Dec. 19, 1958 3 Sheets-Sheet 1

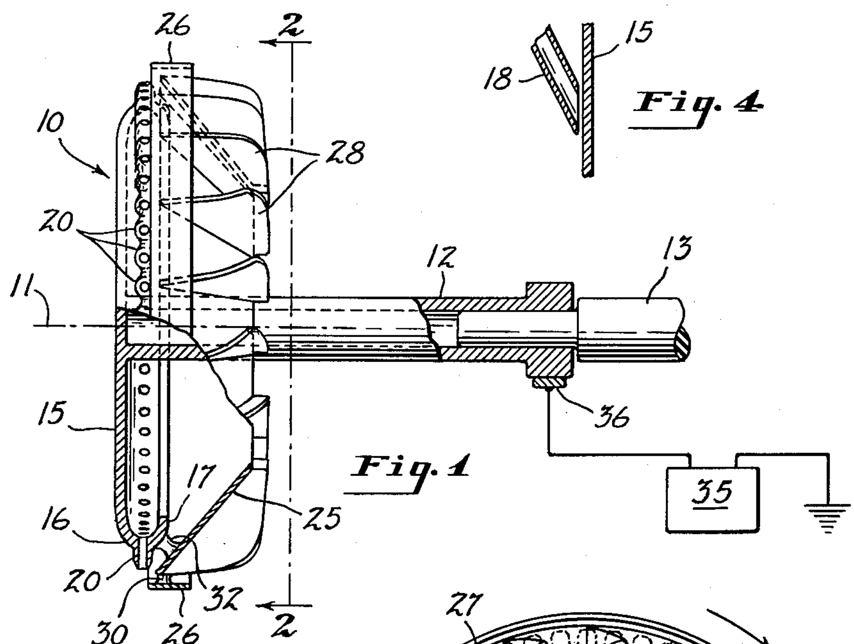


Fig. 4

Fig. 1

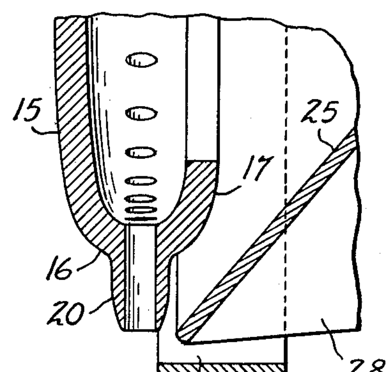


Fig. 3

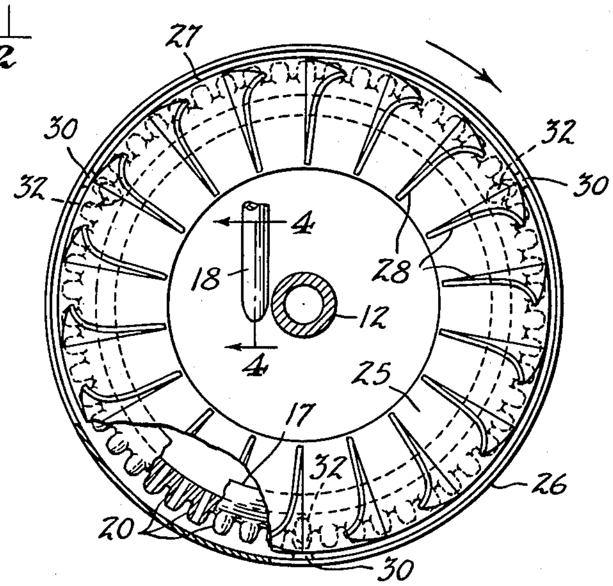


Fig. 2

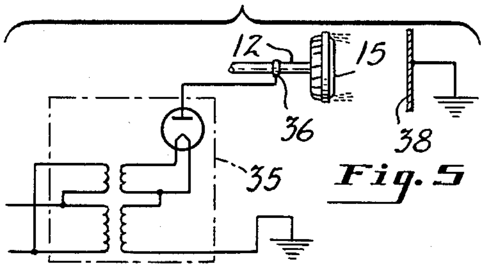


Fig. 5

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ELECTROSTATIC ATOMIZING HEAD

