Dec. 20, 1960 Z. VANE 2,965,232

CENTRIFUGAL SCREEN SEPARATION APPARATUS

Filed May 4, 1959 2 Sheets-Sheet 1

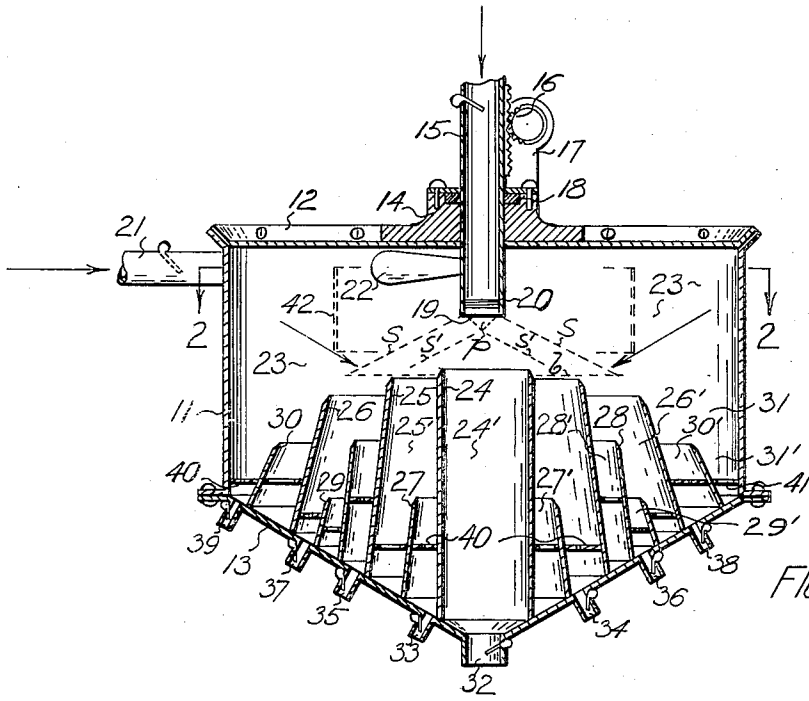


FIG. 1

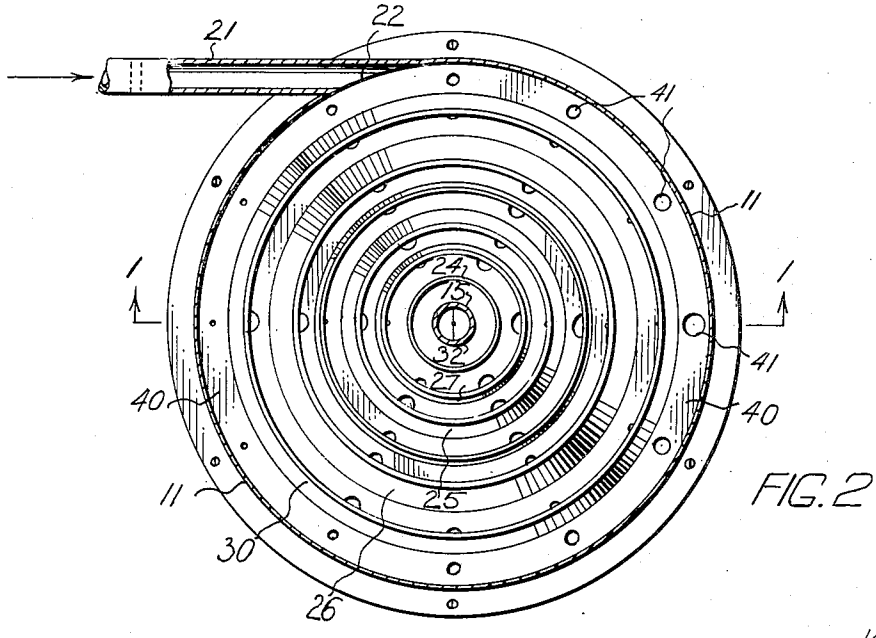


FIG. 2

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CENTRIFUGAL SCREEN SEPARATION APPARATUS

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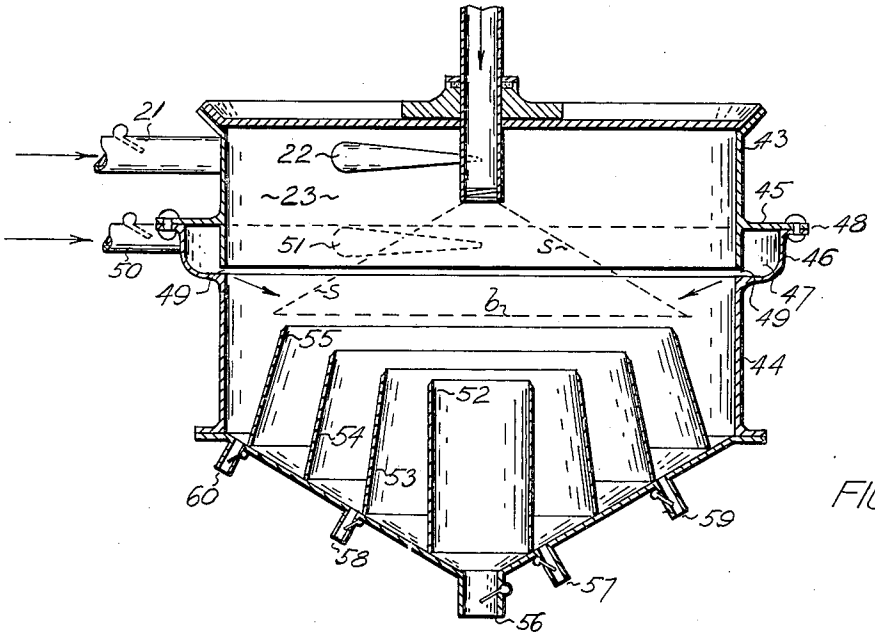


FIG. 3

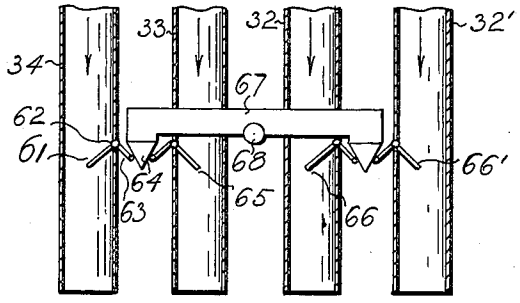


FIG. 4

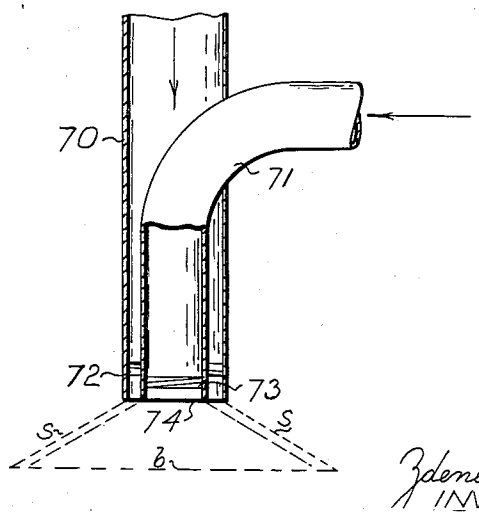


FIG. 5

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CENTRIFUGAL SCREEN SEPARATION APPARATUS

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1 Claim. (Cl. 209—211)

This invention relates to improvements in separating methods and apparatus, and more particularly to multiple separations of suspended solid particles by density difference.

In the prior art, the starting point for density separations of fine solids is a completely stratified mixture in a spinning carrier. Generally, the components are separated from the stratified mixture in a radial or axial direction. When the product of the separation is to be treated again, as it is necessary for instance to separate an excess of the carrier from the solid component, such secondary separation is to be performed in a new apparatus, or apparatus section. Consequently, conventional apparatus possess little compactness of structure and uniformity of method, and are often a mere aggregation of separators, wherein intermediate steps of evacuating and refeeding, conveying and propelling the handled materials accompany a positive separation work. In this invention, spinning particles in suspension are separated out into concentric layers of different density ranges through the action of a free vortex of carrier fluid spinning helically, and are intercepted during their radially outward travel by a system of concentric sleeves. The spin and the radial spreading is continued within said system, the first separation being followed by one or several subsequent separations, using the same primary spin. In this novel method, the starting point of separation is the discharging of a concentrated separable material into a spinning column of a pure carrier fluid. As the stratification of the separable mixture proceeds, the resulting density layers are intercepted by separating means. This novel method divides the spinning carrier into layers wherein the separable material just started to be stratified according to density, and is, therefore, able to operate more economically by treating one separable component in two or more separation steps performed in the same separation chamber while spinning the separable material only once. Moreover, the separable matter spreading in a radially outward direction, being compelled through the carrier fluid spinning radially inward and subjected to a minute pressure control, allows for a high precision of density of separated components. In this invention, the separation of the particles and the evacuation of the carrier fluid are performed in a compact structure, thereby saving in construction material, power of operation, time of separation, and in wear by abrasion.

