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METHOD OF SEPARATING DISPERSED MATTER FROM FLUID MASSES

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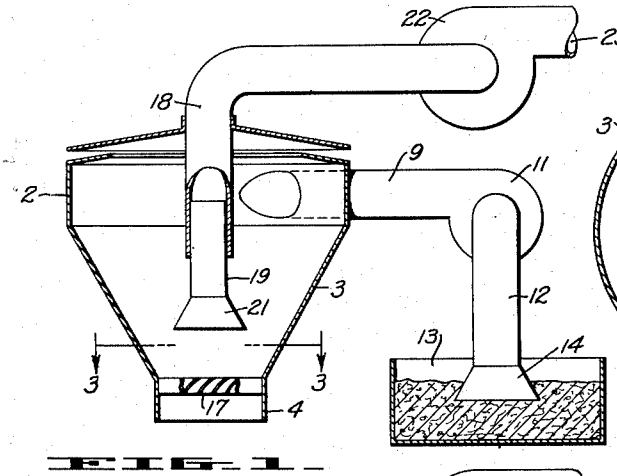


FIG. 1

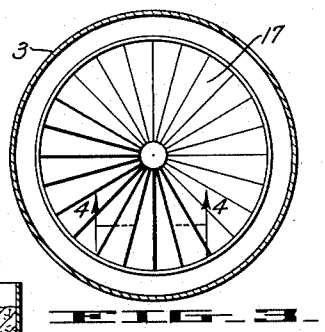


FIG. 3

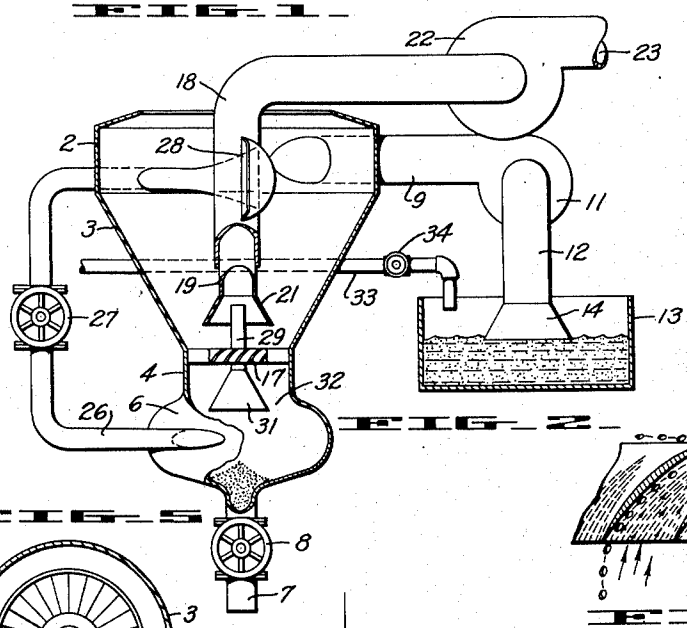


FIG. 2

FIG. 5

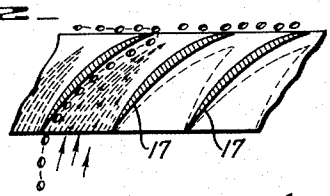


FIG. 4

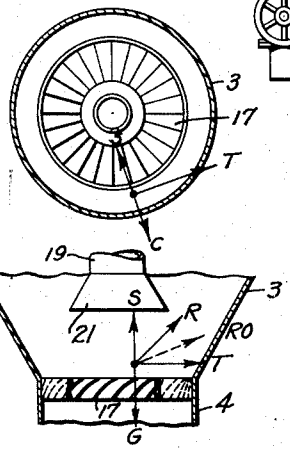


FIG. 6

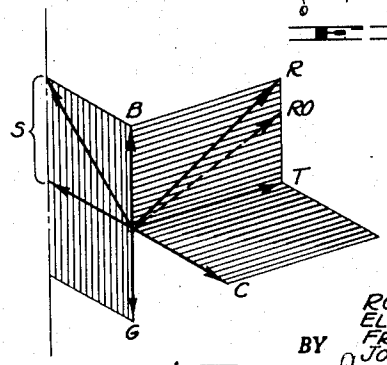


FIG. 7

INVENTORS
ROBERT D. SIMPSON
ELWIN V. GORDON
FRANK CARDOZA
JOHN H. JACOBS
BY Joseph B. Gardner
Atty.