Filed Dec. 19, 1958 3 Sheets-Sheet 2

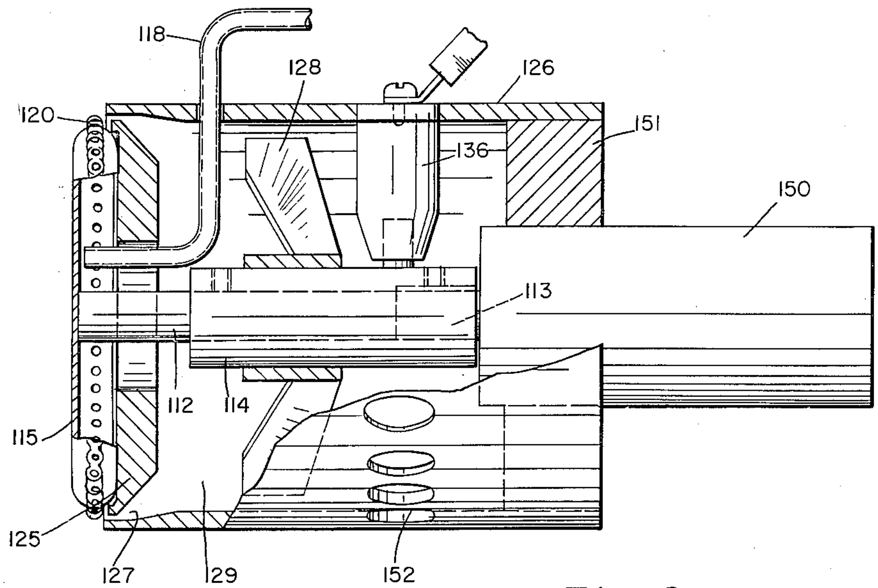


Fig. 6

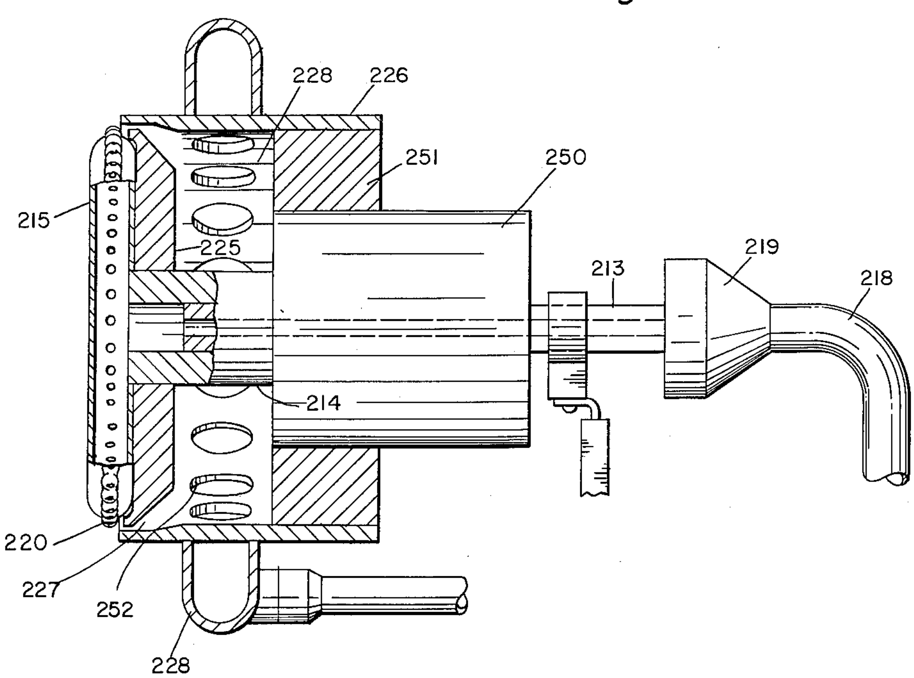


Fig. 7

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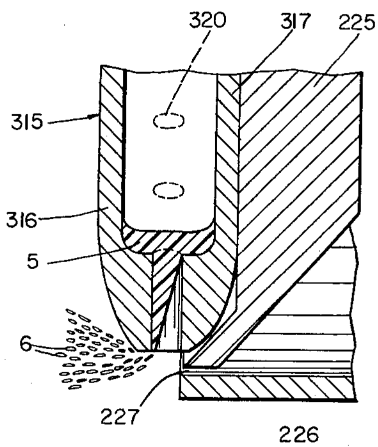


Fig. 8

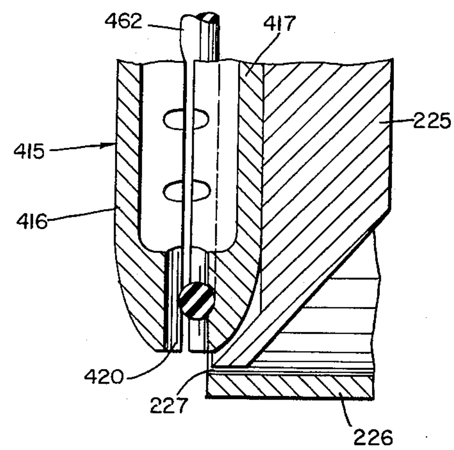


Fig. 9

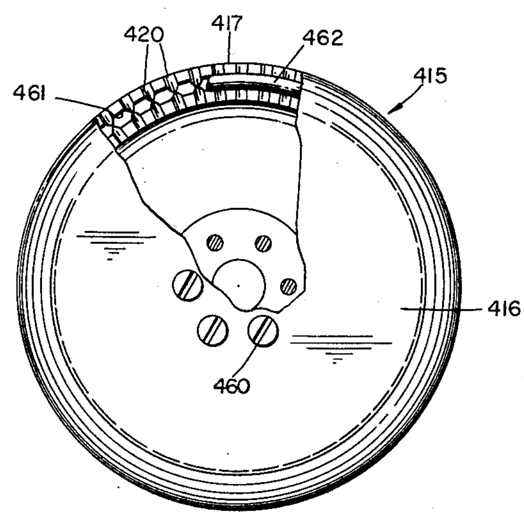


Fig. 10

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# 3,057,558
# ELECTROSTATIC ATOMIZING HEAD

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18 Claims. (Cl. 239—15)

The present invention relates to electrostatic atomizing heads for paints and like coating compositions. More particularly it relates to dual-fluid atomizing heads which effect atomization in non-quiescent air, as distinguished from single-fluid atomizing heads which effect atomization in quiescent air. The invention is applicable to electrostatic atomizing heads of the centrifugal type in which a rotating body has one or more electrode apieces (edges or points) to and/or off which a liquid fluid (the coating composition) is centrifugally urged. This application is a continuation-in-part of our co-pending application Serial No. 716,202, for "Electrostatic Atomizing Head," filed February 19, 1958, and now abandoned.

For years the most common and conventional means for atomizing paints, lacquers, enamels, varnishes, and liquid of like viscosity (hereinafter included in the term "paint") have been the so-called spray guns through which paints and like fluid compositions have been fed for atomization. Such spray guns generally atomize the paint by means of air under high pressure, ejecting the paint in droplets from the nozzle at a relatively high velocity in the form of a cone or fan of spray, which was then directed toward the surface to be coated. Numerous variations of the conventional spray guns have been suggested and used but all had the failing of imparting a relatively high velocity to the paint particles and, due to the pattern of the spray cone or fan, a substantial amount of paint, particularly when the paint was directed toward an edge or an opening in the article being painted, was certain to miss the article. This overspray, so-called, was not only wasteful but required elaborate spray booths and exhaust systems which were expensive to build, operate, and maintain, particularly in plants where production spraying was required. Power and equipment to supply air and paint under high pressure to the spray guns were also substantially expense factors.

