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 (72) Inventors CLARENCE C. DANNELLY
 CHARLES RONALD LEONARD



(54) SPRAY COATING APPARATUS

(71) We, EASTMAN KODAK COMPANY, a Company organized under the Laws of the State of New Jersey, United States of America of 343 State Street, 5 Rochester, New York 14650, United States of America do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly 10 described in and by the following statement:-

The present invention relates to an apparatus for spray coating or encapsulating discrete particles or particulate objects 15 while the particles or objects are suspended in a gaseous fluid such as air. The discrete particles or particulate objects to be spray coated or encapsulated may be particles or objects of for example nutrients, therapeutic 20 substances, seeds, fertilizers, pesticides, herbicides or rodenticides. The coating or encapsulation materials serve to protect, preserve and enhance appearance or engender special properties such as, for example, 25 rumen-stable coatings releasable post-ruminatingly as feed supplements for ruminant animals.

In the processes involving encapsulation, the core material must be contained or 30 "encapsulated" in some manner and then may be released upon demand. The processes in the art may use free-flowing solids and film-forming polymers having a release mechanism that may be based upon pH 35 changes, temperatures, solubility, mechanical forces, light or permeability of the film.

Products which are inherently tacky or are not normally free-flowing, can be encapsulated so as to obtain free-flowing discrete 40 particles.

Low melting solids, waxes and liquids can be solubilized, dispersed or otherwise incorporated into a polymer matrix and then applied on to any suitable core material. 45

Low vapour pressure liquids, although not directly capable of being encapsulated, can be encapsulated by absorbing them first on to a porous particle before encapsulating.

In the field of agriculture, seeds have 50 been encapsulated for specific applications

involving moisture and temperature conditions and to alter physical characteristics without affecting germination and growth. Insecticides, fungicides, herbicides and 55 innoculants have been incorporated into encapsulation formulations. More acceptable rodenticides have been developed through encapsulation techniques. The release of pesticides can be controlled by use of resin films as the encapsulating material. Slow release insecticide fungicide 60 systems have been developed that place the insecticide or fungicide on the seed and protect the plant for longer periods of time.

In the food processing industry, encapsulation can be used to provide stability during 65 processing or to release an active ingredient, such as flavour, leavening agent, or acidulant, at a particular point in the process. Packaging can be simplified in some instances 70 where an incompatible ingredient is encapsulated and packaged with the balance of the mixture. Oily materials may be encapsulated by absorbing them on to a suitable base before coating or by including them as 75 part of a coating being applied. Partial coatings can be effective anti-caking treatment and may also serve as a means to apply colours, surfactants, essential oils and trace additives with a high degree of uniformity. 80 Solid particles may be coated to retain a desired texture, greatly retard either hydration or dehydration, improve handling characteristics of both powders and larger particles, or possibly simply to improve the 85 appearance of a product. Taste-masking ingredients, which add offensive flavour, or the stabilization of desirable flavour, have been used either by direct encapsulation or by inclusion in the coating matrix. 90

In the pharmaceutical field, encapsulation processes are used for purposes of stability, masking of taste and colour, timed release and for enteric properties. For instance, in the use of film-forming materials, a low 95 melting semi-crystalline lipophilic compound may be first coated on to a particle which has a high affinity for the compound, such as a polyethylene glycol wax. Then these particles are encapsulated with a hyd- 100

rophilic film that has a low affinity for the compound. The substrate and encapsulating ingredients thus work together to protect the compound from its environment.

5 Examples of coatings that have been used in the art include methyl and ethyl methacrylates, cellulose acetate phthalate, carboxymethyl and ethyl cellulose, polyethylene, polyvinyl acetate, polyvinylidene chloride, 10 polyvinyl alcohol, polystyrene, cellulose propionate morpholinobutyrate, polymers of vinylpyridine and derivatives of vinylpyridine, copolymers, mixtures of polymers with other polymers and/or pigments, fillers, 15 plasticizers, beeswax, carnauba, castor wax, paraffin, corn syrups, dextrans, molasses, fats, gelatins, glycerides, glycols, gums, lecithin, stearates, sucrose, proteins, shellac, starches, and a host of others that could be 20 mentioned.

One type of coating process used in the industry, such as in the pharmaceutical industry, is the fluidized-bed coating process. This process involves supporting particles in a vertical column by an upwardly 25 moving air stream. The coating solution is atomized and sprayed on to the air-suspended particles, and the particles are dried while suspended by the air. The velocity of the air stream is adjusted so that the 30 air-suspended particles are maintained in a relatively confined working region of the column. The drying time of the applied coating can be governed by controlling either 35 the atomization rate, the temperature of the supporting air stream, or both. Such a process is disclosed in U.S. Patents Nos. 2,648,609 and 2,799,241.