It is an object of this invention to provide a novel method and apparatus for multiple separations of suspended particles according to density by spreading fine solids in a spinning carrier from the center thereof and by intercepting the carrier with therein suspended solid particles during its flow in an axial direction by a system of separating sleeve partitions.

Another object of the invention is to provide a novel compact structure for further sub-separating the product of the primary separation.

Still another object of the invention is to provide a method and structure for density separations of suspended

solids by spreading in a radially outward direction, a mass of suspended solid particles through a spinning fluid carrier moving toward the axis of the spin.

Other objects of this invention will become apparent from the following description and accompanying drawings in which

Figure 1 is a longitudinal section of my new apparatus,

Figure 2 shows a horizontal section of the same along the line 2—2 in Figure 1,

Figure 3 represents a modification of my new apparatus in section,

Figure 4 shows, somewhat schematically, a proposed volume control for the same apparatus, and

Figure 5 is a modification of an embodiment of the apparatus in Figure 1.

Figure 1 shows the novel apparatus wherein the numeral 11 generally designates a shell defining a vortex chamber. The upper part of the separator is provided with a tight cover 12, the lower part with a conically shaped bottom 13. The cover 12 supports a flange 14, wherein a feeding pipe 15 can slide in an axial direction, said movement being controlled by any suitable conventional means, as for example a toothed gear 16, fastened in a bracket 17. A stuffing box 18 secures a tight connection of the two parts, 12 and 15. Adjacent to its discharge nozzle 19, the feeding pipe 15 is provided with spin imparting vanes 20, of the conventional type known. The concentrated separable material is discharged at the nozzle 19. The carrier fluid is entered by the feeding pipe 21, through the tangential inlet 22, into the vortex chamber 23. In the bottom 13, a series of intercepting partition sleeves 24, 25 and 26 are provided concentrically below the discharge nozzle 19. The sleeve 24 is placed centrally in the vertical path of said nozzle 19; the sleeves 25 and 26 are placed concentrically, in a downwardly sloping sequence around the sleeve 24, forming the annular spaces 25' and 26', and that one marked by numeral 31, between the sleeve 26 and the shell 11. The primary separation takes place on their edges so that the sleeves will intercept the spinning carrier fluid in its axial movement, with the therein suspended solid particles. Said edges define the primary separation area; they are preferably beveled, and the thereby separated fluid carrier with therein suspended material will continue to spin in said annular spaces after having been separated by said edges. The downwardly spinning mixture within the annular spaces 25', 26' and 31, being subject to a further density stratification, is separated in the secondary separation areas which are defined by the edges of shorter sleeves 27, 28 and 30, placed inside the annular spaces 25', 26' and 31. A tertiary separation area is provided in the annular space 26', by the very short sleeve 29. An annular space 31' is formed by the sleeve 30 and the shell 11. In the bottom 13, each annular space is provided with an outlet, draining the respective separation area; these outlets are marked by numerals 32 to 39 respectively. All of the annular spaces, except numeral 24', are further provided with drain regulating covers 40, fixed at a small distance from the bottom 13. A cover 40 is shown in plan view in Figure 2, between the shell 11 and the sleeve 30. It is a large washer of a thin material as sheet metal, provided with a series of openings 41, varying from relatively small to large in cross-sectional area. The smallest opening 41 is close to the outlet 39, the largest opening 41 is most remote from the outlet 39. The volume of flow passing through the largest opening 41 must travel the longest distance to reach the outlet 39. The shorter the distance for the fluid to reach the outlet 39, the smaller the opening 41, so that the fluid passing through any one of the openings 41 has to overcome the same resistance. Therefore, equal volumes of fluid will pass through each opening 41, whatever its size. In this manner, the spinning fluid will

