United States Patent

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[54] **METHOD AND APPARATUS FOR SPRAYING ELECTROSTATIC DRY POWDER**
19 Claims, 10 Drawing Figs.

[52] **U.S. Cl.** **239/3,** 239/124; 117/93.4
[51] **Int. Cl.** **B05b 5/02**
[50] **Field of Search** .... 239/3, 15, 379, 124; 222/193, 318; 51/8, 11; 118/308—311, (Church), 93.4; 117/17

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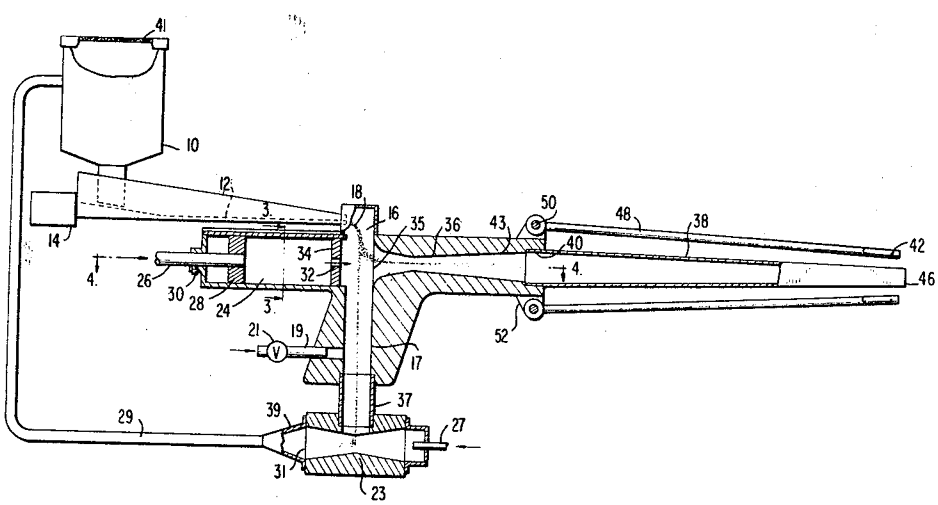
ABSTRACT: Dry nonconductive powder passes from a hopper by means of a vibrating plate through an adjustable, nonclogging eductor and is directed by means of a current of air issuing through a rectangular orifice from a variable volume plenum chamber into a venturi. The powder particles pass into the entrance of the venturi in a stream of air having a rectangular flow pattern or cross section and from the venturi through a discharge nozzle and from the discharge nozzle onto a substrate to be coated. Corona wires are located in the proximity of the issuing end of the discharge nozzle so as to charge the powder particles in order to direct them onto a substrate. A positive draft is maintained downstream from the venturi entrance and serves to pick up excess powder particles which are pneumatically conveyed back to the feed hopper.