The apparatus that has been customarily 40 employed for practising a fluidizing process generally comprises a vertical column, which is constricted at the bottom and expanded at the top. A screen usually extends across the bottom and through 45 which the fluidizing air or gas passes in an upward direction. The air velocity in the constricted portion is such that particles entering this portion are immediately propelled upwards. The air velocity becomes 50 greatly decreased in the expanded portion of the column so that the air velocity will not support the particles and they fall to the central working region of the column. The working region is thus the area where the 55 atomized coating is applied to the particles while they are air-suspended. U.S. Patent No. 3,207,824 discloses an apparatus of the general physical and functional configuration described in which the fluidizing process is practised. There is known apparatus 60 having a chamber which is provided with a cylindrical partition to divide the chamber into two zones, a coating zone and an annular subsidence zone. The particles move 65 upwardly in the coating zone and move

downwardly in the subsidence zone countercurrent to the upwardly flowing gas stream. The partition is elevated a few inches above a screen, through which the 70 upwardly flowing gas streams pass, so as to allow for passage of the particles underneath the partition from the subsidence zone to the coating zone. See U.S. Patents Nos. 3,196,827 and 3,241,520.

Another apparatus for practising a fluidized 75 coating process is disclosed in U.S. Patent No. 3,110,626 which shows a vertically positioned coating chamber, a control element adjustable mounted in the base region of the coating chamber, a venturi tube 80 connected to the base of the coating chamber, an axially positioned atomizer assembly within the throat region of the venturi and a gas foil guidance element. The use of the venturi makes it possible for the 85 particles to be supported in the coating chamber by the gas stream moving from the venturi without the need for a screen. The use of a screen is otherwise described as causing considerable pressure drop. The 90 absence of the screen also enables the patentees to provide for a somewhat different path of circulation for a portion of the particles where some of the particles pass up or exhaust through the top of the chamber 95 into a conduit for subsequent return into the chamber from below the spray nozzle. This is an independent recirculation apart from the recycling of particles occurring within 100 the coating chamber. The venturi is described as causing a drop in pressure and an increase in velocity of the gas stream passing through it. It is stated that the adjustably mounted control element may be in the shape of a cone or a cylinder. In the use of a 105 cone, the base of the cone is larger in diameter than its top. The control element also serves as a partition, to separate the upgoing particles in the coating zone from the downcoming particles. The control element in 110 cooperation with the walls of the neck of the coating chamber and the exit cone of the venturi provide for an annular bed of particles from which particles are circulated up through the control element for coating and 115 down in return to the annular bed of particles. The frictional effect of the combined walls of the coating chamber neck, cone and the exit cone of the venturi, as well as the upwardly flowing gas stream, support the particles at any given instant in the annular bed. The gas foil guidance element is positioned around the atomizer assembly and is axially mounted within the throat region of the venturi. The gas foil guidance 125 element is described as serving to move the gas stream about itself within the venturi without disrupting gas flow and creating disturbances, especially within the throat region of the venturi; and as serving to avoid 130

unnecessary turbulence while increasing the gas flow velocity.

In accordance with the present invention there is provided an apparatus for coating particles, comprising a vertically disposed hollow column in communication with a gas supply system, means within said column for receiving, compressing and accelerating upwardly flowing gases, which means defines a storage zone between an outer wall thereof and an inner wall of said column, a spray nozzle disposed in the bottom portion of the column, and an aerodynamic gas shaping structure for shaping the flowing gases to direct them into and through the means for receiving, compressing and accelerating upwardly flowing gases in such a manner as to create a reduced pressure region surrounding said flowing gases to pull particles from the storage zone and entrain the particles in said flowing gases to transport them through the means for receiving, compressing and accelerating upwardly flowing gases.

The present invention will now be described by way of example with reference to the accompanying drawings in which:—

Fig. 1 shows a general configuration of apparatus of the present invention;

Fig. 2 is a cross-section through one form of apparatus of the present invention showing the gas flows and particle flow path from the annular bed to and through the truncated hollow cone and in return to the annular bed;

Fig. 3 is a cross-section through part of a second form of apparatus of the present invention showing an annular airfoil and showing the flow of gases therein;

Fig. 4 is a cross-section through part of a third form of apparatus of the present invention;

Fig. 5 is a cross-section through part of the upper portion of the apparatus of the present invention showing one form of apparatus for collecting the finally coated particles; and

Fig. 6 is a graphic illustration of the height, thickness and angular relationships of the annular airfoil with respect to the gas shaping structure, and the height above (h_a) and height below (h_b) relationships of the gas shaping structure to the greatest cross-sectional diameter of the gas shaping structure.

Referring to Fig. 1, gas flow upwardly around a gas shaping structure E constitutes an annular flow. Since it has a certain momentum, its emergence beyond the gas shaping structure into the coating chamber is in the form of a jet into the region of a lower pressure. The flow of the jet tends to produce a low pressure region in the vicinity of the jet emergence into the coating chamber so that the surrounding fluid and

the particles from an annular storage bed are induced to flow toward the jet and become entrapped by the jet.

