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VORTICAL SEPARATOR

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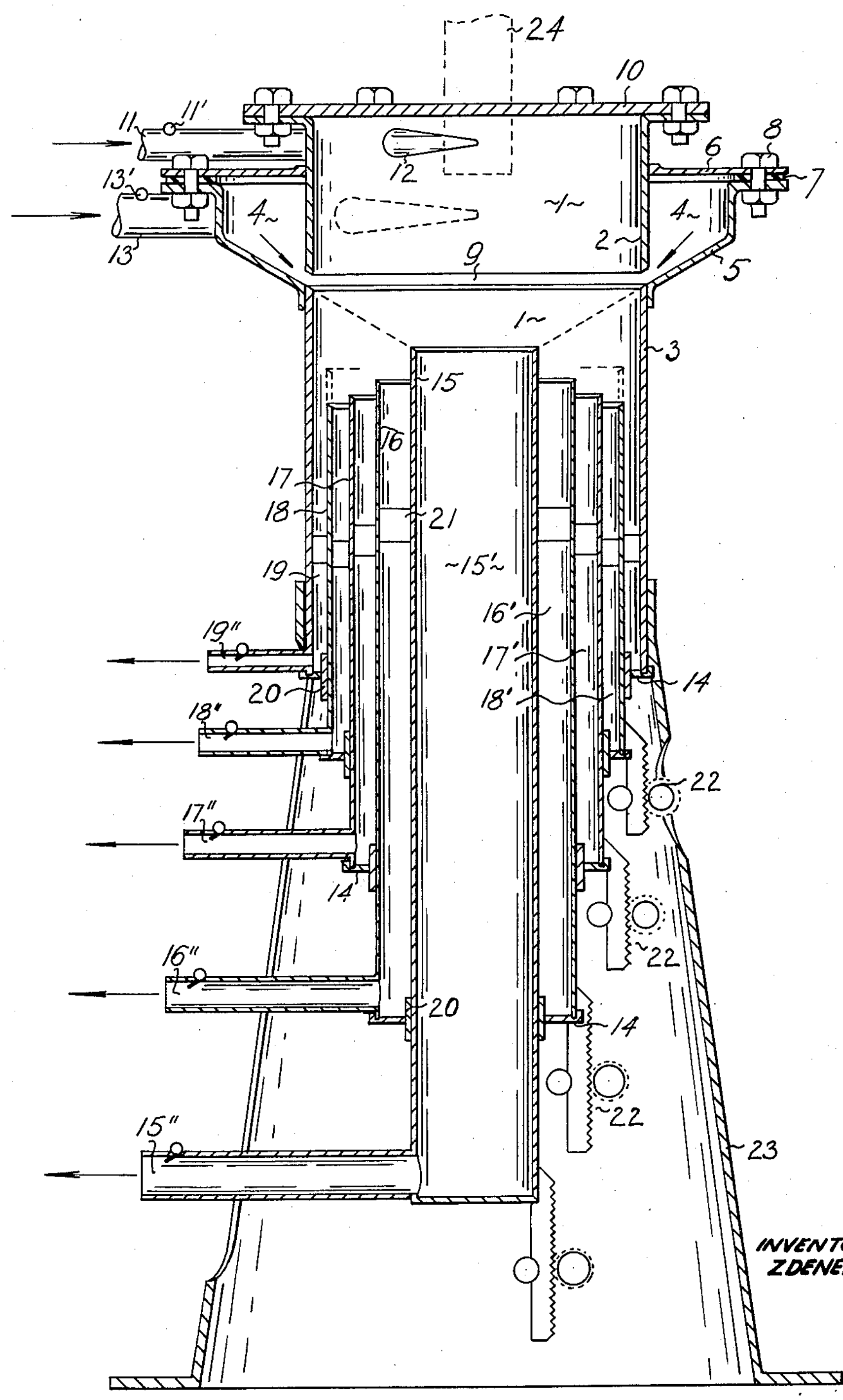

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This invention relates to a method of multiple density separation by centrifugal force. This application is a continuation-in-part of my co-pending application, Serial No. 628,171, filed December 13, 1956, now abandoned.

In density separations carried out from a spinning column of carrier liquid containing suspended particles, methods of this character show that the cost of a process increases when the spread between the density of the carrier liquid and the separable particles is increasing. In order to decrease the cost, sink-and-float methods have been successfully combined with the centrifugal force for separating components whose respective densities differ only slightly. Thus, the carrier used in such combinations has a density which lies between the densities of the two components to be separated. The carrier alters the lighter one of the two "sink" components to a "float" component while the other remains a "sink" component. As a result, the selected lighter component is located far from the outer periphery of the vortex and close to the center thereof so that the lighter component is intercepted at a sufficient radial distance from the heavier one. This solution requires a special carrier whose density must be maintained at a constant value to preserve its separating capacity and can hardly yield more than two fractions in one separation. The expedient has a static character and affords a limited choice only because few true liquids with densities over 2 are available. The suspension-type separatory media consist of finely comminuted solids in a liquid, such as water. To be produced and maintained, these media require an auxiliary equipment, and the cost thereby involved is increased by the necessity to separate the compound carrier from the fractions after the main separation. Many separable materials are excluded from this method since no suitable carrier can be found for them.