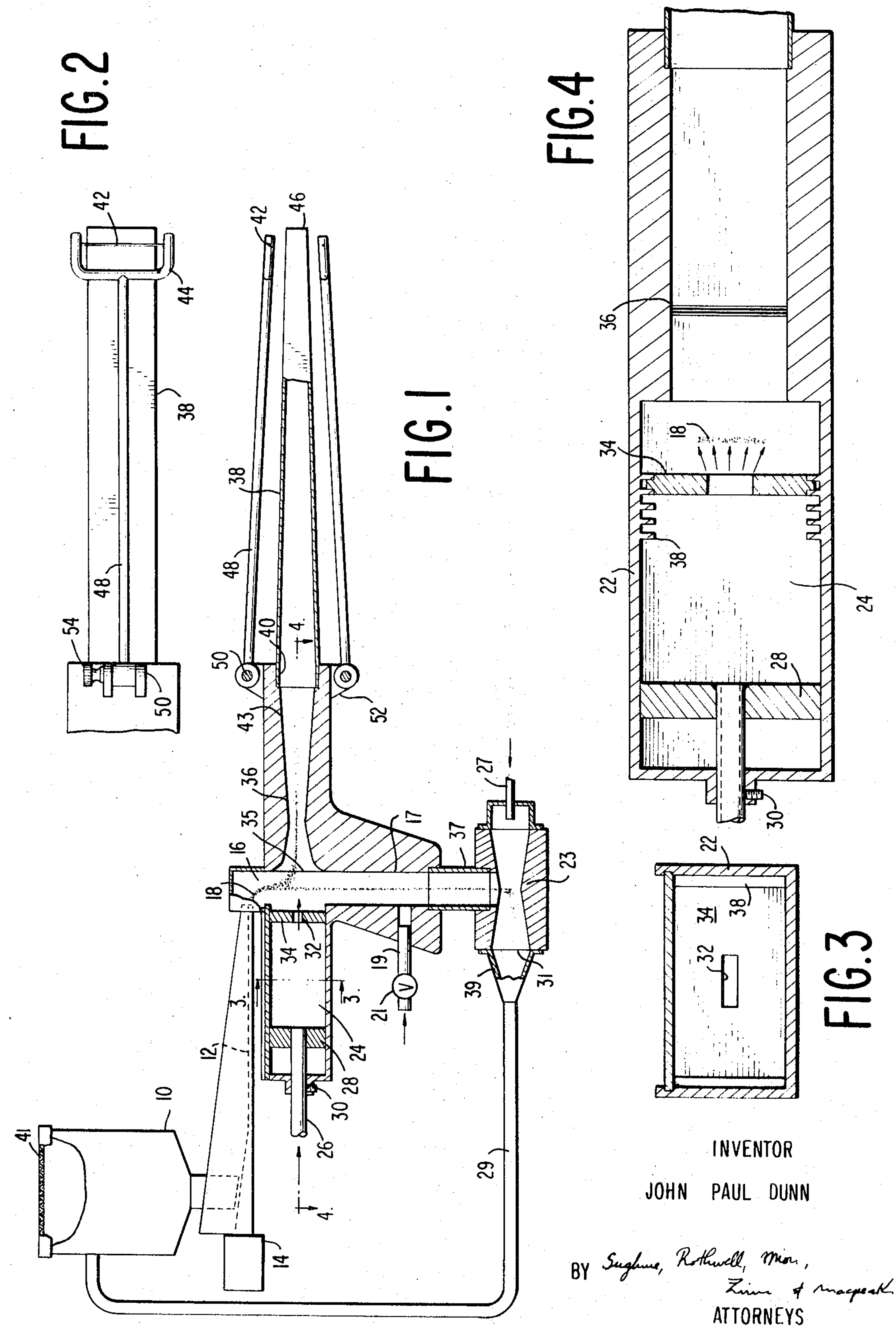


FIG.1 FIG.2 FIG.3 FIG.4

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FIG.5

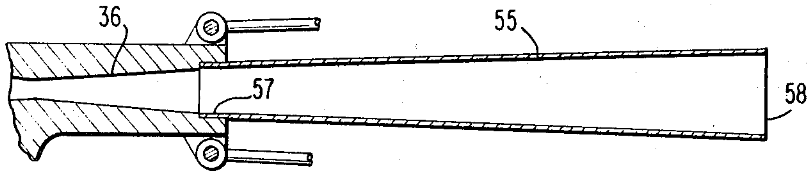
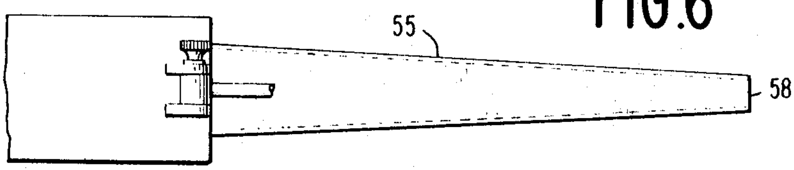