A sharp discontinuity provided along the gas flow path between the gas shaping structure E and the adjacent side wall of the coating apparatus is a consequence of the gas shaping structure E as its upper surface leads sharply away from the adjacent side wall surface and facilitates the adhesion of the upward gas flows to the surface of the gas shaping structure E so that the flow of upwardly moving gases is compressed and focused to pass upwardly through a truncated hollow cone. The adhesion of the upward gas flow to the surface of the gas shaping structure is in the nature of a Coanda flow or "Coanda effect". The "Coanda effect" is named for the tendency of a fluid, either gaseous or liquid, to cling to a surface that is near an orifice from which the fluid emerges. An important part of the effect is the tendency of the primary flow of gas or liquid to entrain, or draw in, more gas or liquid from the surrounding environment.

The slope or pitch of the walls of the truncated hollow cone is such that the particles are accelerated at an increasing rate and not just at a rate so as to maintain the gas velocity at any given point in the cone at a level greater than that necessary to move the particles in a continuous upward direction. The significance of the slope or pitch of the truncated hollow cone of the present invention is that when a particle first enters the cone at one rate of speed, it is then accelerated to a different rate of speed and continues to be accelerated to still different rates of speed as it moves upwardly through the cone. In this manner a separation is brought about between the particles so that after they are coated they may become sufficiently dry before coming into contact with other particles and thereby avoid undesirable clumping or agglomerating together. The pitch or slope is such as to cause a compression of the gas molecules and thereby cause the acceleration at an increasing rate.

With reference to Fig. 2, the details of the present invention will now be described. The coating apparatus is designated in general by numeral 8 and includes a vertically disposed hollow column 10 of regular shape. By "regular shape" is meant that it may be cylindrical, octagonal, hexagonal or of other configurations, so long as the hollow column is generally symmetrical with respect to its central axis. The hollow column contains therewithin the particle storage, coating, drying and deceleration zones, which will be described herein.

A truncated hollow cone 14 which may alternatively be a tapered octagon or of any other tapered polygonal configuration, in other words, generally cone-shaped config-

urations, serving as an enclosure in which the upwardly flowing gases are received, compressed and accelerated, is centrally disposed within the hollow column 10, has a uniformly decreasing cross-section in the upward direction and is of predetermined height dependent upon the size and weight of the particles to be treated. Within the cone 14 in ascending order are the coating and drying zones. The cone 14 serves also to separate the coating and drying zones from the deceleration zone, which lies in the region above the upper end of the cone 14, and from the storage zone, which lies between the cone 14 and the interior wall surface of the hollow column 10.

The hollow column 10 comprises an upper portion 12 provided at its lower end with an inwardly tapered base 16. The lower end of the cone 14 is spaced radially inwardly from the base 16.

A lower portion 18 of the hollow column 10 of regular shape is connected to the base 16, the wall surface of the base 16 forming a juncture with the wall surface of the lower portion 18.

Disposed within the lower portion 18 is a plenum chamber 20 into which a suitable compressed gas, such as air, may be provided through two or more opposed inlets 22, 24, a gas or air collimating plate 26, a second plenum chamber 28 separated from the plenum chamber 20 by the collimating plate 26, at least one gas shaping structure 30 disposed within the plenum chamber 28, and a particle support screen 32, which extends across the hollow column 10 and is located above the gas shaping structure 30.

The collimating plate 26 is a perforated plate which causes the gas or air in the plenum chamber 20 to pass into the plenum chamber 28 in an essentially vertical and uniform flow, as illustrated by the vertical arrows.

The gas shaping structure 30, in cooperation with the adjacent wall surface of the hollow column 10, compresses and focuses the upwardly moving gas or air flow so that it flows over a portion of the surface of the gas shaping structure 30, upwardly through the particle support screen 32 and into the entrance end of the cone 14. The flow upwardly around the gas shaping structure 30 constitutes an annular flow, which adheres to the surface of the gas shaping structure 30 in the nature of a Coanda flow.

A spray nozzle 34, through which is sprayed a suitable coating material, extends above the top of the gas shaping structure 30. It is more convenient to have the spray nozzle 34 located at the top of the centrally disposed gas shaping structure 30. The coating material is supplied from a suitable source (not shown) through a conduit 36 extending up through the gas shaping struc-

ture 30, and an atomizing gas may be supplied from a suitable source (not shown) through a conduit 38, also extending up through the gas shaping structure 30, for subsequent mixing at the nozzle 34. The spray nozzle 34 may also be pressure-operated rather than gas-operated.