be drained evenly along the whole circumference of each annular space, thus avoiding any turbulence in the adjacent separating areas. The outlet 32 in the circular space 24' is located centrally in said space, and will drain evenly said space without any cover. The volume of fluid passing through the outlets must be controllable in order to obtain maximum efficiency of separation in the annular spaces. Many conventional control devices may be used for this purpose. Figure 4 shows one possible solution for controlling the primary and secondary separations in the annular spaces 24', 27' and 28', containing the clean carrier and fine solid components of the separated material. The outlet 32 evacuates the clean carrier fluid obtained from the primary separation in the space 24'. Numeral 32', which may or may not exist, is an auxiliary outlet for illustration purposes only. Baffles 61, 65, 66 and 66' are pivotally mounted in the walls of the outlets 32, 32', 33 and 34, by journals 62, the lever arms 63 forming one piece with the baffles and with the journals, will move said baffles. The control of the flow through the outlets 33 and 34 is regulated by a triangular guide 64. One side of this guide 64 actuates, through the lever arm 63, making sliding contact therewith as a follower, the baffle 61 in the outlet 34, the other side of the same guide actuates the baffle 65 in the outlet 33. A similar triangular guide 64 makes sliding contact with the baffles 66 and 66' in the outlets 32 and 32'. The triangular guides 64 are coupled by a bar 67, which is supported in its center by a fulcrum 68. This fulcrum may be moved horizontally a short distance; it also allows a slight pivoting movement of the two guides 64, so that a vertical movement of one of them in one direction causes the other guide to move in the opposite direction. When the fulcrum 68 is moved horizontally to the right, the volume of flow drained by the outlets 32 and 32', if any, will be decreased to the same extent. The same movement to the left will reverse the effect in the same outlets. An upward movement of the guide 64 on the left hand side, will increase the volume drained by the two outlets 33 and 34, to the same extent in each member of this couple, while simultaneously the guide on the right hand side will cause a reduction of the volume drained by the outlets 32 and 32', also to the same extent in each member of the couple. As it can be seen in Figure 1, by this way of control, the total volume of carrier fluid handled by the spaces 24' and 25' can be maintained constant, even though the ratio of volumes handled by each of the two spaces can be changed, so that the other parts of the same primary separation area will not be influenced by this change. Similarly, the ratio of volumes of fluid yielded by the two secondary separation areas in the space 25', outlet 34, and the space 27', outlet 33, can be changed without changing anything in the respective primary separation area.

In operation, consider a concentrated mixture of copper-nickel-iron ore with rock particles, suspended in water, to be separated. The density of the nickel ore being 4.8, that of iron ore 4.6, copper ore 4.2, rock 2.8, and water 1.0. The particles in the mixture have been previously comminuted and screened approximately to equal grain size. A clean carrier fluid, such as pure water, is fed tangentially into the vortex chamber 23 through the inlet pipe 21 and the inlet 22, and is spinning in the chamber 23. This helical spin has a slight radially inward direction, as shown by arrows, because the major part of this carrier is drained by the outlets 32, 33 and 34. The separable mixture is fed through the pipe 15 past the spin imparting vanes 20 and the nozzle 19 into the chamber 23. The separable material is spinning radially outwardly, thus forming in the spinning carrier a truncated cones *s—b—s*, shown by dotted lines in Figure 1. The nickel ore particles having the greatest density, will spread faster in the direction of the radius than the other components: due to higher inertia, they will work their way through the spinning carrier under the impulse of the centrifugal tension faster and easier, thus, they will spread the longest distance radially outward, before they are intercepted. The rock particles having the smallest momentum, will remain in the central portion of the spinning water, since their radial escape is slower and, moreover, they are unable to overcome the resistance of the carrier spinning toward the central sleeve partitions 24 and 25. Out of two particles of the same size, but unequal density, spread simultaneously by the nozzle 19, the heavier one will travel a greater distance in the direction of the radius in a unit of time. The iron and copper particles will be spinning at intermediate distances, their velocity in the radial direction being proportional to their respective densities. The position of the nozzle 19 is vertically adjusted in such a way that the nickel particles will be intercepted by the annular space 31, between the edge of the sleeve 26 and the shell 11. The iron ore particles will be intercepted by the annular space 26', the copper particles by the space 25', and the much lighter rock by the space 24'. Further sub-separations take place within the annular spaces 31, 26' and 25', as the intercepted fluid continues to spin downwardly and to further stratify itself in density layers. Due to this further stratification, nickel ore particles will be collected by the annular space 31' and evacuated with a minimum of carrier fluid by the outlet 39, while most of carrier fluid intercepted by the space 31 will pass through the annular space 30' and the outlet 38, provided, this outlet 38 is more open than the outlet 39. Thus, the nickel ore has been thickened by a secondary separation within the space 31. Similarly, the copper ore particles intercepted by the space 25' will be thickened in the secondary separation area defined by the edge of the partition sleeve 27 and by the adjacent sleeves 24 and 25; the outlet 33 being open, will evacuate most of the carrier fluid intercepted by the space 25', while the outlet 34, with a passage reduced by the baffle, will evacuate all copper ore particles with a minimum of carrier fluid. The iron ore particles intercepted by the annular space 26' are thickened in a secondary separation by the edge of the partition sleeve 28 and lose most of the carrier, which will travel through the secondary space 28' and the outlet 35, while the iron ore particles with a remainder of the carrier will enter the tertiary separation area defined by the edge of the partition sleeve 29. This reduced flow rotates now at a low speed, the centrifugal tension is less active, and a lighter part of the suspended iron ore, representing a middling, may be thus intercepted by the annular space 29', to be evacuated by the outlet 36, while the heavier part of the same iron ore is drained by the outlet 37. The ratio of partial flows in the tertiary separation depends on the position of the baffles in the respective outlets controlling said partial flows; the separation may be assisted by making the annular space 26' narrower in the zone of the tertiary separation area. The lighter rock particles, unable to escape radially outwardly, will be intercepted with most of the carrier fluid by the space 24' and evacuated by the outlet 32. It is obvious that the rock particles may be subjected to a secondary separation as the other components, if desired, and that any number of sleeves may be employed in this apparatus, depending on the mixture to be separated. Particles of intermediate densities formed of rock and ore, or of two or three kinds of ore, may be intercepted as middlings and thickened as such, in a more developed system of intercepting sleeves. If a radially inward fluid flow is desired, the central outlet passages 32 and 33 receive the largest part of the carrier fluid, thereby promoting the desired lateral pressure of the spinning fluid in the direction shown by arrows. A sufficient pressure must be maintained within the apparatus so that no large vacuum can develop in the area adjacent the discharge nozzle 19.