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METHOD OF SEPARATING DISPERSED MATTER FROM FLUID MASSES

Robert D. Simpson and Elwin V. Gordon, San Leandro, Frank Cardoza, Hayward, and John H. Jacobs, Oakland, Calif., assignors to Farm Production Engineers, Inc., Oakland, Calif., a corporation of California

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5 Claims. (Cl. 209—144)

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This invention relates to the separation of precipitable substances from a fluid carrier.

An object of the invention is to provide a method for effecting the rapid and continuous handling of unusually large volumes of mixtures from which it is desired to separate selected components of specific unit mass weight.

Another object of the invention is to provide a method, for effecting separation as above set forth, wherein minute discrimination may be readily secured between components of a mixture which very nearly have the same unit mass weight so that the resulting extraction will possess the least possible degree of adulteration.

A further object of the invention is to provide a method wherein by the application of opposing forces to a mass of mixed material a delicate degree of unbalance may be established in the mass by means of which a selected component of the mixture may be caused to pass more or less rapidly from the mass.

Still another object of the invention is to provide a method of separation as above described which will function equally as efficiently with aqueous mixtures as with masses in which a gaseous medium comprises the suspending or carrier vehicle.

The invention possesses other objects and features of advantage which, together with the foregoing, will be specifically set forth in the following detailed description of the invention. It will be understood that the invention is not to be limited to the exemplary apparatus or the specific procedure herein shown and described, as variations thereof may be employed which come within the scope of the appended claims.

Referring to the drawing:

Figure 1 is a view, generally diagrammatic in character, of apparatus arranged to carry out the method of our invention.

Figure 2 is a modified form of apparatus to that illustrated in Figure 1.

Figure 3 is an enlarged horizontal sectional view taken in the plane indicated by the line 3—3 of Figure 1.

Figure 4 is an enlarged scale vertical sectional view taken in the plane indicated by the line 4—4 of Figure 3.

Figure 5 is a horizontal sectional view, taken substantially in the plane of the line 3—3 of Figure 1 and illustrating diagrammatically a portion of the forces imposed on the material particles in the separator.

Figure 6 is a vertical sectional view substantially equivalent to the lower portion of Figure 1 and illustrating diagrammatically other forces imposed on the particles within the separator.

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Figure 7 is a vector diagram of the direct and resultant forces imposed on particles during their separation.

In broadest terms, our invention comprises releasing masses of mixed fluid and dispersed matter to fall by gravity along a defined path, applying to the masses force to effect deflection of a selected component of the dispersed matter substantially laterally of the path, arresting the deflection movement of the selected component at an outer zone of the path, permitting continuing movement of the selected component along the path in the aforementioned outer zone thereof, imposing on the remaining components of dispersed matter excepting the selected one thereof a force arresting movement along the path of the said remaining components, collecting the selected components at an intermediate point in the path and subsequently directing the remaining components and fluid along the path away from the collected selected components.

There are numerous ways in which the exact above procedure or a functional equivalent thereof may be carried out but we have chosen for purposes of illustration the particular mechanism of the drawing in which a preferably axially vertical housing 2 is provided having therein a preferably cylindrical and downwardly convergent separation chamber 3 communicating through a duct 4 with a secondary chamber 6 of vertically flattened globular form contained in a housing of corresponding shape disposed axially below the housing 2 and provided in the bottom surface thereof with a discharge spout 7 capable of being opened and closed by a suitable control valve 8. Reference is also made herein to the apparatus disclosed in our copending application, Serial No. 149,346.