The upper surface of the gas shaping structure 30 is centrally disposed within and extends generally horizontally across the cross-section of the vertically disposed hollow column 10. In other words it has a cross-sectional plane generally perpendicular to the vertical axis of the vertically disposed hollow column 10. The outer edge of the upper surface is uniformly spaced from the wall surface of the hollow column 10 and defines with the wall surface of the hollow column 10 a reduced pressure region for acceleration in velocity of the upwardly flowing gases in such a manner that the upwardly flowing gases form a boundary layer that is directed away from the wall surface of the hollow column 10 and that adheres to the upper surface of the gas shaping structure 30 for flow across a portion thereof.

The upper surface of the gas shaping structure 30 may be flat (not shown), but is preferably curved or approximately spherical as shown. It may have a height (h_a) above the cross-sectional plane (See Fig. 6), therefore, of from 0% to 150%, or preferably from 10% to 150% of the greatest cross-sectional diameter (D) (See Fig. 6) of the gas shaping structure 30.

The surface below the greatest cross-sectional diameter may also be flat (not shown) and may have a depth or height (h_b) below of from 0% to 200% of the greatest cross-sectional diameter (D) (See Fig. 6). Preferably, the surface below is formed in the manner disclosed in the drawings.

The gas shaping structure 30 is thus adapted to compress and accelerate the flowing gases near the periphery of the hollow column 10 and direct them toward the centre of the hollow column 10 at an angle of 10° to 45° from a direction parallel to the flowing gases from the gas or air plenums.

The cone 14 defines at its lower end a diameter somewhat smaller than the diameter of the upper portion 12, and 0% to 25% greater than that of the plane of the particle support screen 32. The lower end of the cone 14 is spaced a predetermined distance from the screen 32 and the upper end defines a diameter of 20% to 80% of that of the lower end. The height of the cone 14 ranges from one to six times the diameter of the lower end.

In operation, particles 40 are loaded into the coating apparatus 10 through a closable opening 42 into the storage zone lying between the wall surface of the hollow column 10

10 and the outside wall surface of the cone 14. The particles are thus situated in an annular bed around the cone 14. The sloping outer wall surface of the cone 14, the inwardly tapered base 16 of the upper portion 12 and the screen 32 serve to contain the particles 40 in the annular bed prior to starting-up the coating operation. It should be understood that the particles 40 may be loaded in any other suitable manner.

The gas or air is turned on to start the circulation of the particles or pellets from the annular bed or storage zone into the coating, drying and deceleration zones and in return to the upper portion of the annular bed. The atomizing spray is then turned on and appropriately adjusted in a suitable manner by controls (not shown).

As previously pointed out, the Coanda flow or effect is named for the tendency of a fluid, either gaseous or liquid, to cling to a surface that is near an orifice from which the fluid emerges. Such "orifice" in this instance is formed in the region between the gas shaping structure 30 and the adjacent wall surface of the lower portion 18 at the closest point. The gas flow emerging from the "orifice" region around the gas shaping structure 30 is an annular flow which clings or adheres to the surface of the gas shaping structure 30. The flow, therefore, from any one selected location around the "orifice" is opposed by the other flows so that it is prevented from continuing further over the upper surface of the gas shaping structure 30 by being forced upwardly away from the upper surface at some point for flow into the cone 14. A partial vacuum is formed in the region just above the upper surface of the gas shaping structure 30 and at the lower edge of the cone 14 and this aids in the compression and focusing of the rising annular flow of gases. The upward flow is consequently caused to have a conical shape, as seen in phantom lines in Fig. 2 at 44 within the cone 14, and has a centring effect on the particles 40 impelled upwardly through the cone 14.

As also pointed out, an important part of the Coanda effect is the tendency of the flow of gas or liquid to entrain, or draw in, more gas or liquid from the surrounding environment. In this latter manner, the particles 40 are pulled from the annular bed or storage zone into the upwardly flowing gas due to the aforementioned partial vacuum region that exists just above the screen 32 adjacent the path of upward flow as a consequence of this Coanda effect. This partial vacuum is directed perpendicular to the annular air-flow from the "orifice".

Once the particles 40 are pulled into the upwardly flowing gas within the cone 14, they are impelled upwardly in an accelerating gas or air stream. As the particles 40

pass through the lower central region or coating zone within the cone 14, they are contacted with an atomized spray coating of material. This atomized spray emerges from the spray nozzle 34 because the liquid coating substance is either forced through a single orifice designed to convert bulk liquids into droplets, or the liquid and an atomizing air stream emerge simultaneously from jets adjacent to each other. In either case, the fine droplets of coating material are in a flowable state, because the material is dissolved or melted, in the region immediately above the spray nozzle 34.

Further up the cone 14, the liquid nature of the coating material, as deposited on the pellets or particles, changes to solid by evaporative or other solidification processes. During the transition from liquid to solid, the coated particles pass through a stage when they are sticky or tacky and would agglomerate if they contacted each other. This contact is prevented by the slope or pitch of the walls of the cone 14 and consequent accelerating boost of the particles 40 to separate them in the manner previously discussed.