In the U.S. Patent No. 2,843,265, a method is employed for altering the apparent density of a suspension-type carrying medium during the separation process by a dynamic action, the so-called "angular deflection," that consists in increasing the angular velocity of the column, whereby the layer of the selected component is shifted from the outer periphery of the vortex towards its center. The process is based on the assumption that the suspension will behave as a slightly elastic matter which, under the influence of an increased centrifugal tension, will produce a column of carrier whose density is graduated along the radius of the vortex so that the carrier density on the outer periphery of the column is higher than in the central layers thereof.

Unlike the above combinations in the prior art, the present invention works with dynamic means only, using a plain carrier liquid as pure water, both for spinning the suspended separable materials and for effecting the movement of the suspended particles from the outer periphery of the vortex towards its center in the radial direction. This deflection of particles is operated directly by the added carrier, a true liquid, without increasing the angular velocity. The friction of the spinning column on the walls is limited on the carrier only so that the friction of the handled materials on said walls is avoided at least in the separation area. The radius of the column can be large enough thus permitting any desired number of central intercepting members to be placed in position to split, substantially in one point of the flow, the spinning carrier with the stratified material suspended therein into a number of fractions. The trajectory of the spinning material through the separator is very short whereby the wear by abrasion is reduced and the use of an inexpensive medium as water obviates the above inconveniences of the suspension media. The precision of this separation process is further increased by giving the central intercepting members a sliding movement in the axial direction of the vortex chamber so that the influence of any incidental fluctuations in the quality of the feed on the expected result of the process can be prevented, and the wear on the edges of said members can be compensated for. In this method, even materials with very high densities can be successfully handled with clean water as carrier because the lateral pressure on the spinning column can be increased to any desired degree. It can be varied also during the process. Finally, this method can be performed with gaseous carriers as well.

It is an object of this invention to provide a method of multiple centrifugal separation from a column of fine solids suspended in a carrier spinning in free vortex wherein the "sink" particles, stratified in density layers substantially along the outer periphery of the column, are deflected or shifted in a radially inward direction by the action of an additional carrier flow coming from outside in the direction of the radius of the vortex.

It is another object of the invention to provide a method of separation wherein the contact of the spinning suspension on the outer wall of the vortex chamber is avoided.

Other advantages of the invention will be apparent from the following description and accompanying drawing in which the sectional elevation of an apparatus according to the invention is shown.

A vortex chamber **1** is bounded by a shell having a circular cross-section and consisting of two portions **2** and **3** which are flanged to form an outer, auxiliary vortex chamber **4**. The shell portion **3** is provided with a circular vessel **5**, the portion **2** with a cover **6** closing said vessel **5**, and a suitable packing ring **7** therebetween. The cover **6** is welded to the portion **2**, the vessel **5** to the portion **3** so that the two shell portions **2** and **3** assembled by bolts **8** form one continuous vortex chamber **1** having an uninterrupted circumferential gap **9** whereby the two vortical chambers **1** and **4** communicate. The upper end of the main chamber **1** is closed by a tight cover **10** and provided with a horizontal feed conduit **11** which ends in the chamber **1** by a tangential inlet **12**. A variable valve **11'** is set in the conduit **11** to control the rate of the feed. The auxiliary vortex chamber **4** is provided with one or more feed pipes **13** supplying an additional fluid flow, volume controlled by a valve **13'**. The vortex chamber **1** is closed at its lower end by a bottom **14** in the form of an annular space in which a set of central intercepting members are inserted. These are co-axially arranged tubes **15** to **18** of different diameters and graduated from small to large, each of them being closed at its lower end by a similar bottom in form of an annular space in which the next smaller tube can slide in the axial direction. The length of each of the tubes **15** to **18** depends on its distance from the vortex axis as it can be seen in the drawing, and on its axial sliding movement varying the distance of its intercepting edge from the gap **9**. The four tubes **15** to **18** divide the lower part of the main vortex chamber **1** into four annular spaces **16'**, **17'**, **18'** and **19**, and a central circular spacer **15'**.