Means for delivering material to be separated into the separation chamber 3 is here shown as comprising an inlet conduit 9 which is arranged to discharge tangentially into the upper portion of the aforesaid chamber and which is connected through a pump 11, or other suitable flow inducing means, with a supply duct 12 into which fluid and entrained material may be introduced, preferably by suction existing in the said duct, from a material supply hopper 13 or other equivalent means. Where the entrained material comprises comminuted solid matter carried in a fluid carrier, whether air or liquid, the end of the

supply duct 12 may be equipped with a suction nozzle 14 immersed in the mass of material 16 contained in the hopper 13; the pump 11 under such circumstances serving to lift the material 16 from the hopper, together with the carrier stream which may be ambient air about the hopper or liquid introduced into the latter in the required suitable amounts, and to forcibly discharge the mixture of carrier vehicle and entrained material into the separation chamber 3. In some instances, such as where separation of seed values from grain is desired, the pump 11 may comprise a fan-type blower into which cut stalks with their attached seed heads may be fed through the suction duct 12, the blower thereupon threshing the grain and effecting thorough detachment of the seeds or kernels from the heads, the resulting mixture being then conveyed by the carrier air stream into the separation chamber 3.

As the carrier stream of fluid tangentially enters the upper portion of the separation chamber 3 the mass of fluid and entrained material will be caused to whirl rapidly about the vertical axis of the chamber with the result that both centrifugal and gravitational forces acting on the heavier components of the mass will primarily cause the components to work their way radially outwardly of the mass to occupy a peripheral zone thereof limited in radial dimensional extent by the inner wall surface of the chamber and secondarily will cause the concentrated heavier components to gradually move, under the influence of gravity, downwardly along the converging wall surfaces toward the throat 4. In the case of threshed grain or the like, the weightier seeds or kernels will act similarly to the heavier components of the aforesaid mixture, the lighter tares forming a whirling central core mass in the separation chamber which will also move under the influence of gravity downwardly toward the throat 4.

In the throat 4 and separating the chamber 3 from the space therebelow, here shown as the chamber 6, is disposed what may be termed a grid comprising a plurality of circumferentially spaced vanes 17 radiating from a common center which coincides with the central axis of the chamber 3 and arranged so that their facial surfaces angularly intersect the said axis of the chamber 3 and arranged so that their facial surfaces angularly intersect the said axis, the degree of said angularity being dependent upon several factors and the nature of the mixture in which particle separation is to be effected. Each vane 17 in cross-sectional form is preferably curvate rather than flat, the subjacent surface facing the chamber 6 being concave so that any fluid stream which may move from the chamber 6 upwardly into the chamber 3 is intercepted by the vanes and caused to enter the latter chamber in tangential relation to the vertical axis thereof and in a degree of angularity, normal to the axis, which is a function of the vertical inclination of the vanes. The preferred arrangement of the parts is such that the aforesaid entering stream will be caused to conform in direction of rotation with the whirling mass of fluid in the separation chamber and will smoothly merge therewith so that minimized turbulence in the plane of confluence of the fluid masses will obtain.

Means is provided in the separation chamber 3 for effecting continuous removal of core portions of the mass of carrier fluid and entrained substances other than the concentrations of selected particles in the peripheral zone of the