The conical nature of the cone 14 causes a compression and acceleration of the rising column of gases and the upward velocity or acceleration of the particles 40 occurs at an increasing rate as they rise in the cone 14. This acceleration causes an increasing vertical separation in space between the particles 40 and therefore reduces the tendency for the particles to contact each other until the coating has become nontacky. It is this region of the cone 14 that is thus called the "drying zone".

When the compressed gases and entrained particles pass upwardly out of the upper end of the cone 14, they expand into the larger area of the upper portion 12 of the hollow column 10 and thus decelerate to a velocity too low to suspend the particles 40. This is the deceleration zone, where further drying takes place, and the particles 40 then fall by gravity action to the annular bed where they gradually move down, also due to gravity, until they are pulled into the coating zone again. This recycling or recirculation continues until, based upon previous experiments, a sufficient coating has been applied. This depends upon the particle size and surface and nature of the material being spray coated.

The atomized spray is turned off, and the gas or air entraining flow may be shut down or may be increased to drive the coated particles into the uppermost region of the hollow column 12, as for collection in the manner illustrated in Fig. 5. Any other suitable manner of unloading the finally coated particles may alternatively be used.

The following example shows one size of

apparatus that may be employed, airflows, amount of pellets to be treated, coating material, nature of particles being coated, and other conditions.

5 Example

A coating apparatus having the design characteristics, essentially as shown in Fig. 2, in which the truncated hollow cone 14 has a diameter of 8 inches across the lower end and 4 inches across the upper end, is charged with 25 pounds of generally spherical pellets of animal feed supplement. The pellets are composed of 90% methionine and 10% binders. The average diameter of the spherical pellets is approximately 3 millimetres. Approximately 250 standard cubic feet per minute of air at about 7 p.s.i.g. is admitted to the plenum chamber 20. This air causes a circulation of pellets through cone 14, and the height of the cone 14 above the support screen 32 is adjusted to obtain a pellet flow rate such that all the pellets in the annular storage zone move through the cone 14 about once every minute. A coating solution composed of 6% cellulose propionate morpholinobutyrate in acetone is pumped through the spray nozzle 34 at the same time as 5 SCFM of atomizing air at 40 p.s.i.g. is supplied to the spray nozzle 34. The pumping rate is adjusted to pump one pound of solution per minute. The apparatus is operated for about 45 minutes. The product is a pellet core coated with about a 2-mil layer of the polymer. The pellet is useful as a feed supplement for ruminant animals because the polymer resists alteration by microorganisms in the rumen but is dissolved by higher acidity in the abomasum where the methionine is absorbed by the ruminant animal.

If the gases flowing upwardly around the gas shaping structure 30 could be regarded, for the purposes of discussion, as a series of layer of molecules, it is thought that there is an insignificant flow of a layer or layers of molecules along the interior wall surface of the lower portion 18. By "insignificant" is meant that such layer or layers of molecules will not perform any supporting function of the particles in the annular bed.

Moving, therefore, radially inwardly from the interior wall surface of the lower portion 18, the more significant layers of molecules are caused to bend toward the gas shaping structure 30, the innermost adhering to the surface of the gas shaping structure 30 as they pass upwardly through the "orifice" region. This adherence of the molecules to the surface of the gas shaping structure 30 may be favourably compared to the "teapot effect", which is a low-speed form of the "Coanda effect". When water is poured slowly from a glass, it tends to stick to the side of the glass in the same way that tea sticks to the spout of a teapot. High speed

fluids behave similarly and adhere to a surface of suitable shape.

As the rising molecules flow over the surface of the gas shaping structure 30 after having passed the "orifice" region, previously mentioned, at some point along the upper surface of the gas shaping structure 30 the opposing character of the annular flow forces the molecules upwardly away from the upper surface as well as the adjacent molecule layers. A partial vacuum is created above the gas shaping structure 30 due to the high speed upward flow of gases, causing an inward bending of the upwardly moving molecules.

In the apparatus referred to above as shown in U.S. Patent No. 3,241,520 the upward gas flow extends across the cross-section of the apparatus. Part of the air molecules pass upwardly through the annular subsidence zone so that they serve to counteract the weight of the particles returning to the annular subsidence zone. The particles are caused to be in a state of "incipient fluidization" ("the point at which particles which are disposed in a bed in a closed chamber through which a gas is being passed upwardly become suspended in the gas stream and gain some freedom to move") and thus "dance" around in the annular subsidence zone until reaching the lower edge of the cylindrical partition where they are moved into the upwardly flowing column of molecules passing through the cylindrical partition. Some of the molecules, upon encountering the mass of particles in the annular subsidence zone are shunted horizontally or radially toward the interior wall surface and radially toward the central region of the apparatus. The effect upon the particles within the annular subsidence zone is a randomizing action of the particles gradually moving from the annular subsidence zone and into the region beneath the edge of the cylindrical partition where they are then moved upwardly within the column for coating, drying and subsequent deceleration and return to the upper region of the annular subsidence zone. The "dancing" of the particles in the annular subsidence zone causes a certain amount of attrition or wear of the particles upon or against each other.