FIG.6



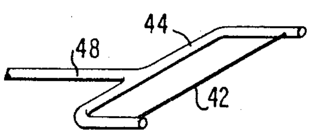


FIG.7

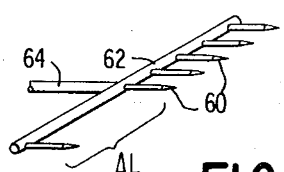


FIG.8

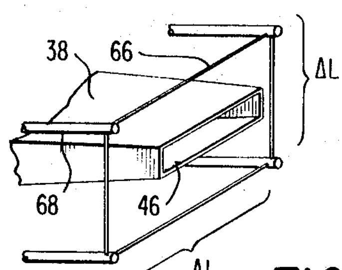


FIG.9

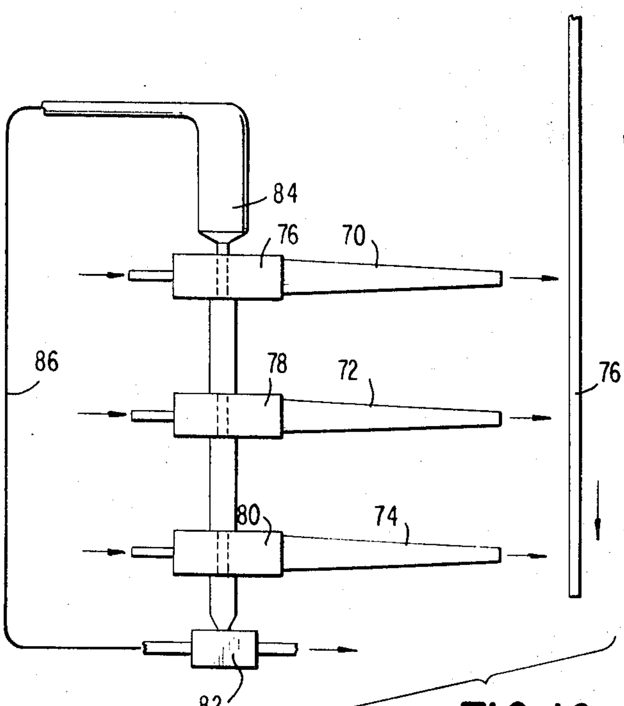


FIG.10

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METHOD AND APPARATUS FOR SPRAYING ELECTROSTATIC DRY POWDER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates broadly to the field of spraying dry nonconductive powders onto various substrates for coating purposes and, more particularly, to an apparatus which pneumatically conveys the powder particles in a patterned flow through a discharge nozzle, into an area were the powder particles are charged and finally directed onto the surface of a substrate to be coated.

2. Prior Art

The broad concept of directing dry particles of powder or like material onto a substrate through the use of a directed flow of air or like conveying fluid is generally well-known in the art. However, in the practice of these prior art methods and associated devices directed to the electrostatic spraying of dry nonconductive powders, difficulties are often encountered in attempting to apply coating of uniform thickness and density. It is generally recognized that uniformity of the deposited coating of powder can best be accomplished if the spray consists of discrete and evenly dispersed particles, flowing through and from the discharge nozzle at a uniform rate.

Prior art systems encounter problems of uniform coating in that the resultant spray is a mixture of discrete and agglomerated particles. A number of limitations on the existing spray systems are caused directly by the high specific gravity of the powder or like materials being sprayed. A powder having a high specific gravity has a tendency to settle and collect or buildup within the apparatus of the spray system. This, of course, tends to clog the discharge nozzles and other delivery conduits through which the powders are being pneumatically conveyed. To overcome this settling problem, prior art-spraying systems have utilized high velocity fluid flow for conveying the powder particles. This, in turn, has created a number of additional problems which also leads to a nonuniform coating of the particles onto the desired substrate. To overcome this settling problem, the velocities of the conveying air or fluid, and consequently, the velocities of the conveyed powder particles, are normally greater than 600 feet per minute and often reach a velocity in excess of 1000 feet per minute. The flow of air and powder at this velocity through the discharge nozzles of the spraying devices, while eliminating the problem of settling within the nozzles, created turbulence and resulted in the particles striking the desired substrate with such force as to bounce off or ricochet from the surface of the substrate thereby creating an uneven coating. Consequently, the existing spray systems are limited to spraying powders having a specific density in a somewhat limited range because spraying powders having a relatively high specific density necessitates the need of a high velocity air flow resulting in the above-mentioned problems.