When the way of draining by the central outlets is used in a vortex chamber of a certain vertical height, wherein the distance of the tangential inlet 22 from the intercepting sleeves 24, 25 and 26 is large, the helical fluid flow will tend to rotate rather in the center of space 23, cutting

short its way towards the outlets 32, 33 and 34, while the remote peripheral layers will be idle, thus, little or no lateral pressure. This condition may be corrected by installing in the chamber 23, one or more feeding sleeves 42, marked in dotted lines. The spinning carrier directed by the lower edges of the sleeves 42 will exert a lateral pressure at any desired height in the conically outstretched fine solid material; the sleeves should be suspended from the wall 11 by brackets shaped as helical vanes, to prevent any turbulence in the spinning carrier.

In density separations requiring high accuracy, as in the above quoted example of components differing very little in their respective densities, such a lateral pressure may be very useful, especially when it can be made variable in any convenient manner, to subject the treated mixture to a severe density test. This can be achieved by feeding an additional carrier fluid flow into the vortex chamber 23 radially inwardly, discharging a flow into the primary separation area itself from outside. In the Figure 3, a modification of the shell 11 from Figure 1 is shown, meeting said requirements, the details of the secondary and tertiary separations are omitted. The general outline of the primary separation area defined by edges of the partition sleeves 52 to 55 is here concave, an auxiliary vortex chamber is provided on the outside periphery of the housing. The housing of the apparatus consists of two parts 43 and 44; they both are flanged so that the lower part 44 provides a shell 46 defining the outward periphery of an auxiliary vortex chamber 47, while the upper part 43 provides a cover 45 for the same, the two parts 43 and 44 being connected by flanged edges 48 on the whole circumference. This outer connection is tight and will be secured by a gasket of a suitable thickness, not shown in the drawing. When the two parts 43 and 44 are assembled as shown, there is formed a slot 49 of a uniform width along the whole circumference of the chamber 23, connecting the main vortex chamber 23 with the auxiliary chamber 47. Obviously, the width of the slot 49 may be changed by inserting a gasket of a suitable thickness at 48. The additional fluid is fed in by the tube 50 and the tangential inlet 51 into the chamber 47; this flow is controllable by a baffle. The lateral pressure produced by this device in the direction of the arrows is most efficacious in precision work, such as described above. It can be seen from the Figure 3 that the whole separating process is performed in the central parts of the spinning carrier, that a contact between the structure parts and the separable material is reduced to a minimum, thus avoiding the well known corrosion by friction of fine solids on the apparatus walls. The separable material stretches out from the feed pipe in the form of a cone *s—b—s* and will be completely intercepted by the partition sleeves. The lateral pressure of the flow coming from the slot 49 and acting upon the slant side of the cone *s—b—s*, must be set up by the control in the tube 50, so as to deflect particles of lower selected density towards the central intercepting sleeves, while the heavier ones overcome said lateral pressure and are intercepted by the outer sleeves.