Each of these spaces has to collect one separated fraction and is drained by an outlet having a flow rate control therein. The outlets are shown by numerals 15″, 16″, 17″, 18″ and 19″ respectively. The correct concentric position and a tight sliding connection is secured for each sliding tube by suitable guides 20 provided with stuffing boxes, not shown in the drawing, or with an equivalent thereof. The tubes are further retained in their co-axial position by sets of radial vanes 21 inserted between the tubes in sets of three or more vanes equally spaced along the circumference of each annular space. These vanes are fastened preferably to the smaller one of each tube couple and at such a distance from their intercepting edges that in no position of the tubes said vanes can project out of their respective annular spaces. Suitable spacing between the parting edges of the tubes and the vanes is required, since the latter serve also as spin straightening means in the spaces and must not disturb by their presence the spin in the separation area. The parting edges of tubes are beveled to reduce their resistance to the spinning flow. Suitable devices for moving the tubes 15 to 18 in the axial direction are shown schematically at 22 and an adequate supporting structure 23 completes the equipment of the apparatus. All the flow rate control means mentioned in this description are variable valves of any suitable well known type and are shown in the drawing by symbols only.

In operation, a plain carrier fluid as water or air, with the separable fine material suspended therein, is fed into the chamber 1 through the tangential inlet 12 under pressure and rotated. The "sink" particles, subject to centrifugal tension, are flung towards the outer periphery of the vortex chamber and take their place in a density spectrum which is quickly formed close to the periphery, according to the density of each of the components. An additional fluid is supplied into the outer vortex chamber 4 by the pipe 13 having a tangential inlet so that the added fluid is rotated in the vortex chamber 4 and introduced into the chamber 1 as a spinning flow having substantially the same angular velocity as the spinning flow in chamber 1. The volume of the added fluid will depend on the spread between densities of the carrier fluid and the lightest "sink" component. It will normally be twice as much as that entered by inlet 12 in most cases, and considerably more if very heavy components are to be separated. The gap 9 has a uniform width along the whole circumference and said width can be varied by varying the thickness of the packing 7. The added spinning fluid exerts an equal pressure in each point of the gap 9. By a simultaneous operation of the controls 11′ and 13′, and all the valves in the outlets 15″ to 19″, the spinning flow is directed in the form of a whirlpool towards the inlets of the central tube 15 and 16. It is achieved when the drain capacity of the outlet 15″ is approximately equal to the volume of the added fluid, while the other outlets drain smaller volumes of carrier fluid, totalling that infed at the inlet 12. Due to the pressure maintained within the chamber 1, a relatively small partial vacuum develops in the central part of the shell portion 2. The general direction of the whirlpool is shown in the drawing by dotted lines connecting the gap 9 to the inlet of tube 15. The apex angle of the whirlpool cone is variable to a certain extent by position of the edge of tube 15, and must be maintained so as to suit the pitch of the spin of the mixture fed by inlet 12 to avoid unnecessary turbulence in the separating area. For the same reason, the slope of the bottom of vessel 5, and the bevel of edges defining the gap 9 must suit said apex angle. The density layers of the spinning mixture travel along the wall 2, very close to each other and sometimes intermixed. When they approach the gap 9, they are deflected away from the wall and follow the pull of the whirlpool in the direction of the inlets of tubes 15 and 16. The tube 15 drains the volume of fluid equal to that entering by the gap 9. The spaces 16′, 17′, 18′ and

19 drain together a quantity approximately equal to that supplied by the inlet 12, in fractions decreasing progressively from space 16′ to 19 so that the free vortex in the whirlpool is undisturbed. The carrier supplied by inlet 12 is collected by tube 15, while that intercepted by the other spaces is rather a part of that entered by gap 9. The cross-section area of each collecting space is made proportional to the volume to be collected. For a moment, the solids shifted from the wall 2—3 are spinning in the fluid carrier directed radially inwardly. They are thus subject to centrifugal tension which is opposed to the centripetal pull of the whirlpool. In this interaction of the two forces, the density of each particle determines the radial distance which it is deflected from the wall 2—3. An extended density spectrum is formed and the particles which were originally gathered on the wall 2, are spread in density layers along the major part of the vortex radius when they come out of the whirlpool zone to continue their spin in the axial direction. When the particles are out of said zone, they would tend to return to the wall 3. They can be fractioned in several different manners. If a set of intercepting tubes is arranged to have their parting edges in a straight line parallel with and near to the whirlpool outline shown in the drawing, they will divide the spinning body so that most of the clean carrier fluid with some incidental "float" particles is intercepted by tube 15, the lightest sink particles entering the space 16′, and the heaviest components being deflected only slightly in the radially inward direction, returning to the wall 3 to enter the space 19. The particles with intermediate densities are intercepted by tubes 17 and 18.

