AMENDED SPECIFICATION.

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(54) DECANTER CENTRIFUGE

(71) We, PENNWALT CORPORATION, a corporation organised and existing under the laws of the State of Pennsylvania, United States of America, of Pennwalt Building, Three Parkway, Philadelphia, Pennsylvania 19102, 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 described in and by the following statement:—

This invention relates to decanter centrifuges.

Decanter centrifuges usually include a rotating centrifuge bowl in which a screw conveyor revolves at a slightly different speed.

Such centrifuges are capable of continuously receiving feed in the bowl and of rapidly separating the feed into layers of light and heavy phase materials which are discharged separately from the bowl. It is the function of the screw conveyor to move the outer layer of heavy phase material to a discharge port therefor, usually located in a tapered or conical end portion of the bowl.

Effective and efficient centrifugal separation requires that the light phase material, usually liquid, be discharged containing little or no heavy phase material. In addition, the heavy phase material should contain only a small amount of light phase material. For example, if the light phase material is water and the heavy phase material comprises soft solids, it is preferred that fairly dry solids and clear water be separately discharged.

In addition to being capable of performing continuous separation, decanter centrifuges have the advantage of being less susceptible to pluggage by solids than other kinds of centrifuges. Furthermore, decanter centrifuges may be shut down for long or short periods and then restarted with minimum difficulty, whereas most other centrifuges require cleaning to remove dried solids.

Despite these advantages, decanter centrifuges have seen limited application for separating a mixture of materials having nearly the same specific gravity, or wherein the heavier phase material is slippery or very fine. When the materials of the light and heavy phases have nearly the same specific gravity they separate slowly, and they tend to re-mix when disturbed by turbulence. Turbulence may be caused by axial flow within the bowl, by the splashing introduction of feed, or by agitation of the revolving screw conveyor. In conventional decanter centrifuges remixture is further promoted by contact of the phases as the heavier phase material passes through the inner layer of lighter phase material while advancing along the tapered end of the bowl. It is therefore difficult to keep such materials separated after they have been separated. In addition, even if the separated materials could be kept separated, conveying of slippery or very fine solid materials by a screw conveyor is very difficult, just as it has been virtually impossible to scroll separated liquids of low viscosity by means of the slowly revolving screw conveyor.

The disclosure of U.S. Patent No. 3,172,851 teaches a method and apparatus for centrifugal separation which improves the ability of the conveyor to move light solids in the tapered part of the bowl toward the solids discharge port. This is accomplished when the solids discharge port is placed at a greater radial distance from the bowl axis than is the liquid discharge port. However, with this construction the solids in the tapered end of the bowl are totally immersed in liquid until the moment before discharge, and therefore the discharged solids will be quite wet.

The present invention provides an improve-

ment in decanter centrifuges of the type described above. In particular, the present invention provides a decanter type centrifuge of increased versatility and separating efficiency and which can be used to separate solid/liquid mixtures to give a solids discharge having an appreciably lower moisture content than obtainable heretofore with decanter centrifuges. Also the improved decanter centrifuges of this invention can be used to facilitate previously difficult liquid-liquid separation, for example, in triglyceride refining.

According to this invention, there is provided a decanter centrifuge comprising an elongated bowl mounted for rotation about its longitudinal axis, said bowl having at one end thereof an inwardly tapering end section in which is located a heavy phase discharge port and, at the opposite end, a light phase discharge means having a lip or weir over which separated light phase material flows prior to discharge from the bowl through said means, a screw conveyor coaxially mounted within the centrifuge bowl for rotation relative thereto and effective upon rotation thereof relative to the bowl to convey separated heavy phase material axially along the interior wall of the centrifuge bowl towards said heavy phase discharge port, and means for feeding materials to be separated into said centrifuge bowl along the axis thereof, to a feed entry point located intermediate the ends of the bowl, said screw conveyor comprising an elongated cylindrical hub extending substantially the length of the centrifuge bowl and having over its own length between said feed entry point and said heavy phase discharge port, an external radius less than the spacing of said lip or weir from the axis of the centrifuge bowl, and a helical screw flight mounted externally on the hub, and wherein there is also mounted externally on said hub a baffle, said baffle being positioned between said feed entry point and the heavy phase discharge port, thereby to divide the interior of the bowl into a discharge section communicating with said heavy phase discharge port and a separating section communicating with said feed entry point and with the light phase discharge means, and wherein the baffle extends radially a distance such that the outer edge thereof, in use, projects into the separated layer of heavy phase material, thereby to prevent the passage of separated light phase material from the separating section into the discharge section and forming with the adjacent internal wall of the centrifuge bowl a restricted passageway through which the separated heavy phase material passes on its way towards the heavy phase discharge port, and wherein means are provided, operable independently of the conveyor, to apply a pressure head to the separated heavy phase material located on the side of the baffle remote from the heavy phase discharge port, thereby to assist the passage thereof through the restricted passageway.