It early occurred to the art that, in atomizing any liquid, whether a coating composition or otherwise, the problems presented by overspray could be overcome or minimized (regardless of whether the liquid was atomized by air, by emission from a nozzle without air, a discharge onto a rotating disk—all recognized as equivalent atomizing means by the art) if the liquid were atomized in an electrostatic field and the droplets carried an electrostatic charge. Then if the article to be coated or otherwise receive the atomized liquid carried a charge opposite to that of the spray droplets (or particles in form other than droplets), the droplets would be attracted to it. If the article were not a good conductor, it would be interposed over a pole having a charge opposite to the droplets. While sound enough in theory, in practice spray equipment using air guns still produced overspray, when the volume of paint atomized was adequate to deliver a sufficient volume of paint to be practical and competitive with ordinary, non-electrostatic spray guns. The explanation given was that the air used to atomize the paint created a turbulence which carried the spray particle out of the electrostatic field.

As a consequence, in an effort to continue to utilize the well-known phenomenon that articles carrying different electric charges attract and to overcome the turbulence of air atomization, the art has gone to various so-

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called single-fluid or airless atomizing devices. That is, the paint is fed as a film moving at a relatively low velocity toward an edge or a linear collection of points charged oppositely to the charge of the article to receive the paint. As the paint arrives at the edge or point, it picks up an electrostatic charge and is drawn away toward the article to be painted, the film breaking up as the paint leaves the edge or points. The degree to which the film of paint is thus atomized or broken up depends upon several interrelated factors, such as the volume of paint, the voltage gradient across the gap between the atomizing head and the receiving surface, and the viscosity and other characteristics of the paint vehicle, such as its "length" or "shortness" and dielectric characteristics. The condition of the paint particles as they arrive at the receiving surface and whether a satisfactory coating will be obtained, if that be the result desired, depends upon numerous factors, such as the volatility of the volatile solvent in the paint vehicle and the "flow-out" of the vehicle as it is received. No matter how satisfactorily the paint may appear to be atomized at the discharge head, due to factors wholly independent of the atomizing means the physical form the paint takes on the receiving surface may vary from a smooth film, to an "orange peel," to a collection of relatively non-adherent dust or powder, or even a hairy deposit of fibers (if the paint vehicle contains a highly volatile solvent and the residual vehicle is "long").

While the inherent characteristics of the paint must be taken into account when using an atomizing head, as in any prior art electrostatic atomizing head, a paint atomizing head made according to this invention can provide a greater degree of control over the factors which direct the selection of the paint to be sprayed and thus render the selection of physical characteristics of the paint vehicle less critical than in prior art atomizing heads.

Regardless of the care exercised in selecting the paint to be sprayed, the so-called airless or single-fluid atomizing heads have characteristics of volume, direction, and pattern of the spray emitted which have limited their acceptance in industry. If the paint is fed to an edge or collection of points in a straight line, care must be exercised to feed the paint uniformly to all segments of the edge. Otherwise, a heavier film will be delivered to one segment than to another or the droplets will be unequally atomized, with the result that the larger droplets will fall out of the electrostatic field and constitute overspray (if the atomizing edge and surface are vertical).

Even if the problem of securing uniform distribution of paint to all segments of a straight line edge or series of points is solved by various expedients (or if no more paint is fed to a segment than it can effectively atomize, thereby "starving" other segments) that shape of head has an inherent disadvantage. It has been heretofore vaguely sensed that the amount of paint which can be electrostatically atomized from any given integer of an edge is limited and, consequently, the geometery of dispersing the paint from a straight edge is generally poor. Either the surface to be coated has to move so slowly past the fan of paint particles that production is slow and inefficient or a number of multiple parallel edges has to be employed, increasing equipment size and costs and multiplying operating and maintenance costs, particularly in clean-up operations or if color changes are required.

To improve the compactness of an electrostatic single-fluid spray head, the art has generally gone to the use of a circular head, in which the paint is fed, usually centrifugally, to a circular edge. The effect of uneven flow to integers of the edge is somewhat masked or compensated for, but the pattern of spray insures an uneven coat, due to the fact that it is in the form of a cone having a large hollow interstice which is also an outwardly divergent cone. That is, when directed perpendicularly toward a fixed plane surface, the paint is applied in the form of a "doughnut" having a relatively distinct outside diameter and an inside diameter which is characteristically larger than the diameter of the circular atomizing head. To compensate for the uneven coat obtained with the so-called airless or "single-fluid" circular heads producing this "doughnut" pattern, it has been the general practice to employ a plurality of heads staggered with respect to each other.

We have discovered that remarkably improved directional characteristics and resulting reduction in overspray and improvement in spray pattern may be achieved and that uniformity of coating may be improved by a degree of disturbance of ambient air at the electrode apices of a centrifugal type atomizing head which definitely renders such ambient air non-quiescent but which can be far less than that which would be affected by a pressurized air spray gun. This intermediate range of degree of air disturbance may be effected by air impelling means associated with the rotating motion of the atomizing head, thereby accomplishing electrostatic-centrifugal atomizing and coating which is superior to that of single-fluid centrifugal atomizing heads while at the same time avoiding the cost and inconvenience of providing and maintaining the auxiliary air pressurizing equipment heretofore required by the dual-fluid atomizing heads of the prior art. However, the superior coating results achieved by the invention are not in all respects limited to use of air impelling means with or as part of the centrifugal head, and in certain aspects the invention contemplates use of high or low pressure air from an independent source.