In the present invention, however, the particles move down in the annular bed by gravity without any "dancing" occurring, and are drawn into the upwardly flowing gases by the partial vacuum. Thus any attrition that might occur is greatly minimized, and the overall operation is much more efficient.

In the apparatus shown in U.S. Patent No. 3,110,626, the gas or air flow through the venturi expands outwardly across the entire cross-section and provides a necessary supporting function for the particles in the

annular bed as well as an upward impelling effect upon the particles within the control element. The same shunting action occurs in the apparatus shown in U.S. Patent No. 3,110,626 as in the apparatus referred to above as shown in U.S. Patent No. 3,241,520. This is apparently what is meant in U.S. Patent No. 3,110,626 when discussing the control element as providing a "desirable sharp discontinuity in the velocity profile of the particles in the coating chamber". In other words, the upwardly flowing gases meet resistance upon coming into contact with the particles in the annular bed, thereby resulting in the sharp discontinuity in the velocity profile. Some of the gases pass upwardly through the particles in the annular bed and thereby provide a supporting function. Other gases are shunted to the side wall and bounce back, while other gases flow more readily up through the control element. The same random action occurs, however, among the particles in the storage bed as in the storage bed in U.S. Patent No. 3,241,520. The particles are fluidized, can move a limited direction upwardly, sidewardly and finally downwardly within the storage bed until moving into the horizontally shunted air flow below the bottom of the bed for subsequent movement into the control element. Thus, there would also be a certain amount of undesirable attrition or wear of the particles upon or against each other as they "dance" about in the annular bed.

One disadvantage of the venturi approach in U.S. Patent No. 3,110,626 is that as the size of the apparatus is increased to process greater and greater batch loads of particles, the necessity of using the upward air or gas flow to support the annular bed as well as to lift and circulate the particles up through the control element results in a significantly greater amount of required airflow. However, in the present invention the air or gas flow is only employed to impel the particles upwardly within the cone.

With reference to Fig. 3, in which a modification of the present invention is shown, the same reference numerals will be used to identify similar elements previously described, but they will be primed.

Fig. 3 shows an embodiment of the present invention wherein the size of the coating apparatus 10' has been increased in order to handle larger batch loads of particles for coating treatment. It has been found that it is more practical to add an additional gas shaping structure or an annular airfoil 50 instead of increasing the size of the gas shaping structure 30'. In this manner, larger amounts of upwardly flowing gas or air may be supplied undiminished or unobstructed by a larger gas shaping structure, and the annular airfoil 50 serves to supplement the

compression and focusing action on the upward gas flows so that substantially all gas flows move through the truncated hollow cone 14'.

Additional or multiple gas shaping or annular airfoils (not shown) also may be used for still larger coating apparatus. The exact shape and placement of the airfoils are functions of a number of variables. The most significant of the variables are size of the apparatus, size of the particle to be coated, density of the particle, rate of gas or air flow and the rate of recirculation of the particles through the coating zone desired.

In a larger-scale coating apparatus, therefore, one or more annularly shaped and placed gas shaping structures or airfoils, angled or curved, may be provided concentric with and radially outwardly of the central gas shaping structure. The annular airfoils may be attached to the central gas shaping structure or to the walls of the coating apparatus by radial struts in such manner as to exert a minimum deflection of the upwardly flowing gases.

The annular gas shaping structure is inwardly inclined in the upward direction so that its inclination lies in a plane extending 10° to 45°, as measured from the axis perpendicular to the diameter of the coating apparatus. The inwardly inclined annular structure provides a surface on which the gas or air impinges for subsequent shaping and direction upwardly into the truncated hollow cone 14'.

The vertical height of the annular structure may be 10-50% of the perpendicular cross-section diameter of the coating apparatus 10'.

With reference to Fig. 6, when the annular gas shaping structure 50 has the configuration of an airfoil having at least one curved surface extending generally in the direction of gas flow, the overall angle of a line described from a point, p₁, on the lower rim of the airfoil 50 to a point, p₂, on the upper rim in the vertical direction, or perpendicular to a line which is tangent to the upper curved surface of the centrally disposed gas shaping structure 30', is from 10° to 45° inward facing, as measured from the axis perpendicular to the diameter of the coating apparatus.