SUMMARY OF THE INVENTION

This invention relates to a spray system for spraying dry nonconductive powder particles uniformly onto various substrates. The apparatus of the invention includes a feed bin containing dry powder particles which is delivered into the air stream of an eductor system. The powder cascades, in the shape of a substantially uniform ribbon of powder, downwardly through the eductor system to a point where it is picked up by an air jet issuing from a variable volume plenum chamber through a rectangular orifice. The air jet directs the powder particles into the entrance of a rectangular-shaped venturi where the particles are evenly dispersed through the action of the air jet and the pressure differential created by the venturi. The powder continues to flow through a rectangular-shaped issuing nozzle and the particles are eventually charged by corona or like conducting wires arranged in the proximity of the issuing end of the nozzle. The charge particles are then attracted to the oppositely charged substrate to provide an even coating on the surface of the substrate.

The quantity of powder delivered to the surface of the substrate is proportional to the rate of powder feed into the eductor system, to the velocity of the air or other conveying fluid and to the volume of conveying fluid which is a function of the plenum chamber orifice. Consequently, in the present invention, the necessity for a high velocity gas flow is eliminated through the use of a gas plenum orifice having a rectangular-shape and by delivering a uniform curtain or ribbon of powder to the entrance to the venturi section.

The purpose of combining a system using a ribbon of powder and a powder delivery system having a rectangular cross section is to overcome the problems encountered when converting a flow of powder having a circular cross section into a flow powder having a rectangular flow pattern or cross section. When converting a circular flow pattern to a rectangular flow pattern, a larger pressure differential occurs causing a particle velocity differential across the section or pattern of the flow. This results in a nonuniform flow and also in a nonuniform deposition of the powder onto the substrate. The present invention minimizes this pressure differential and creates an even laminar flow of powder by forming the desired cross-sectional pattern in the flow of powder at the entrance to the venturi and accordingly designing the nozzle section following the venturi so as to maintain the laminar flow.

If the powder delivered to the venturi has a circular cross-sectional pattern, then the flow of powder traveling in the marginal portions of the circular cross section are traveling at a slower velocity than the flow of powder traveling in the central portion of the circular cross section. If the powder traveling through the system has a sufficiently high specific gravity, the slower velocity powder has a tendency to settle which results in clogging of the system as previously mentioned. Consequently, to prevent settling, the velocity of the powder in the slower traveling portions of the circular pattern flow is increased resulting in a proportional increase of the powder in the central portion of the circular pattern. This greatly increased powder velocity creates the problem of bounding or ricocheting of the particles from the substrate as previously described. When a relatively uniform rectangular cross section of powder is delivered to the venturi the powder in all portions of the cross-sectional pattern are traveling at approximately the same rate, consequently, the conveying gas may be allowed to travel at a relatively lower velocity without the worry of clogging of the system due to the settling of powders having a high specific gravity. While it is recognized that when spraying powders having a relatively high specific gravity, the velocity of the conveying gas will have to be increased, the present invention eliminates the need of a relatively high velocity gas which results in the problems previously described.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 s a side elevation view of the spray system with a partial sectional view of the eductor and delivery portions of the apparatus;

FIG. 2 is a top plan view of the nozzle and corona wire support means;

FIG. 3 is a cross-sectional view taken on line 3–3 of FIG. 1 through the plenum chamber viewing the plenum chamber orifice;

FIG. 4 is an enlarged top longitudinal sectional view taken on line 4–4 of fig. 1 of the plenum chamber, plenum chamber orifice and venturi portion;

FIG. 5 is a side sectional view of a delivery nozzle arranged to coat a substrate passing the discharge end of the nozzle in a horizontal plane;

FIG. 6 is a top plan view of FIG. 5;

FIGS. 7 and 8 are perspective views of two embodiments of a corona wire or like electrode structure which may be used with the present invention;

FIG. 9 is a perspective view of yet another embodiment of a corona wire arranged in the proximity of the discharge end of the nozzle, and

FIG. 10 is a side elevational partially schematic view of a plurality of discharge nozzles operated from a central eductor.

DESCRIPTION OF PREFERRED EMBODIMENTS

The apparatus of the present invention comprises a feed hopper **10** arranged above a vibrating pan **12** which is activated into vibrating movement by a vibrating source **14**. FIG. 1. The vibrating pan **12** communicates directly with the upper portion of eductor **16**. The width of the eductor can be adjusted to vary in proportion to the size of the substrate and accordingly the quantity of powder to be ejected. The eductor communicates and leads past orifice plate **34** in which is located rectangular orifice **32**. During operating, a jet of air is directed from variable volume chamber **24** through rectangular orifice **32** into the entrance **35** of venturi **36**. The rectangular orifice **32** and the entrance **35** of the venturi **36** are axially aligned and are located on opposite sides of the eductor **16**. The variable volume plenum chamber **24** includes an air inlet conduit **26** channeling air into the variable volume chamber **24** from a source which is not shown. The conduit **26** is supported within the housing **22** by a support member **28** and is maintained in proper position by set screw **30**.