Our invention is based in part upon our discovery that, within reasonable limits, air turbulence, per se, is not an undesirable factor when spraying in an electrostatic field but, properly directed, may be used advantageously on heads embodying the principles of our invention. Rather, we have discovered that the disturbing effect of turbulence in the air between an electrostatic atomizing head and the surface to be coated is the extent to which the velocity of individual paint particles, in the outside of the spray pattern, imparts a momentum having a component transverse to the lines of force of the electrostatic field between the atomizing head and the surface to be coated. Further, overspray results only when the transverse component of the momentum of individual paint particles is outwardly divergent from the pattern of spray and greater than an opposite transverse and convergent force resulting from the electrostatic attraction of the particle toward the surface being coated.

Our invention is also based in part upon our realization that the art was apparently mistaken in advancing toward the socalled single fluid systems of electrostatic atomization and in their attempts to atomize, disperse, and deposit paint solely or largely by electrostatic forces. While elemental physical principles indicate that the force exerted on a charged particle in an electrostatic field is purely a matter of the charge on the particle and its distance from a body having an opposite equal or greater charge, the advantages of our invention seemed to be explained by the fact under the dynamic conditions of the paint being atomized by a spray head embodying the principles of our invention, as contrasted with the static conditions from which accepted physical principles were derived, we are able to use other forces, namely, centrifugal forces and the force of the moving body of air in and by which the paint is at least partly atomized, to assume all or a major portion of the functions of atomizing, dispersing and depositing the paint particles, thereby conserving and utilizing the force of the electrostatic forces primarily for the purpose of directing paint particles toward the surface on which the particles are to be coated or received (if not received in the form of a



fluid coating). We do not intend that our invention is limited to or by this explanation and theory of operation; as statistical and other experience with spray heads made according to our invention increases, other theories and explanations may occur to those skilled in the art.

The drawings and following description are intended, therefore, to illustrate forms of the invention which presently appear to be preferable and which have been successfully tested. But it is to be understood that this description is given by way of illustration and example only.

FIGURE 1 is a view showing a dual-fluid atomizing head of the centrifugal type embodying the invention, the liquid supply conduit being omitted for purposes of clarity in this view but not in other appropriate views.

FIGURE 2 is a section taken on the plane of line **2—2** of FIGURE 1.

FIGURE 3 is an enlarged fragmentary detail view similar to the lower left hand portion of FIGURE 1, but taken on a plane of section removed from that of FIGURE 1.

FIGURE 4 is a fragmentary sectional view taken on the plane of line **4—4** in FIGURE 2.

FIGURE 5 is a diagrammatic illustration of a circuit and arrangement of the atomizing head relative to an article to be coated.

FIGURE 6 is another embodiment of our invention, partly in section.

FIGURE 7 is still another embodiment of our invention, partly in section.

FIGURE 8 is a detail similar to FIGURE 3, but showing a modified form of a cup that may be used in the embodiments shown in FIGURES 1, 6, and 7.

FIGURE 9 is a detail similar to FIGURE 8, but showing a still further modification of a cup which may be used in the embodiment of this invention.

FIGURE 10 is a detailed front elevation of the cup as shown in FIG. 9.

The illustrated atomizing head includes a body generally indicated by the reference numeral **10** which is mounted for rotation about its central longitudinal axis **11**, as by being fixed to an integral shaft **12** which may be, in turn, mounted on a dielectric drive shaft **13**, which drives the atomizing head in a clockwise direction as viewed in FIGURE 2. The body **10** includes a shallow cup **15** which has an outwardly bulging side portion **16** and an inwardly extending rim portion **17**. Means are provided for supplying liquid coating material to the interior of the body **10**, such means including a stationary conduit **18** leading from a source of coating material (not shown), the conduit preferably terminating adjacent the inner wall of the cup **15**, as seen most clearly in FIGURE 4.

A plurality of annularly distributed hollow stems **20** communicate with the interior of the cup **15** and extend radially outwardly from the outwardly bulging side portion **16** of the cup. The radially outer ends of the stems are sharp-edged as shown most clearly in FIGURE 3 to constitute electrode apices.

The invention contemplates the provision of means for discharging air, as the second fluid, past the electrode apices during rotation of the atomizing head in a direction having a longitudinal component. In the embodiment of the invention shown in FIGURES 1 to 4, the air discharge in the desired direction is accomplished by the provision of air impeller means mounted for rotation with the atomizing cup **15**. Particularly, the air impeller means shown comprises an inner conical shroud band **25** and a concentric outer annular shroud band **26**, these bands being axially displaced to the side of the outer ends of the stems **20** as shown in the drawings. The shroud bands **25** and **26** converge toward each other adjacent the stems **20** to provide between them an air discharge orifice or orifices, such as the slot **27**, for discharging air past the outer ends of the stems **20**. The air is impelled between the shrouds **25** and **26** in this embodiment by a plurality of radially extending blade members 28 disposed between the shrouds. The blade members 28 may be supported on the shroud 25, as shown, and the shroud 26 may be spaced from the shroud 25 by small supports 30. The shroud 25 is, in turn, supported on the cup 15 by means of the members 32.

As illustrated, the atomizing head is connected to a source of a high voltage indicated at 35 through one terminal of the high voltage source, the other terminal thereof being grounded as shown. This connection may be effected through a brush or slip ring or the link 36. The high voltage source is connected through ground to an article 38 (FIGURE 5) to be coated. Thus, there is created an electrostatically charged field between the atomizing head 10 and the article 38 which is to be coated. The sharp edges of the conduits 20 act as electrodes and the term "electrode apices" will, therefore, be understood to be appropriate to these edges. The grounded article 38 may be referred to as a collecting electrode of one potential with the atomizing head provided with its sharp edges functioning as a discharge electrode of a different potential.