As will be appreciated, the characteristic feature of this invention is a baffle mounted on the conveyor and providing a restricted passageway for the throughflow of the separated solid or heavy phase material, which throughflow is assisted by exerting a pressure differential on the heavy phase material on opposite sides of the baffle. In one arrangement the baffle may take the form of an annular flat plate normal to the bowl axis, but preferably it is frusto-conical in shape. In either case the baffle is positioned to divide the interior of the bowl into: a first or separation zone, and also a second zone surrounded by the tapered end portion of the bowl. The baffle has an outer edge in closely spaced relation to the inner surface of the bowl, thereby defining a restricted passageway for the underflow of heavy phase material from the first zone to the second zone. The flow area for this restricted passageway should be large enough to prevent an accumulation of heavy phase material in the separation zone of the bowl, and not appreciably larger than the flow area of the solids discharge port.

The baffle extends outwardly, beyond the annular interface between the separated phases, a sufficient radial distance from the bowl axis to prevent the flow of any portion of the light phase layer from the first zone to the second zone. In this regard it is to be distinguished from prior art baffles in decanter centrifuges. For example, in U.S. Patent No. 3,447,742 the baffles merely extend to just beneath the surface of the light phase layer in order to block the flow in axial direction of light solid particles floating on the inner surface of the light phase layer.

The present invention is also distinguishable from many other prior art constructions, e.g. U.S. Patent No. 3,228,594, in that the baffle is positioned between the heavy phase discharge port and the entering path of feed to the bowl. It is preferred that incoming feed be directed onto the inwardly facing surface of a conical baffle so that, with the aid of acceleration vanes on such surface, as the feed flows outwardly therealong it will be given an angular velocity approaching that of the separated phases in the separating zone; and the feed will therefore enter the separating zone without creating excessive turbulence.

The baffle is imperforate, at least for that portion thereof coming into contact with the materials in the separating zone, in order to prevent flow therethrough from one zone to the other zone. This is to be distinguished from the perforated construction of some parts shown in U.S. Patent No. 2,593,278. Furthermore, with an imperforate baffle extending almost to the inner surface of the bowl, it is possible to establish favorable pressure relationships between the heavy phase material in the second zone and the layers of light and heavy phase

materials in the separating zone.

According to a preferred aspect of the invention, the heavy phase material in the separating zone is pressurized well beyond the usual pressure applied, in a conventional centrifuge, by the centrifugal force of an inner layer of light phase material having conventional depth. This is accomplished, in the preferred embodiment, by setting the dam, discharge port, or other discharge means for light phase material so that the inner surface of the light phase material is maintained radially inward of the heavy phase discharge port, instead of being conventionally maintained radially outward of the heavy phase discharge port. The deeper layer of light phase material, under centrifugal force, subjects the underlying layer of heavy phase material to increased pressure. The increased pressure on the heavy phase material in the separating zone is transmitted therethrough via the restricted passageway to the heavy phase material in the discharging zone, thus helping to advance it to the discharge port.

Alternatively the heavy phase material in the separating zone may be pressurized, without increasing the depth of the light phase layer, by pressurizing the separating zone with gas introduced by a suitable delivery means.