FIG. 4 is an enlarged view of the plenum chamber and orifice plate **34**. The orifice plate **34** is removably mounted within the spray housing so as to be able to change the size of the orifice opening **32**. The adjustable mounting means include various notches **36** formed by a plurality of ribs **38** arranged on each of the internal walls of housing **22**. Alternately to the embodiment shown in FIG. 4, the air plenum chamber itself may be movably mounted within the spray housing by mechanically securing together plates **28** and **34** which define the chamber **24** so that they may be movably mounted as a unit but immovable relative to one another. In other words, plate **28** could be mechanically connected to orifice plate **3** that longitudinal sliding movement of plate **28** would result in the movement of plate **34** either towards or away from the falling ribbon of powder **18**. The effect of the relative position of plate **34** to the ribbon of falling powder **18** will be described in greater detail later.

The eductor **16** has a lower portion **17** in which a positive draft is created through an air flow entering through conduit **19** and check valve **21** from a source which is not shown. A second venturi **23** is connected by coupling **37** to the lower portion **17** of the eductor. A current of air is directed into the entrance of venturi **23** through conduit **27** from a source which is not shown. Coupled to the exiting orifice **31** is a funnel or conical-shaped member **39** and a powder return conduit **29**. The return conduit **29** extends from the second venturi to the feed hopper **10** and serves to deliver by recirculation the excess powder particles which were not taken into the entrance **35** of the first venturi **36**. The feed hopper has a vent such as a screen top **41** so that pressure of the delivery stream can be relieved.

As previously mentioned, the entrance **35** of the venturi **36** is arranged in axial alignment and on opposite sides of eductor **16**. A discharge nozzle **38** having a rectangular cross section has a connection **40** to the diverging outlet **43** of the venturi **36**.

Corona wires or like conducting wires **42** are mounted on a forklike structure **4** in close proximity and behind the outlet **46** of nozzle **38**. The forklike mounting structure **44** of corona wire **42** is itself supported by arm member **48** which is adjustably attached by pivotal mount **50** secured to the housing of the venturi by braces **52**, or like mounting means, and which may be manually adjusted by knob **54**.

FIGS. **5** and **6** show an additional embodiment of the present invention comprising another shaped nozzle **55** attached to venturi **36**. The nozzle **55** of this embodiment also has a rectangular cross section and is positioned to coat a substrate passing the exit **58** of the nozzle in a horizontal direction. Consequently, the longitudinal sides of orifice **58** are arranged in a vertical plan rather than in a horizontal plane as shown in FIGS. **1** and **2**. It should be noted that entrance **57** to nozzle **55**, as well as any other nozzle useable with the device of the present invention, has the same configuration as nozzle **38** of FIGS. **1** and **2**, so as to allow rapid removal and insertion of different nozzles when a change in nozzles is desired.

FIGS. **8** and **9** are directed to different embodiments of a corona or like conductor used to create the ionization field between the outlet of the discharge nozzle and the substrate. FIG. **8** shows a plurality of electrodes **60** arranged on a crossbar support **62** which is attached to a supporting arm **64** in a manner similar to that previously described in the embodiments shown in FIGS. **1** and **2**. FIG. **9** is an embodiment of the present invention which includes the arrangement of corona wires **66** in a rectangular-shape in the proximity of but behind the exit **46** of discharge nozzle **38**. The wires **66** are supported in a generally rectangular-shape by means of support arms **68** which may or may not be attached to the housing of the spray device. The designations ΔL indicated in FIGS. **8** and **9** represent the length of the corona wires or distances between the electrodes which may be varied in order to effect the spray pattern issuing from the orifice **46** of the nozzle, as will be more fully explained later.