mass and for allowing the said concentrations to settle downwardly toward the upper plane of the grid preparatory to final and complete separation from the parent mixture. Arranged concentrically of the separation chamber and extending vertically downwardly therein is an exhaust duct 18 having at its lower end an axially and vertically adjustable tubular section 19 provided at its lower end with a downwardly flared collector bell 21 capable of being positioned variably above the upper horizontal plane of the grid. The opposite end of the exhaust duct 18 is connected to suitable flow inducing means here shown as the suction inlet of a blower or similar rotary pump 22 whose discharge 23 may be directed into the atmosphere or into a suitable distribution duct for disposal. In the separation of grain, for instance, from its supporting stalks and seed heads, the mass of previously threshed and relatively detached seeds and tares or the integral grain immediately after harvesting, is brought into proximity with the suction nozzle 14 and is drawn, by suction existing in the duct 12, into the pump or blower 11 wherein the mixture of grain and carrier fluid is vigorously and thoroughly agitated so as to effect the most complete detachment of the seeds or values from the tares, the resulting mixture being then discharged as previously described tangentially into the separation chamber 3 through the lead-in conduit 9. Once in the separation chamber, the solid particles and tares will be whirled, together with their mass of carrier fluid, about the vertical axis of the chamber with the result that the heavier particles will be urged, by centrifugal force, radially outwardly of the mass to occupy the peripheral zone of the latter while the core mass will comprise the lighter tares and other undesired components of the mixture. The additional force of gravity will be exerted on both the selected heavier particles and the core mass, the former being the most affected, so that both components will move downwardly toward the grid at the bottom of the separation chamber while still whirling within the chamber.

The suction pump or blower 22, being activated, establishes a suction current in the exhaust duct 18 and in the bell 21. In the case of the structure of Figure 1 wherein the space below the grid is open to the atmosphere, the suction flow moving in the duct 18 will induce an upward flow of atmospheric air through the grid and past the vanes thereof with the result that the induced stream in emerging from the grid at the upper plane surface thereof is, as previously explained, whirling in substantial conformity with the rotational movement of the mass of mixture in the superposed separation chamber 3. As the entrained materials in the fluid mass contained in the separation chamber descend, the radially inner core portions of the mass, comprising fluid and the rejected particle components of the mixture, upon coming into substantial registry with the bottom plane of the bell will be brought under the influence of the suction flow entering the bell with the result that all components other than the particles occupying the peripheral zone of the mass will be drawn out of the separation chamber and disposed of as previously mentioned.

A peculiar action takes place during movement of selected material particles toward and through the grid unit. As hereinbefore specified, a constantly moving stream of fluid is flowing at prescribed velocity upwardly through the grid unit

between the vanes 17 as shown in Figure 4. Each division of the stream passing upwardly between adjacent vanes is adjusted to move at such critical velocity that all components of the mixture of fluid and entrained particles immediately above the grid in the separation chamber, with the exception of the selected particles which are to be recovered, are buoyed upwardly and sustained in suspension above the grid where they will eventually come under the influence of the suction draft flowing in the duct 18 and will be carried off and disposed of. Where air comprises the stream moving upwardly through the grid, it has been found that in each division of the stream the latter varies in density and velocity in successive radial increments of cross-sectional area from a maximum at the center of the stream division to a lesser amount in the zonal extremity thereof immediately adjacent the surfaces of the vanes. This means that at circumferentially spaced points around the upper facial area of the grid unit, fluid jets will be projected generally upwardly which at their centers possess sufficient velocity only slightly less than that required to impart full buoyancy to the selected particles to be recovered and more than sufficient to double back against the force of gravity all other components of the fluid borne material. The spaces between the higher velocity centers of adjacent jets will be traversed by outer longitudinal zones of the jets having lesser velocities which, however, are not so low as to allow substantial amounts of the rejected components of the fluid-borne materials to gravitate toward and to penetrate the grid unit. It will be seen that as the concentrate of selected particles moving downwardly along the inclined sidewall surfaces of the separation chamber 3 reach the upper plane of the grid unit, they will be caught in the zone of substantial equilibrium between the upper swirling fluid mass in the separation chamber and the similarly swirling flow of fluid rising through the grid unit. This will cause the particles to become spread out laterally in a horizontal plane slightly above the upper facial plane of the grid unit and to be carried along the former plane for one or more revolutions of the fluid mass during which time gravity will act upon the particles and cause them to approach and skim over the said facial plane of the grid as indicated in Figure 4. As the latter particles lose their momentum, they will pass over the upper ends of the vanes 17 and vertically downwardly into the stream divisions moving upwardly between the vanes, each particle penetrating a stream until the former reaches a velocity zone of the stream which will resist its fall whereupon the particle will rebound into or through one or more of the adjacent zones of lesser velocity thereafter again falling substantially vertically until the aforementioned higher velocity zone is reached, resulting in the above described cycle repeating itself. Thus, as indicated in Figure 4, the particles will cascade downwardly along the stream divisions, and counter to movement of the latter, into the comparatively low velocity fluid mass existing below the grid unit whereupon the particles may fall unimpeded through the discharge spout 24 and into any suitable receiver placed below the spout.