With the aforesaid pressurizing means, the flow of heavy phase material is promoted from the outer layer of the separating zone through the restricted passageway and then axially and inwardly along the inner surface of the tapered portion of the bowl. Such promotion of heavy phase flow augments the action of the screw conveyor as it conveys heavy phase material to the discharge port in the tapered portion of the bowl. Even if the heavy phase is mostly liquid, it will readly flow together with sedimented solids to the heavy phase discharge port according to this invention.

The invention will be further described with reference to the accompanying drawings, in which:

FIGURE 1 is an elevational view, partly in section, of a centrifuge embodying one form of the invention;

FIGURE 2 is an elevational view, partly in section, of a centrifuge embodying another form of the invention;

FIGURE 3 is an enlarged elevational view, partly in section, of a portion of the centrifuge shown in FIGURE 1;

FIGURE 4 is a fragmentary bottom view of the centrifuge portion of FIGURE 3, with screw flights omitted for clarity; and

FIGURE 5 is a schematic illustration of a centrifuge embodying the invention in further modified form.

Shown in Figure 1 is a centrifuge 10 comprising a frame 12 having main bearings 14 in which are journaled the ends of a hollow, elongated centrifuge bowl 16 of circular cross section. The bowl 16 is adapted for rotation about its longitudinal axis within a housing 18. A plurality of discharge ports or openings 20 are formed in one end wall 22 of the bowl 16 and annularly disposed about the rotational axis for the discharge of liquid or light phase material. A plurality of similarly disposed solids or heavy phase discharge ports or openings 24 are provided adjacent the other end wall 26.

In other respects the peripheral wall of the bowl 16 is of imperforate tubular construction, a major portion 28 thereof being cylindrical.

The end portion 30 of the bowl 16 adjacent the end wall 26 is tapered or convergent, its inner surface gradually decreasing in diameter towards and beyond the solid discharge openings 24. The liquid discharge openings 20 and the heavy phase discharge ports or openings 24 are at selectively adjustable radial distances from the rotational axis, so that during proper operation the inner surface of the light phase material will be disposed radially inward of the weir surfaces of the heavy phase discharge ports 24.

Mounted coaxially of the bowl 16 in suitable bearings 31, adjacent the ends of the bowl 16, is a screw conveyor 32. The bowl 16 is rotated by connection through a pulley 34 to suitable drive means, such as a motor (not shown). In order to rotate the bowl 16 and the conveyor 32 at slightly different speeds the rotation of the bowl 16 is transmitted to a gear box 36 having torque control means 38 and thence through a spline shaft 40 within the bowl shaft to the conveyor 32.

The process feed stream, or mixture to be separated, is delivered to the interior of the centrifuge through a stationary feed tube 42. The latter projects in axial direction and terminates concentrically of the feed chamber 44 partly defined by the interior of a hub 46 having an internal lining 48.

The hub 46, which is part of the conveyor 32, carries outwardly projecting, cylindrically coiled screw flights 50, and also outwardly projecting, conically coiled screw flights 52. The flights 50 and 52 are mounted with small clearance from the bowl 16 for rotation with the hub 46 relative to the bowl 16, preferably at a speed suitably different from the speed of the bowl to move settled solids toward the discharge openings 24 for discharge therethrough. The hub 46 is further provided with one or more feed passages 54 which also extend through the lining 48 in order to discharge the feed outwardly from the feed chamber 44 for separation within the bowl 16.

The feed chamber 44 within the hub 46 extends in axial direction from a partition 56 to an accelerator 58. The latter comprises a cup-shaped plate secured in sealing relationship with the inner surface of the hub 56 and having a vane assembly 60 secured thereto for imparting radial and tangential velocity to the feed mixture delivered thereto by the feed pipe

42. As shown, the feed pipe 42 lies concentrically within the feed chamber 44.

An annular seal (not shown) may be secured to the partition 56 to close the space between the outer surface of the feed pipe 42 and the partition 56.

A broken line "*a*" designates the maximum and desired level of materials within the cylindrical portion 28 of the bowl 16 which is maintained by the discharge ports 20. The outermost portion of the surface defining each port 20 acts as a weir over which light phase material flows when discharged from the bowl 16.