The cross-sectional configuration of an annular airfoil in a plane described from the centre of the cross-sectional area of the coating apparatus to a point, p₁, on the lower rim of the airfoil to a point, p₂, in the upper rim of the airfoil is teardrop, or similar to the cross-sectional shape of a lifting aerodynamic shape, and having the thicker cross-section on the forward part with reference to the direction facing the upwardly flowing gases. The thickest part is located two-fifths to one-half of the height in the

vertical direction. In other words, the height (HT) of the thickest part (T), is equal to $\frac{2}{5}H$ to $\frac{1}{2}H$, where H is the height of the airfoil. The thickest cross-section (T) is equal to $\frac{1}{6}H$ to $\frac{2}{5}H$.

The size, placement and geometrical configuration of the annular gas shaping structure are such, therefore, that the upwardly flowing gases are deflected radially inwardly at an angle of 10° to 45° from a direction parallel to the original gas flow.

With reference to Fig. 4, in which a further modification of the present invention is shown, the same reference numerals will be used to identify similar elements previously described, but they will be double-primed.

Fig. 4 shows an embodiment of the present invention wherein the size of the coating apparatus 10" has been increased to the same extent as that disclosed in the Fig. 3 embodiment. The embodiment in Fig. 4 differs from the embodiment in Fig. 3 in that the column portions 12' and 18' have been modified to be co-extensive in cross-sectional diameter. In other words, the coating apparatus is disposed within a single column portion 12". It could also be of smaller size so that only one gas shaping structure 30" is employed as in Fig. 2, instead of a size requiring the annular airfoil 50".

The recycling or recirculation in this embodiment is necessarily faster because the particles are not as readily restrained in the annular bed region as they would be if there were an inwardly tapered base to assist in such restraint. Proportionately smaller batch loads may be used, therefore, since the recirculation of the particles is substantially continuous with the particles spending very little time in the annular bed. For this reason, an embodiment of this character is suitable for special purposes, while the embodiments of Fig. 2 and Fig. 3 are deemed to be of more general use.

In Fig. 5, there is shown one manner of unloading a coating apparatus, as referred to above with respect to one possible operation of the embodiment of Fig. 2.

Only the upper portion of a coating apparatus 60 is shown, and it could be used for any of the previously described embodiments of the present invention. A conduit 62 is installed within the upper portion of the apparatus and a gas or air porous collection bag 64 may be installed at the remote end of the conduit 62 for collecting the finally coated particles in the manner already heretofore described.

In any of the embodiments of the present invention described above, the truncated hollow cones may be adapted to be adjusted for movement upwardly or downwardly in a vertical plane. The same may also be accomplished with the gas shaping structure,

the annular airfoils and the spray nozzles, as desired to suit gas or air flows, particle sizes and weights, coating material consistencies and whatever other controlling factors may be concerned.

The particles or pellets to be coated may be batch-loaded and treated; or if deemed advantageous, two or more such coating apparatus may be arranged in cascaded manner to provide for a continuous coating operation. The inlet for the particles in a cascaded arrangement may be disposed above the annular storage of one apparatus and the particles metered in predetermined manner into the annular storage bed, while the outlet to the next coating apparatus may be disposed on the opposite side of the annular storage bed and constitute a weir for outflow of excess coated particles. The inlet may also be disposed for gravity flow of particles to or into the annular storage bed. It may be desirable to provide for different coatings in different apparatus, or provide supplemental coatings.

WHAT WE CLAIM IS:-

1. An apparatus for coating particles, comprising a vertically disposed hollow column in communication with a gas supply system, means within said column for receiving, compressing and accelerating upwardly flowing gases, which means defines a storage zone between an outer wall thereof and an inner wall of said column, a spray nozzle disposed in the bottom portion of the column, and an aerodynamic gas shaping structure for shaping the flowing gases to direct them into and through the means for receiving, compressing and accelerating upwardly flowing gases in such a manner as to create a reduced pressure region surrounding said flowing gases to pull particles from the storage zone and entrain the particles in said flowing gases to transport them through the means for receiving, compressing and accelerating upwardly flowing gases.

2. An apparatus according to Claim 1 further comprising means disposed in the bottom portion of the column below the aerodynamic gas shaping structure for forming an annular column of gas.

3. An apparatus according to Claim 2 wherein the annular column of gas has essentially the same velocity throughout its cross-sectional area.

4. An apparatus according to any one of the preceding Claims wherein the aerodynamic gas shaping structure has an upper surface centrally disposed within and extending generally horizontally across the cross-section of the hollow column, the outer edge of said upper surface being uniformly spaced from the inner wall surface of the hollow column.