The forces exerted on each particle from the time that it enters until the time that it leaves the separation chamber are rather complex and are believed to be adequately illustrated in Figures 5, 6 and 7 of the drawing. Here, it will be seen, the arrows C and G represent respectively

the horizontally outward centrifugal force exerted on the particles by the whirling motion of the fluid carrier and entrained material within the separation chamber and the perpendicular force constantly exerted on the particles by gravity. Also present and represented by the arrow T is the tangential force substantially horizontally at right angles to the centrifugal force line C which indicates the impelling force behind the particle causing the latter to whirl with the parent mass in the separation chamber. Directly opposing the centrifugal and gravitational forces C and G is the suction force S created by the exhausting fluid flow in the duct 18 which, as shown in Figure 7, is directly opposite to the centrifugal force at the plane of the lower end of the suction bell 21 and which is more vertically angularly related to the centrifugal force at the upper facial plane of the grid unit. Thus the two force arrows S shown in Figure 7 represent the space between the relatively confronting plane faces of the suction bell 21 and grid unit in which radial opposition to the centrifugal force takes place. The upward component of the suction force S induces the upward flow of fluid through the grid unit and creates the buoyancy force B which is in direct opposition to the force G of gravity. All of these forces combine to produce a resultant R which represents both the driving force causing the particle to substantially float above the grid unit before settling thereon and passing therethrough. In normal operation, the updraft or buoyancy force B must be maintained slightly less than the gravitational force G so as to produce a resultant RO not exceeding the suction force S, otherwise the particles which are to be separated from the fluid mass will be caught up by the suction draft in the duct 18 and discharged with the tailings from the separation chamber. It will be seen therefore that it is possible, by regulating the updraft or buoyancy force B, so that it is exceeded only very slightly by the countering or gravitational force G, to effect efficient separation of particles from a mixture which differs in unit mass weight to a very small degree in relation to the similar characteristics of other particles which are to be rejected.

In the separation of certain substances such as minerals from comminuted ore masses it is preferred that liquid be substituted for air as the carrier vehicle, in which case the slightly modified form of apparatus, shown in Figure 2, is required to effect selection of desired components of a mixture in accordance with the method of our invention. As here shown, the secondary chamber 6 is provided with a supply duct 26 for liquid entering the chamber tangentially thereof and preferably connected, through a control valve 27 or similar element, with a scoop 28 positioned within the separation chamber 3 and facing circumferentially thereof so as to intercept a portion of the fluid mass contained in and revolving about the axis of the latter chamber. The grid unit is also modified to the extent that it is provided with a centrally disposed axially vertical jet tube 29 terminating at its upper end within the bell end 21 of the suction duct 18 and having at its lower end a downwardly flared bell spout 31 positioned within the duct 4 and sized to provide an annular opening 32 between the periphery thereof and the confronting inner wall surface of the duct 4. A further modification comprises providing a liquid supply duct 33, suitably con-