In operation, paint is fed to the cup 15 through the conduit 18 from which it is distributed by the outer side portion 16 to the entrances of the hollow stems 20 at the cavity formed by the rim 17. The constant rate of atomization from the apices provided by the stems 20 indicates that the rim 17 possibly provides at least a slight reservoir for the paint before it enters the stems 20. Under ordinary lighting conditions, only a faint cloud of very finely atomized paint is visible for a short distance in front of the atomizing cup 15, where it seems to disappear only to materialize on the receiving surface, i.e., the collecting electrode 38 in the form of an annular or "doughnut" having a sharply defined circular outer edge with a relatively small inner "hole" in which no paint is deposited.

In production painting, the articles to be painted are conveyed past the atomizing head. If the articles are conveyed singly and present a smaller surface area than the area of the annulus of paint spray in the plane in which the articles move, the atomizing head may be fixed, but usually the head is oscillated or reciprocated in a plane parallel to the path in which the article being painted is conveyed, especially if the article being painted presents a larger surface area than the area of the annulus. Relatively small articles are generally hung on a rack carried by the conveyer and usually the rack is turned slowly as it passes in front of the head. With an electrostatic field of sufficient strength between the atomizing head and the article which serves as the receiving electrode, overspray is negligible. Ventilating hoods or booths may be required to exhaust the fumes of volatile solvents on the paint but substantially all paint solids collect only on the artices being painted and their unshielded but grounded supports.

As the paint leaves the apices or stems 20, it is apparently substantially atomized by centrifugal force alone. This is demonstrated by removing the shrouded impeller blades 28 and disconnecting the high voltage source 35. The paint will be thrown in droplets of varying size in a plane perpendicular to the shaft 12. The degree of atomization by centrifugal force depends, of course, on the speed of rotation of the cup 15, for which there appears to be an optimum limit for paint of a given viscosity. Thus, with a standard metal primer paint having a viscosity of from 16 to 19 seconds in a No. 4 Ford cup, no more effective atomization by centrifugal force alone appears to be achieved above 3,000 r.p.m. In fact, if a high voltage source is connected to an unshrouded cup 16 so that paint would be directed by electrostatic forces toward the collecting electrode, rotational speeds above the optimum for a given paint are generally avoided to prevent paint particles being thrown by centrifugal force out of the electrostatic field, or, at least, with a radial momentum force exceeding the attractive force of the electrostatic field.

If the shrouded impeller is then replaced and paint is atomized without the high voltage source 35 connected, the annular jet of air through the circular slot 27 strikes the paint emitted from the apices provided by the stems 20. As will be noted from FIGURE 3, as the air leaves the slot 27, it will tend to move radially as well as axially and the outer shroud 26 preferably overhangs the inner shroud 25 so as to direct the air radially inwardly rather than radially outwardly. Also, as the air moves over the ends of the tubes provided by the stems 20, apparently substantial local turbulence is created. In any event, paint is atomized by the centrifugal force and air jet into a cone of spray concentric with the axis of the cup. The paint is far more finely and uniformly atomized than it is by centrifugal force alone. The fact that a substantial portion of the paint moves parallel to the axis of the cup demonstrates that the air, directly or by local turbulence as it moves over the apices, directs some of the paint droplets radially inwardly; if the air exerted only an axial force, the resultant direction of the paint particles under the combined radial centrifugal force and the axial movement of the air would necessarily be an outwardly divergent only.

The effect of the air and centrifugal force in atomizing, dispersing, and depositing the paint may be observed by placing a sheet of paper in front of the cup at a distance substantially equal to its outer diameter. Approximately 80% of the paint fed to the spray head, without the high voltage source connected, will be deposited on the paper.

The optimum speed for rotation of the spray head as shown in FIGURE 1 varies according to the efficiency of the impeller blades as well as the physical characteristic of the paint, except that these speeds appear to be higher than if no air is employed. Thus, using the primer paint mentioned above, optimum speeds appear to be in the range of 6,000 to 8,000 r.p.m., but speeds up to 10,000 r.p.m. have been achieved with no indication that an overspray would be produced by operating at higher speeds. Evidently the combined effect of the axially moving air and centrifugal force is to atomize the paint so finely that the droplets become substantially massless and are wafted toward the article to be painted by the air as it expands from the slot 27.

The pattern produced by our atomizing head is still "doughnut" shaped. However, the hollow of the zone is cylindrical rather than conical. The margins of the annulus deposited from our atomizing head are more sharply defined than those obtained by electrostatic atomization, dispersion, and disposition alone, or by a combination of only electrostatic and centrifugal force. Moreover, in the area covered by the annulus the paint is deposited more uniformly. Not only is the area of the annulus greater but it may be coated more quickly because a greater volume of paint may be atomized. The increase in area coated can be observed by comparing a "doughnut" deposited by a first head made as shown in FIGURE 1 and a second head of the same construction but with the shrouded impeller removed so that paint was atomized, dispersed, and deposited by a combination of centrifugal and electrostatic forces only. Both cups were 4 inches in diameter and spaced 4 inches from the receiving surface. Both deposited annuli 17 inches in diameter. Not only was the paint from the second head somewhat less evenly distributed, but the inner diameter of its inner "hole" was 8 inches, as compared with a 4 inch "hole" produced by the first head; that is, the inner unpainted area produced by the first head embodying this invention was only one-fourth that of the inner, unpainted area produced by the second head.