5. An apparatus according to Claim 4 as appendant to Claim 2 or 3 wherein said

upper surface of the aerodynamic gas shaping structure has a cross-sectional plane generally perpendicular to the vertical axis of the vertically disposed hollow column, said upper surface having a height above the cross-sectional plane of 0% to 150% of the greatest cross-sectional dimension of the gas shaping structure, and the surface below the greatest cross-sectional plane having a depth of 0% to 200% of the greatest cross-sectional dimension of the gas shaping structure, the aerodynamic gas shaping structure serving to compress and accelerate the flowing gases near the periphery of the hollow column and direct the flowing gases toward the centre of the hollow column at an angle of 10° to 45° from a direction parallel to the column of upwardly flowing gases.

6. An apparatus according to Claim 4 or 5 wherein said upper surface of the aerodynamic gas shaping structure is curved.

7. An apparatus according to Claim 6 wherein said curved upper surface is approximately spherical.

8. An apparatus according to any one of the preceding Claims wherein the means for receiving, compressing and accelerating the upwardly flowing gases is a tapered hollow member open at both ends.

9. An apparatus according to Claim 8 wherein the tapered hollow member has a uniformly decreasing cross-section in the upward direction.

10. An apparatus according to Claim 8 or 9 wherein the tapered hollow member has at its lower end a diameter smaller than the diameter of the adjacent part of the hollow column and at its upper end a diameter of 20% to 80% of that of the lower end, the height of the tapered hollow member ranging from one to six times the diameter at the lower end.

11. An apparatus according to any one of the preceding claims comprising a particle support screen disposed between the aerodynamic gas shaping structure and the means for receiving, compressing and accelerating upwardly flowing gases.

12. An apparatus according to Claim 11 wherein the particle support screen has an opening which is disposed concentrically relative to an opening in the spray nozzle.

13. An apparatus according to Claim 11 as appendant to Claim 8, 9 or 10 or to Claim 12 when Claim 11 is so appendant wherein the tapered hollow member has at its lower end a diameter 0% to 25% greater than that of the plane of the screen, the lower end of the tapered hollow member being spaced from the screen.

14. An apparatus according to any one of the preceding claims wherein the hollow column comprises a first portion and a second portion, the second portion having a

diameter less than that of the first portion and being connected to an inwardly tapered base of the first portion, the wall surface of the inwardly tapered base forming a juncture with the wall surface of the second portion, said second portion having therewithin the aerodynamic gas shaping structure.

15. An apparatus according to Claim 14 wherein the lower end of the means for receiving, compressing and accelerating upwardly flowing gases is spaced from the inwardly tapered base.

16. An apparatus according to Claim 14 as appendant to Claim 11, 12 or 13 or to Claim 15 when Claim 14 is so appendant wherein the screen extends across the cross-section of the hollow column at said juncture thereof.

17. An apparatus according to any one of the preceding Claims comprising an annular airfoil concentrically disposed with respect to and outwardly of the aerodynamic gas shaping structure.

18. An apparatus according to Claim 17 wherein the annular airfoil is inwardly inclined in the upward direction so that its inclination lies in a plane extending 10° to 45°, as measured from the axis perpendicular to the diameter of the apparatus and has a vertical height of 10 to 50% of the perpendicular cross-section of the apparatus.

19. An apparatus according to Claim 17 or 18 wherein the annular airfoil has at least one curved surface extending generally in the direction of gas flow.

20. An apparatus according to Claim 19 wherein the overall angle of a line described from a point on the lower rim of the airfoil to a point on the upper rim of the airfoil in the vertical direction is from 10° to 45° inward facing, as measured from the axis perpendicular to the cross-sectional diameter of the apparatus.

21. An apparatus according to Claim 19 or 20 wherein the cross-sectional configuration of the airfoil in a plane described from the centre of the cross-sectional area of the apparatus to a point on the lower rim of the airfoil to a point on the upper rim of the airfoil is teardrop, the thicker cross-section being on the forward part with reference to the direction facing the upwardly flowing gases, the thickest part being located from two-fifths to one-half of the height of the airfoil from a point on the lower rim and the thickest cross-section being from one-sixth to two-fifths of the height of the airfoil.

22. An apparatus according to any one of the preceding Claims wherein the spray nozzle is positioned to spray liquid coating material into the flowing gases immediately downstream of the aerodynamic gas shaping structure.

23. An apparatus according to Claim 22 when appendant to Claim 4 wherein the

spray nozzle extends centrally from the upper surface of the aerodynamic gas shaping structure.

24. An apparatus according to any one of the preceding Claims wherein additional apparatus as defined are combined in a cascaded arrangement, each apparatus having an inlet for supplying particles to the storage zone and an outlet for coated particles to be

supplied to the corresponding inlet of the next apparatus.

25. Apparatus according to Claim 1 substantially as hereinbefore described with reference to, and as shown in, the accompanying drawings.

L. A. TRANGMAR, B.Sc., C.P.A.
Agent for the Applicants

1584283 COMPLETE SPECIFICATION

4 SHEETS

*This drawing is a reproduction of
the Original on a reduced scale
Sheet 1*

FIG. 1