FIG. **10** discloses another embodiment of the present invention which includes a plurality of nozzles **70**, **72** and **74** directing powder or like material onto a vertically traveling substrate **76**. Each of the nozzles is associated with a separate variable volume plenum chamber and venturi generally indicated at **76**, **78** and **80**, and operate in the same manner as the embodiment shown in FIG. **1**. All of the nozzles, however, can operate from a common feed hopper **84** and common eductor arrangement **82** and are serviced by a common return system generally indicated at **86**.

The operation of the preferred embodiment shown in FIG. **1** will now be described and will substantially the same as the operation of the system utilizing the various embodiments shown in FIGS. **5** through **10**.

The powder particles are delivered by means of gravity from feed hopper **10** into the fibrating screen or tray **12**. The dry powder particles are delivered into the upper portion of eductor **16** in a substantially uniform curtain or ribbon **18**. The uniform ribbon of powder then passes into the air jet issuing from variable volume plenum chamber **24** through rectangular orifice **32**. As explained previously, the position of orifice plate **34** may be varied relative to the position of the falling ribbon of powder **18** and the entrance **35** to the venturi. By adjusting the distance between the orifice plate **34** and the ribbon of falling powder, the position of the intersection between the air stream issuing from orifice **32** and the powder curtain is changed. Accordingly, the point of intersection between the issuing stream of air and the powder curtain determines the air flow pattern entering the venturi entrance **35**. Consequently, a regulation of the powder transfer and the powder dispersion is established by changing the intersection between the directed flow of air and the falling curtain of powder.

For example, considering that the position of the falling curtain of powder is relatively fixed in relation to the air chamber orifice **32** and the venturi entrance **35** and further assuming that the cross-sectional area of the falling curtain of powder is generally constant, then by adjusting the air chamber orifice plate **34** closer to or away from the powder curtain, the ratio of powder sprayed into the entrance to the venturi in relation to the amount returned through the return portion of the eductor **17** can be regulated. It is obvious that the current of air issuing from orifice **32** starts to diverge immediately upon clearing orifice **32**. Consequently, it is apparent that the farther away orifice plate **34** is from the falling curtain of powder, the larger the air flow pattern of the issuing air current will be when it intersects the falling curtain of powder. This results in a larger patter and increased cased amount of particles traveling in the air flow beyond the point of intersection.

A flow of particles having the desired cross-sectional flow pattern then enters the venturi **36** where separation of the particles occurs. The principle of using a converge-diverge member or venturi section is to cause particle separation by virtue of the air velocity differential and the shear force established by the venturi. The particles then flow into the entrance of nozzle **38** which also has a rectangular cross section as described above. the dry nonconductive powder particles issue from orifice **46** of nozzle **38** where they may be charged due to the action on the particles by a corona wire **42** or like conductive wire.

The charging electrodes have been made adjustable and interchangeable to control the patterns of the flow of particles as they issue from the exit **46** and are deposited onto the surface of a substrate (not shown). By changing the dimensions and/or position of the charging electrode, the electric field distribution established between the electrode and the substrate is also changed, resulting in the ability to establish various spray patterns which may adequately serve to coat difficulty shaped parts or substrates. It is also important to note that the charging electrodes **42** are arranged behind the nozzle orifice in order to prevent powders from adhering to the fine wires. Dust or powders accumulating on these electrodes reduce their operating efficiency which eventually results in wire breakdown and a nonuniform coating. In the specific embodiment shown in FIG. **1**, the arms **48** are connected directly to a pivoted mount **50** which may be manually adjusted by means of knob **54**. Consequently, the conducting wires **42** are allowed to move in an arc which, as previously mentioned, varies the pattern of the issuing powder particles. The pattern of the issuing particles may also be varied by changing the length ΔL (FIGS. **8** and **9**) of the conductor wires thereby changing the ionization field between the issuing orifice **46** of the nozzle and the substrate.

Only a portion of those particles cascading from vibrating screen **12** into the upper portion of eductor **16** are picked up by the air jet issuing from orifice **32**. The excess particles fall through the lower portion **17** of the eductor and, if necessary, their travel may be aided by a positive draft by an air flow-entering portion **17** through an inlet conduit **19**. The air is provided from a source which is not shown and may be controlled by check valve **21**. Due to the positive draft, the excess particles fall into a second venturi **23** into which a stream of air is directed from a source not shown through inlet conduit **27**. The particles are directed into return conduit **29** through which they are conveyed back to the feed hopper **10** for reuse. Although air has been mentioned as the carrier gas, it will be apparent that other gases, preferably inert to the powder and substrate, could be used. Further, the invention can, if desired, be utilized without the corona discharge wires.