There may be many correct explanations for the fact that overspray may be kept to a negligible minimum with an electrostatic spray head made according to this invention, despite the fact that heretofore the art found that turbulence of the air through which the paint particles moved was to be avoided. The most logical explanation at the present appears to be: First, the turbulence at the periphery of the cup 15 created by air from the slot 27 may be severe, but the very turbulence greatly enhances the atomization of the paint into small, relatively weightless particles. Second, in the plane transverse to the axis of the cup 15, the area of the front portion 16 of the cup is very large compared to the narrow annular area of the perimeter in which the turbulence occurs and where atomization takes place under the combination of centrifugal force and air flows from the slot 27. Third, the finely atomized paint as a result of the forces acting on it at the annulus of emission tends to fill a volume defined by first cone outwardly diverging from the periphery of the cup 15 and a second cone inwardly converging from the periphery of the cup to its axis, whereas the lines of force in an electrostatic field between the cup and a receiving electrode comprising a plane surface theoretically fill a paraboloid diverging from the rim of the cup toward the collecting electrode. At the plane where this theoretical paraboloid intersects the outer surface of the volume of spray, the volume of spray would have so expanded that any turbulence becomes very gentle and, in any event, it would be an extremely remote probability that any paint particles reaching that plane of intersection would have sufficient mass and velocity in a direction transverse the line of force of the field to allow it to escape from the field. Stated in more general terms, more than sufficient energy is supplied by the centrifugal force and air movement acting on the paint to thoroughly atomize it and disperse it toward the collecting electrode and deposit it thereon; the energy of the electrostatic field need only be utilized to confine the paint droplets within the field.

If the foregoing geometrical explanation of the operation of an electrostatic spray head embodying the principles of this invention is even approximately correct then, upon cursory consideration, all that would be required to eliminate the inner hole of the "doughnut" would be to place receiving electrodes beyond the apex of the inner cone of the volume filled by the spray. The explanation for this seeming paradox between a theoretical consideration and actuality is that the paint particles carry similar electrostatic charges and the forces of repulsion between the particles act against forces tending to converge them within the volume filled by the spray. In practice, the extent to which the inner hole in the spray pattern is lessened from that created by the repulsion forces of adjacent free charged droplets appears to depend upon the extent to which other forces, such as the radially inwardly directed force of the air supplied at the periphery of the cup 15, tends to overcome such forces of repulsion.

Spray heads made according to this invention are by no means confined to an embodiment shown in FIGURES 1 to 5. Due to the wide range of speeds which may be applied to the shaft 13 of the embodiment shown in FIGURE 1, by conventional variable speed motors or drives, the cup 15 can accommodate paints having a relatively wide variety of physical characteristics such as viscosity, "length" of vehicle, and the like. A shrouded impeller of the type shown in FIGURE 1, should have its blades 28 of a shape and size to deliver the optimum volume of air to the slot 27 at the optimum rotational speed selected from the particular paint being handled in the cup 15. If a paint of different characteristics is to be handled the impeller may not deliver the required volume of air for best atomization of the different paint, requiring a change of impellers. FIGURE 6 shows a different embodiment in which a simpler replaceable impeller may be employed. Further, at certain rotational speeds, heads of the type shown in FIGURE 6 may be more efficient due to the more efficient impeller involved.

As shown in FIGURE 6, the head comprises a cup 115 similar to the shaft 15 of FIGURE 1. The cup 115 is carried by a shaft 112 connected through a sleeve 114 to a dielectric shaft 113 of a high speed air motor 150, driven by an air line from a suitable source of compressed air, not shown. Paint is fed to the cup 115 by a conduit 118 and is discharged from the hollow stems 120. The outer shroud 126 is a cylindrical sleeve supported at its rear by an insulating wall 151 carried by the air motor 150 and tapered at its forward end to form with the ring-shaped inner shroud 125 a slot 127 similarly disposed with respect to the stems 120 as the slot 27 is with respect to the stems 20. The inner shroud 125 may be fixed, as is the outer shroud 126, with respect to the cup 115, but usually it is carried by the cup. A brush 136 carried by the shroud 126 connects the sleeve 114 and, thus, the cup 115, to a suitable high voltage source. A suitable blower fan 128 is removably mounted on the sleeve 114, defining a plenum chamber 129 within the outer shroud 126 and the cup 115 and ahead of the fan 128. Air under pressure with the plenum chamber escapes through the slots 127 to assist in atomizing and directing paint spray from the stems 120. Air for the blower fan 128 is supplied through inlets 152 in the shroud 126 and located behind the fan 128.

Except as the fan 128 may supply a larger volume of air than the blades 28 in the embodiment of FIGURE 1 for a given speed of the cup and, thereby, cause the annular jet of air from the slot 127 to exert a greater converging force on the atomized droplets of paint, the operation of the head shown in FIGURE 6 is similar to that of FIGURE 1. To remove the cup for cleaning or to replace the fan 128 with another designed to operate at a different speed, a wrench is simply inserted through inlet 152 to loosen the set-screw fixing the sleeve 114 to the shaft 113 and assembled fan and cup is slid out of the head.

A simplified version of the head shown in FIGURE 6 is shown in FIGURE 7, in which a high speed air motor 250 carries a wall 251 on which is mounted a fixed outer shroud 226. The shaft of the air motor 250 is a hollow tube 213 upon which a sleeve 214 is removably secured. The sleeve 214 carries an inner shroud 225 similar at its periphery to the shroud 125 of FIGURE 6 and a cup 215 similar to the cups 15 and 115, except that in this instance the inner rim of the cup does not require a large central opening. Instead, paint is fed by a flexible line 218 connected by a suitable coupling 219 to the hollow shaft 213; from the shaft 213 paint flows through the sleeve 214 to the cup 215 and is discharged from the stems 220. Air under pressure from a suitable line is fed into a manifold 228 and thence through inlets 252 in the outer shroud 226 into a plenum chamber 229 defined by the outer shroud, the inner shroud and the motor 250 and wall 251. Air within the plenum chamber 229 escapes through the slot 227 to atomize and direct paint emitted by the stems 220. To keep the plenum chamber 229 uncluttered, high voltage is supplied by a slip ring 236 mounted behind the motor on the shaft 213 which, in this instance, is electrically conductive. To prevent the high voltage from shorting out, the motor is mounted on an insulated support (not shown) and the flexible paint and air lines to the head are non-conductive. The volume and pressure of air supplied to the plenum chamber 229 is controlled by a suitable regulator valve (not shown) on the line to the manifold 228.