trolled by a valve 34, through which regulated amounts of water or other desired liquid may be admitted to the hopper 13 for admixture with the contents 16 of the hopper and to provide the carrier vehicle for conveying the said contents into and through the separator apparatus. In operational characteristics the modified form of apparatus is substantially similar to that previously described. When the mixture of fluid and material particles entrained therewith is admitted tangentially into the chamber 3 through the discharge orifice of the supply duct 9, the mass will whirl as before with the heavier particles to be separated working their way radially outwardly of the mass and concentrating in a surface layer over the vertical side wall surface of the separation chamber, the said concentration then working its way, under the influence of gravity, downwardly along the said side wall surface toward the grid unit. Some of the core mass of liquid and particles of lesser unit mass weight will be drawn into the bell spout 21 and out through the suction duct 18, the rate of such removal and consequently the degree of suction in the latter duct being of course capable of regulation by variations in the operating speed of the pump 22. Other quantities of the core portion of the fluid mass will be intercepted in its rotational movement by the scoop 28 which will direct the collected fluid through the duct 26 and tangentially into the secondary chamber 6 wherein the fluid will be caused to whirl in reversed direction to rotation of the fluid mass in the upper separation chamber 3. The admittance of fluid into the secondary chamber 6 causes primarily, an upward flow through the gap 32 into the chamber of the duct 4, defined by the grid unit and the bell member 31, and thence upwardly through the grid unit to supply the buoyant force which is the full equivalent of the updraft previously described, and secondarily a flow into the bell member 31 to create a forcible jet of fluid which discharges from the upper end of the tube 29 into the lower end of the suction duct 18. This results in the production of an injector action in the suction tube assisting the evacuation effort of the pump 22 and effecting more efficient removal of fluid and rejected components of the mixture from the separation chamber. The selected components of the mixture which succeed in passing downwardly through the grid unit, in the manner previously described, cling to the inner wall surface of the chamber 6 due to the action of the centrifugal force of the swirling fluid mass in the latter chamber and eventually gravitate downwardly to collect in the spout 7 from whence they may be removed as desired by opening the control valve 8. It frequently occurs that in the concentration of selected particles moving downwardly through the grid unit and passage 4, some particles of matter may become entrapped which should have been separated from the select particles in the chamber 3. In the construction shown, the concentrate in passing downwardly through the gap 32 will become agitated to the extent of releasing the undesired particles which will then either be carried upwardly with the fluid flow through the grid unit or will pass into the bell member 31 and be ejected by the jet flow issuing from the upper end of the injector tube 29.

The foregoing description has dealt with the separation from a fluid-borne mixture of substance particles, of the components having the heavier unit mass weight. This was done simply to avoid complications in the description of the procedure rather than to limit the scope of the invention since it will be seen that the method may be employed to select from any mixture a particular component having a unit mass weight of intermediate quantity. Such selection may be carried out by running a batch through the processing apparatus so that division of the batch is effected at the point where the particles of the desired and selected unit mass weight form either the lightest component of one batch section or the heaviest component of the other. The batch section containing the desired particles is then re-run through the apparatus so as to discard all but the wanted elements. It will be seen therefore that under certain conditions, discharge of selected components of a mixture may be had at either the normal delivery points below the separation chambers or at the discharge orifice of the exhaust pump or blower 22.

In the above description it will be noted that the flow of fluid entering the secondary chamber 6 is directed in such manner that rotation of the fluid mass in the latter chamber is counter to that of the fluid mass in the separation chamber 3. It would ordinarily be expected that the rotational directions of both masses should be the same in order that the fluid rising from the lower chamber 6 through the grid unit into the upper chamber 2 will flow smoothly between the vanes 17 and be ejected angularly into the upper fluid mass without causing undue turbulence therein. It has been found, however, that for some unexplainable reason, the fluid rising into the chamber of the duct 4 from the chamber 6 will reverse its rotational direction of movement which, if the mass of fluid in the lower chamber was rotating in conformity with the rotational motion of the separating chamber fluid mass, would cause the rising fluid to strike the vanes 17 substantially normally to their flow-directing surfaces and create severe turbulence in the streams emerging from the grid unit into the separation chamber. This condition of course does not obtain in the structure of Figure 1 wherein the fluid may freely flow into the bottom of the grid unit.