The actual arrangement of the parting edges of tubes 15 and 18 shown in the drawing, in combination with the sliding movement of the tubes in axial direction provides a means for an improved density control of the separated fractions, when a heavy particle is shifted by the whirlpool into an intermediate position between the layer traveling in the direction of the space 19 and the space 18′. The particle shows to have an intermediate density between the two fractions. When it is desired to keep the fraction in 19 as clean as possible with exclusion of any middling, said intermediate particles can be attracted by an increased drain in outlet 18″ towards the space 18′, during the travel of those particles from the whirlpool zone towards the collecting spaces. When, on the contrary, it is desired to keep the fraction in space 18′ as clean as possible, an increased drain in outlet 19″ will pull the middling towards the space 19. When at the same time the tube 18 is put into advanced position shown by dotted lines in the drawing, only a minimum of particles traveling on the inner periphery of the outer layer will be pulled into the space 18′. In order to protect the layer traveling towards the space 17′ against the increased draft in outlet 18″, the tube 17 can be risen more or less as the one at 18. When a larger number of intercepting tubes is used than that shown, any one of the tubes pushed into an advanced position divides the separation area under the whirlpool into two parts so that in one part changes of density as that described above can be achieved without disturbing the separation in the other part, even when larger variations in draining capacity of the spaces takes place. Obviously, the sliding movement of the tubes in the axial direction allows for compensation for any wear by abrasion on the tube parting edges. A uniform grain size of the fed fine solids and an undisturbed spin of the carrier in the separation area are prerequisite for a sharp density separation. Therefore, said spin should continue for a small distance within spaces 15′ to 19; for that reason the spacing vanes 21 are placed at a sufficient distance from the tube inlets, and the edges are beveled.

The inlet 12 should be as close as possible to the gap 9 so that the infed mixture tends less to cut short its spiralling way towards the inlet of tube 15. The outer vortex chamber **4** can be built separately as a gasket of smaller vertical height and inserted between the shell portions **2** and **3**. The space for rotating the added fluid is developed in a radial direction, and has several channels curved as involute discharging from outside circumferentially equally spaced flows to obtain a well equalized spinning flow in the gap **9**, directed substantially in right angle towards the axis of the vortex chamber **1**.

In a variation of the apparatus shown in the drawing, the fine solids to be separated are fed by a separate feed conduit **24** drawn in dotted lines. The conduit **11** is of smaller size to supply the clean carrier only. The pressure maintained within the chamber **1** is increased to reduce to a minimum any vacuum around said feed conduit **24**. A provision must be made that the solids discharged through said conduit cannot fall directly into the inlet of tube **15**. A suitable feed conduit meeting this requirement is the object of my co-pending application for patent, Serial No. 712,000, filed January 29, 1958. The fine solids discharged centrally into the spinning clean carrier are rotated by the carrier and, being "sink" particles, spread in the radially outward direction within the spinning carrier. The conditions of spin are controlled in such a manner that the particles must reach the whirlpool before they would come in contact with the shell portion **2**. Thus, before they reach said wall **2** they are shifted centerwards and the process proceeds as described above. The heaviest fraction after separation can be intercepted by the space **18'** instead of space **19**; this depends only on flow rate controls by variable valves and on the position of the parting edge of the tube **18**.

For very short movements of tubes in the axial direction, the packing in bottoms **14** can be made inexpensive when said bottoms are made of some flexible material such as rubber and fixed to ecah of the adjacent tubes so that the bottom forms a tight fit without any stuffing box.

I claim:

1. An apparatus for multiple separation of suspended articles from a fluid carrier 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, tangential feeding means in said circular wall section enabling said fluid carrier to spin in said vortex chamber, a continuous circumferential gap in said chamber wall section for discharging an additional fluid carrier into said main chamber, an outer vortex chamber enclosing said gap from outside, feeding means connected to said outer vortex chamber and adapted to supply said additional fluid carrier and to impart it a spin, a series of intercepting tubes in said bottom portion of said main chamber and concentric with each other and with said chamber, said tubes being of different lengths and diameters and graduated from small to large having lower ends slidingly connected with each other to form a bottom of said chamber, said tubes thus having a sliding movement along said chamber in an axial direction thereof enabling each of them to be adjusted individually and to control a distance of the upper edge of each of said tubes from said circumferential gap, means to drain products of separation from annular spaces defined by said tubes and by said circular wall of said main chamber, and means to control said sliding movement of said tubes.

2. Apparatus of claim 1 further comprising separate feed means for a mixture of particles treated arranged in said chamber top portion concentrically with said chamber so as to discharge said mixture axially.

3. Apparatus of claim 1 further comprising flexible connectors between said tubes to form a bottom for the main vortex chamber and for each of said annular spaces.

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