The viscosity of the carrier fluid is a constant obstacle to a lateral penetration, and is that factor which makes, in this method, density separations possible. In precision work as cited above, it is necessary that all particles leaving the nozzle 19, start their spinning motion at the very moment of discharge, if they are to be correctly separated. This requirement is not always met in a single discharge nozzle 19, as shown in Figure 1, wherein the flow leaving said nozzle forms a solid cylinder containing the axis of the spin. There is little or no radius of rotation in this cylinder axis, thus, there is little or no centrifugal tension to move the particles radially into the spinning fluid. As said cylinder disintegrates progressively in the adjacent spinning carrier, a small cone of the handled material projects downwardly from the discharge nozzle 19, and will be spread later than the other particles discharged at the same time from the same nozzle 19. In the Figure 1, said small cone is shown in dotted lines, and the slant dotted lines *s'* starting from the apex *p* of the small cone show clearly, that such heavy material discharged from said apex *p* cannot reach the space 31, thus cannot be separated correctly.

In Figure 5, a new feed pipe 70 is shown, which corrects this condition. The pipe 70 is provided with a core, concentric pipe 71, and the annular space between them has spin imparting vanes 72, of any conventional type. The pipe 71 has its own helix 73. A fine solid material discharged by this device, will leave by said annular space, and all its particles will start rotating instantly as soon as discharged. The effect may be further assisted by feeding a clean carrier fluid through the core pipe 74. The spreading solids *s* will form a thin layer, achieving a perfect density spectrum at the base *b*, provided, the discharged particles have a fairly uniform size. Out of two particles of the same density, the larger one will penetrate laterally faster than the smaller one; this must be considered, wherever fine density differences are to be achieved by this new method. In the separation of materials in which the respective densities of the components are far apart from each other, relatively large grain size differences are admissible. For instance, in threshing operations, the finer part of the output of a thresher discharged by a single feed pipe 15 into a spinning air column, is separated correctly, even though the kernels differ sharply in size from the accompanying dust and straw particles.

It will be noted that the abrasive effect of the handled material on the separating members may be avoided by providing them with a rubber coating or alike. The friction in the intercepting sleeves is reduced by giving them a conical shape as shown in Figures 1 and 3, which provides a reduced friction angle. At the same time, the bottom space, needed for connections is larger and helpful for slowing down the angular velocity of the partial flows before their evacuation. The use of draining covers 40 with openings 41 can be avoided, either by enlarging said bottom space downwardly so that the distance of an outlet from the respective separation area is large enough to stop the spin, or by increasing the number of outlets in each bottom space, to drain the whole circumference thereof evenly, or by combination of both methods. Obviously, the bottom 13 may be flat as well, or project into the vortex chamber 23. Connections of structure parts by seam or spot welding have been contemplated in the drawings shown. Wherever covers 40 are used, the openings 41 along the centerline of a cover may be substituted for by peripheral indentures of a varied size.

In the description of the method steps and structure parts given above, many variations may be made without departing from the scope of this invention. Therefore, the details disclosed are not limitative of the embodiments of the invention except as claimed hereinafter:

I claim:

An apparatus for multiple separation of suspended fine solids by density difference, comprising in combination: a closed main vortex chamber having a substantially horizontal top portion, a circular wall section, and a bottom portion, a circumferential gap in said wall section, an auxiliary vortex chamber arranged concentrically outwardly of said main vortex chamber in a radially adjacent position thereto, said gap connecting said auxiliary chamber to said main vortex chamber, feeding means in said circular wall section adapted to feed and to rotate a carrier fluid in said main vortex chamber, feeding means in said auxiliary vortex chamber adapted to feed and to rotate therein an additional carrier fluid, separate feeding means for a mixture of fine solid particles arranged concentrically with said main vortex chamber and substantially perpendicular to said feeding means and movable in an axial direction thereto, said separate feed-

ing means having a mouth open in an axial direction and being able to discharge said mixture axially so as to spread it radially outwardly in a fine layer into said spinning carrier, a first series of partition sleeves arranged concentrically within said main vortex chamber and providing primary annular spaces to split into fractions said carrier fluid with said particles suspended therein, a second series of partition sleeves arranged concentrically within said primary annular spaces and providing secondary annular spaces, a partition sleeve of tertiary separation within one of said secondary annular spaces, and draining means for each of said annular spaces.

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