We claim:

1. The method of separating components of prescribed unit mass weight from a mixture entrained in a volume of carrier fluid and including other components of differing unit mass weight, which comprises moving along a path a mass including a carrier stream of fluid having entrained therein particles of different unit mass weight, whirling said fluid and entrained particles to set up centrifugal force in the mass sufficient to cause segregation of particles of greater unit mass weight from particles of lesser unit mass weight in different zones of the mass, subjecting said mass to gravitational force to effect descension of all particles, inducing a flow of fluid into said mass in opposition to said gravitational force at sufficient velocity to at least suspend particles of lesser unit mass weight in said mass and to permit descension of particles of greater unit mass weight in said mass, imparting to said flow of fluid a tangential force so as to cause the latter to move in a path substantially in conformity to the movement of said mass, and causing said descending mass to be spread out in a generally horizontal plane at the confluence of said flow of fluid and said mass.

2. The method of separating components of prescribed unit mass weight from a mixture en-

trained in a volume of carrier fluid and including other components of differing unit mass weight, which comprises moving along a path a mass including a carrier stream of fluid having entrained therein particles of different unit mass weight, whirling said fluid and entrained particles to set up centrifugal force in the mass sufficient to cause segregation of particles of greater unit mass weight from particles of lesser unit mass weight in different zones of the mass, subjecting said mass to gravitational force to effect descension of all particles, introducing into said mass in opposition to said gravitational force a flow of fluid at sufficient velocity to at least suspend particles of lesser unit mass weight in said mass and to permit descension of particles of greater unit mass weight in said mass, subjecting said mass to a force to effect a spreading out of the mass in a substantially horizontal plane so as to permit said lesser unit weight mass particles to overcome the gravitational force while permitting said greater unit weight mass particles to be subjected to said gravitational force, and whirling said introduced flow of fluid in conformity with the whirling movement of said mass to minimize turbulence at the confluence of said flow of fluid and said mass.

3. The method of separating components of prescribed unit mass weight from a mixture entrained in a volume of carrier fluid and including other components of differing unit mass weight, which comprises moving along a path a mass including a carrier stream of fluid having entrained therein particles of different unit mass weight, whirling said fluid and entrained particles to set up centrifugal force in the mass sufficient to cause segregation of particles of greater unit mass weight from particles of lesser unit mass weight in different zones of the mass, subjecting said mass to gravitational force to effect descension of all particles, directing a portion of said carrier fluid into said mass in a flow in opposition to gravitational force acting on said mass and with sufficient velocity to at least suspend particles of lesser unit mass weight in said mass and to permit descension of particles of greater unit mass weight in said mass, causing said mass to spread out laterally in a generally horizontal plane immediately above the confluence of said flow of fluid and said mass, and whirling said introduced flow of fluid in conformity with the whirling movement of said mass to minimize turbulence at the confluence of said flow of fluid and said mass.

4. The method of separating components of prescribed unit mass weight from a mixture entrained in a volume of carrier fluid and including other components of differing unit mass weight, which comprises moving along a path a mass including a carrier stream of fluid having entrained therein particles of different unit mass weight, whirling said fluid and entrained particles about a vertical axis to set up centrifugal force in the mass, moving said mass axially to effect vertical and inward movement of all particles, spreading said mass in a generally horizontal plane, inducing a flow of fluid into said mas through said spread layer at sufficient velocity to at least suspend particles of lesser unit mass weight in said mass and to permit continual movement of particles of greater unit mass weight in said mass, and moving the lighter particles centrally and in a generally vertical direction.

5. The method of separating components of prescribed unit mass weight from a mixture entrained in a volume of carrier fluid and including other components of differing unit mass weight, which comprises moving along a path a mass including a carrier stream of fluid having entrained therein particles of different unit mass weight, whirling said fluid and entrained particles about an axis to set up centrifugal force in the mass, moving said mass axially to effect axial movement of all particles, spreading said mass in a general transverse plane at said axis, inducing a flow of fluid into said mass through said spread layer at sufficient velocity to at least suspend particles of lesser unit mass weight in said mass and to permit continual movement of particles of greater unit mass weight in said mass, and moving the lighter particles centrally and in a general axial direction.

ROBERT D. SIMPSON.
ELWIN V. GORDON.
FRANK CARDOZA.
JOHN H. JACOBS.

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