I claim:

1. A dry powder spray apparatus comprising;

a. a spray housing including a venturi with a powder-gas entrance;

b. a gas inlet for admitting gas under pressure to the housing, a gas inlet chamber directly communicating with the gas inlet and located ahead of the venturi, the gas from said inlet directed toward the venturi through the gas inlet chamber;

c. a powder inlet to the spray housing above the inlet chamber, positioned such that the powder falling by gravity from the powder inlet is picked up by the gas flowing from the gas inlet into the venturi, and

d. an excess powder exit from the spray housing below the powder inlet and the gas inlet chamber so that the excess powder which has not been picked up by the entering gas may flow from the housing.

2. Apparatus as in claim **1** further comprising a nozzle attached to the venturi exit.

3. Apparatus as in claim **2** wherein the nozzle is interchangeable with other nozzles having different cross-sectional outlet openings and the same inlet openings cooperating with the venturi exit end.

4. Spray apparatus as in claim **1** wherein the venturi is rectangular in cross section and the venturi entrance is rectangular in section.

5. Apparatus as in claim **1** wherein one wall of the gas inlet chamber has an orifice therein through which gas is directed into the venturi entrance, the wall being adjustable to vary the gas flow pattern of the gas entering the venturi entrance.

6. A spray apparatus as in claim **5** wherein the adjustable wall is movable relative to the venturi entrance.

7. A spray apparatus as in claim **1** wherein one wall of the gas inlet chamber has an orifice therein through which gas is directed into the venturi entrance, the gas inlet chamber movably mounted within the spray housing, whereby said wall is adjustably positioned relative to the falling powder so as to vary the pattern of gas entering the venturi entrance.

8. A spray apparatus as in claim **1** further comprising a return eductor connected to the excess powder exit for returning excess powder to a powder feed means.

9. A spray apparatus as in claim **8** further comprising: a gas inlet in the excess powder exit prior to the return system whereby said inlet creates a positive draft serving to guide the excess powder into he return eductor system.

10. A spray apparatus as in claim **1** wherein the powder feed means includes a powder hopper, a vibratory screen, and a conduit connected to the powder inlet.

11. An apparatus as in claim **1** wherein particle charging conductors are mounted adjacent the powder exit but upstream from the powder exit.

12. An apparatus as in claim **9** wherein said conducting wires are mounted so as to completely surround the powder exit.

13. An apparatus as defined in claim **12** wherein said conductors are arranged in a rectangular configuration.

14. A spray apparatus as defined in claim **13** wherein the conductors are adjustably attached to the outside of the spray housing.

15. A spray apparatus as defined in claim **14** wherein a conductor is supported by an arm pivotally mounted on the spray housing so as to be capable of positioning said conductor in one of a number of positions along an arcuate path in the proximity of the powder exit.

16. An apparatus as in claim **1** wherein there are a number of spray housings connected in series with a single feed hopper and a common eductor system.

17. A method for the electrostatic spraying of dry particles onto a substrate, said method comprising:

a. feeding by gravity a uniform ribbon of powder particles past a directed gas flow;

b. forming a directed gas flow having a specifically and uniformly shaped cross section;

c. directing said gas flow onto the flow of particles traveling transversely to said directed gas flow;

d. directing a portion of said powder particles carried by said gas flow and said gas flow into a venturi;

e. conveying powder particles not carried by the gas flow into the venturi to recycle the powder particled;

f. separating the powder particles in the venturi from each other through the action of the venturi;

g. guiding the particles into an electrical charging zone adjacent the venturi outlet, and

h. charging said particles and directing them onto a substrate.

18. A method of spraying particles as described in claim **17** further comprising forming said gas flow so as to have a rectangular cross section whereby said flow of particles in the venturi has a rectangular cross section.

19. Apparatus as in claim **1**, wherein the gas flow for carrying powder is less than 600 feet per second.