Although it is preferred that the paint be discharged from hollow stems acting as electrode apices because such apices appear to be the points on the atomizing cups from which the lines of force in the electrostatic field flow, we have found particularly when high pressure air is supplied from a source independent of the drive for the cup, as in FIGURE 7, the operational advantages provided by the stems diminish in importance and permit the use of less expensive cups which omit them. One such cup is shown in detail in FIGURE 8, replacing the cup **215** of the embodiment shown in FIGURE 7. As shown in FIGURE 8, the cup **315** has a front portion **316** and a rim **317** similar to those shown in previous embodiments, except that, at the periphery, the cup is simply drilled to provide outlet orifices **320**.

FIGURE 8 also shows the distribution of the paint **5**, as it appears, from examination of the residual paint in a cup after use, to occur with the cup end as it is atomized. As indicated, as the paint flows over the inside wall of the portion **316** toward the inner periphery, it forms a thin film or meniscus which apparently covers the entrances to the discharge orifices. Possibly because the velocity of the paint increases as it flows through the orifices, it fills less than the entire volume of the orifice and is discharged from the front edge or lip of the orifice. High speed photographs indicate that the paint, for a very short distance beyond the lip of the orifice, maintains the form of a thin film until surface tension and/or the atomizing forces break it up into droplets. We suspect that the transverse flow of air from the slot provided by the shrouds accelerates the break-up into very fine droplets **6**, as indicated in FIGURE 8.

Another advantage of the stemless construction of the cup, as shown in FIGURE 8, is that it also permits the cup to be split and made in separable front and rear sections, as shown in FIGURES 9 and 10. As indicated in FIGURES 9 and 10, the cup **415** may comprise a front half **416** similar to the portion **316**, and a separable rim or rear half **417**.

The halves may still have discharge orifices **420** extending through the periphery. If it is desired to direct paint through such orifices **420** and not through the slit thus provided, the halves may be fastened together by suitably located screws **460** and one or both of the adjacent peripheral surfaces may be provided with a groove **461** on which a sealing ring **462** may be located. Depending upon the degree to which the sealing ring is compressed the orifices **420** will be restricted, thus providing a means for metering the orifices for different paints. The principal advantage of the split construction as shown in FIGURES 9 and 10, however, is that by disassembling the front and rear halves of the cup, the discharge orifices may be readily cleaned.

It is to be noted that in all of the above-described modifications of this invention, a plurality of factors are involved, each one of which may be varied to control the degree of atomization. In the so-called single fluid atomizing head of the prior art, only one variable factor is effective in controlling the degree of atomization for a given rate of paint feed, namely, the applied voltage gradient. In atomizing heads made according to this invention, not only may the voltage gradient be varied, but the rotational speed and the volume of atomizing air may be adjusted to accommodate paints of varying characteristics. Thus, the paints need not be so carefully selected for successful atomization. Even paint having highly volatile solvents may he handled by the expedient of chilling the paint and, in embodiments exemplified by FIGURE 7, by chilling the atomizing air to retard evaporation of the volatile paint solvent.

As is evident from the foregoing variations of this invention as exemplified by the above described specific embodiments, this invention is not limited to the specific embodiments disclosed or the explanations for their operation. Instead still other variations may be made without departing from the spirit and scope of this invention as defined in the following claims.

What is claimed is:

1. In electrostatic coating apparatus, a dual-fluid atomizing head comprising a body mounted for rotation about a central axis, said body including a shallow cup having the same central axis, an outwardly bulging side portion and a radially inwardly extending rim portion, means for



supplying liquid coating material to said body comprising a conduit discharging into the interior of said cup, a plurality of annularly distributed hollow stems communicating with the interior of said cup and extending radially outwardly from said outwardly bulging side portion of said cup, the radially outer ends of said stems being sharp-edged to constitute electrode apices, air impeller means mounted for rotation in association with said body and including means for discharging air in a longitudinal direction past said outer ends of said stems.

2. In electrostatic coating apparatus, a dual-fluid atomizing head comprising a body mounted for rotation about a central axis, said body including a shallow cup having the same central axis, an outwardly bulging side portion and a radially inwardly extending rim portion, means for supplying liquid coating material to said body comprising a conduit discharging into the interior of said cup, a plurality of annularly distributed hollow stems communicating with the interior of said cup and extending radially outwardly from said outwardly bulging side portion of said cup, the radially outer ends of said stems being sharp-edged to constitute electrode apices, air impeller means comprising inner and outer annular shroud bands longitudinally displaced to one side of said outer ends of said stems and spaced relatively closely to each other on their sides which are toward said outer ends of said stems to provide between them an air discharge orifice for discharging air past said outer ends of said stems, and a plurality of annularly distributed blade members disposed between said shrouds.

3. In electrostatic coating apparatus, a dual-fluid atomizing head comprising a body mounted for rotation about a central axis, means for supplying liquid coating material to said body, electrode apex means on said body for centrifugally discharging the liquid coating material from said body in a direction having a major component perpendicular to said axis, air impeller means mounted for rotation in association with said body and including air discharge orifice means for dischargng air in a longitudinal direction past said electrode apex means and toward the front of said body in a direction having a major component parallel to said axis and transverse to the direction of discharge of said coating material from said body, and means for creating an electrostatic charge differential between said electrode apices and articles located in front of said body.

4. In electrostatic coating apparatus, a dual-fluid atomizing head comprising a body mounted for rotation about a central axis, means for suplying liquid coating material to said body, electrode apex means on said body for discharging the liquid coating material from said body in a direction having a major component transverse to said axis, means for discharging air in a longitudinal direction past said electrode apex means and toward the front of said body during rotation of said body, and means for creating an electrostatic charge differential between said electrode apices and articles located in front of said body.

5. In an electrostatic paint atomizing apparatus, a collecting electrode, a paint atomizing head spaced from said electrode and having a surface generally perpendicular to the direction of said electrode from the atomizing head, means to establish a voltage potential between said head and said electrode, an edge on said surface, means supplying paint to said surface, means to force paint to flow along said surface to a plurality of points along said edge with sufficient velocity to cause the paint to break into droplets as it leaves said edge, whereby said droplets, in the absence of other forces, would move generally in said perpendicular plane, and means supplying a jet of air as an envelope around the periphery of said head and having a major component moving in a direction toward said electrode to strike said paint as it leaves said edge and forces said paint to move from a perpendicular plane toward said electrode.

6. Electrostatic paint atomizing apparatus as defined

in claim 5, in which means supplying said jet of air directs said jet toward said edge in a direction having a component parallel to the direction to said electrode and components transverse to said direction to said electrode, whereby at least some of said droplets move in a path less divergent from the direction to said electrode than the resultant direction would be if the force of the air jet were only parallel to said direction to said electrode.

7. In an electrostatic atomizing head, a shallow cup, means to supply paint to said cup, means to rotate said cup, said cup having at least one opening in its periphery constituting an orifice directly to the interior of the cup to permit said paint to leave said cup in a direction transverse to the axis of said cup under centrifugal force imparted by said rotating means and in the absence of other forces, a member defining an annular slot adjacent said periphery and means for supplying air under pressure to said slot, said slot and the member defining the same constituting means oriented with respect to said periphery to direct air over said periphery in a non-divergent direction having a component axial to said cup and another component extending radially inwardly of said periphery.

8. In an electrostatic atomizing head, a shaft, a circular member mounted on said shaft, means supplying paint to said circular member, means to rotate said shaft, whereby paint fed onto said circular member will be thrown by centrifugal force from the periphery thereof in a plane perpendicular to the axis of rotation of said shaft, an outer concentric shroud member having an inner periphery adjacent and concentric with the periphery of said circular member, and means to supply air to the inner periphery of said shroud member in a direction parallel to said shaft whereby air leaving the periphery of said shroud member moves over the periphery of said circular member and diverts said paint from the generally perpendicular plane in which said paint moves under the influence of said centrifugal force.

9. Apparatus defined in claim 8 including an inner shroud member concentric with said outer shroud member, the outer periphery of said inner shroud member and the inner periphery of said outer shroud member defining a slot concentric with the periphery of said circular member.

10. An atomizing head including a shaft, a shallow cup member having a front portion and a rim portion, openings through said rim portion at the periphery of said cup, means for rotating said cup, means to supply paint within said cup, whereby the paint will be thrown with centrifugal force through said opening, an inner shroud member, an outer shroud member spaced concentrically with respect to said inner shroud member to define a slot concentric with the periphery of said cup, said slot being connected to a plenum chamber, and means to supply air to said plenum chamber so that air escaping from said chamber through said slot is directed over the periphery of said cup member and has a component directed axially of said cup and a component directed radially inwardly of said cup, whereby said paint thrown centrifugally from said cup is diverted axially in a direction less divergent from said axis than the resultant direction would have been if said air escaped from said slot only in a direction parallel to said axis.

11. Apparatus as defined in claim 10 in which said means for rotating shroud cup includes a shaft and said means for supplying air to said plenum chamber includes a fan member mounted on and driven by said shaft.

12. Apparatus as defined in claim 10 in which said plenum chamber is provided with opening into it, air compressing means operated independently of the means for rotating said cup, and conduit means connecting said air compressing means to said plenum chamber through said opening.

13. In an electrostatic atomizing head, a shallow cup member having a rim portion defining an inner annular concavity having openings through to the outer periphery of said cup member, a shaft supporting said cup member, an inner shroud member concentric with the periphery of said cup, an outer shroud member, a wall member spaced from said inner shroud member and supporting said outer shroud member concentrically with said inner shroud member to define a slot concentric with and adjacent to the outer periphery of said cup, said shroud members and wall members at least partly enclosing a plenum chamber into which said slot opens, means to supply air under pressure to said chamber, whereby air will escape from said slot over the periphery of said cup member, means to supply paint to the inner concavity of said cup member, an electrical contact on said shaft to connect said cup to a source of high voltage, and means to rotate said shaft, whereby paint in said concavity will escape to the periphery of said cup member and be subject to the atomizing force of air escaping from said slot, to centrifugal force, and to an electrostatic field between said cup and an electrode at a potential different from that of said cup member.

14. An electrostatic atomizing head as defined in claim 13 in which said means for supplying air to said plenum chamber comprise openings through said outer shroud member, a manifold surrounding said openings, and means connecting said manifold to a source of air pressure.

15. An electrostatic atomizing head as defined in claim 13 including a fan member mounted concentrically with and driven said said shaft, said fan member being located between said inner shroud and said wall member, said outer shroud having openings therein between said fan member and said wall member.

16. In an electrostatic atomizing head, a shallow cup member having a front portion and a rim member defining an internal annular concavity and openings between said concavity and the periphery of said shallow cup member, the front portion being convexly curved toward the periphery, the intersection of the convex curvature of the front portion and said opening defining sharp lips tending to interrupt and break into droplets any paint flowing out of said openings and drawn over said lips.

17. In an electrostatic atomizing head, a shallow cup as defined in claim 16 in which said front portion and said rim portion are separable along a plane located by said openings, and means to removably secure said separable portions in a concentric relationship.

18. In an electrostatic atomizing head, a shallow cup as defined in claim 16 including means to limit the axial spacing between said front portion and said rim portion whereby the flow of paint out of said concavity may be metered.


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