As shown in Figure 1, the coiled flights 52 are welded on the outer surface of a baffle 62 of frusto-conical shape. The baffle 62 tapers in the same direction as the tapered end portion 30 of the bowl 16. The smaller end 64 of the baffle 62 is securely attached to the hub 46; and the coiled flights 52 are structurally connected between the outer surface of the larger end of the baffle 62 and the hub 46. Reference is made to Figure 3 for an illustration of the latter.

The conical baffle 62 of Figure 1 is preferred to the modified construction of Figure 2 in which a flat annular baffle 66 is employed.

The baffle 62 is positioned within the bowl 16 to divide the elongated chamber between the outer surface of the hub 46 and the inner surface of the bowl 16 into two axially adjacent zones: a first or separating zone 68, and a second or discharging zone 70. The second zone 70 lies radially outwardly of the baffle 62 and inwardly of the bowl 16, being surrounded by the tapered portion 30 of the bowl 16. The second zone 70 extends in axial direction from a peripheral edge 72 of the baffle 62 to the end wall 26, although for all practical purposes the second zone 70 terminates with the discharge ports 24 for heavy phase material. The ports 24 communicate with the second zone 70. The first or separating zone 68 lies outwardly of the hub 46 and extends outwardly thereof to the inner surface of the baffle 62 on one side of the peripheral edge 72 and to the inner surface of the bowl 16 on the other side of the peripheral edge 72. The axial extent of the first or separating zone 68 is from the small end 64 of the baffle 62 to the end wall 22, terminating in the discharge ports 20 for light phase material. The cylindrical portion 28 of the bowl 16 surrounds the first zone 68. The ports 20 communicate with the first zone 68.

Preparatory to further description of the baffle 62, it is to be understood that feed entering the separating zone 68 within the rapidly rotating bowl 16 is subjected to high centrifugal forces which are usually 2000 to 4000 times gravitational force. This separates the mixture of light and heavy phase materials in zone 68 into an inner annular layer of light phase material and an outer annular layer of heavy phase material. The annular interface between the two layers in zone 68 is shown by a broken line designated "*e*". The layer of heavy phase material lies outwardly of the *e* line; and the layer of light phase material lies inwardly of the *e* line. The inner surface of the light phase layer is approximately in axial alignment with the outermost or weir surface portion of the structure surrounding each port 20, with some allowance for cresting of the liquid discharging from the ports 20.

The *e* line is adjustable by adjusting the level of the ports 20. This is commonly done by providing an end wall 22 having the ports 20 in the desired location. This adjustment is usually suited to the specific gravities of the materials comprising the feed mixture, the percentage of each in the feed, the inflow rate of the feed, and various other factors. In any event, the *e* line may be established by known procedures.

It is important that the peripheral edge 72 of the baffle 62 be carefully positioned relative to the inner surface of the bowl 16 and the *e* line.

Firstly, the baffle 62 must extend outwardly beyond the inner layer of light phase material, i.e., the *e* line, in order to prevent the flow of light phase material from the first zone 68 to the second zone 70. It is better practice to have the peripheral edge 72 disposed outwardly of the *e* line a substantial distance in order to ensure that some light phase material will not be entrained by heavy phase material flowing from the first zone 68 to the second zone 70. It can also be seen that the baffle 62 must be imperforate at least for the radial distance it contacts the light phase layer, again to prevent flow of light phase material into the second zone 70.

Secondly, the peripheral edge 72 is positioned inwardly of the bowl 16 to define a restricted annular passageway 74 between them for the underflow of heavy phase material therethrough from the first zone 68 to the second zone 70. The spacing between the peripheral edge 72 and the bowl 16 determines the flow area of the passageway 74; and it should be large enough to prevent an excessive accumulation of heavy phase material in the separating zone 68, that is, at least large enough to permit passage of the heavy phase in the feed at the rate the heavy phase material is separated in the separating zone. The peripheral edge 72 must always extend in radial direction, relative to the axis, at least to the weir surface of the discharge ports 24 for heavy phase material.

The centrifugal force applied to the light and heavy phase materials in the separating zone 68 produces a centrifugal pressure head which is transmitted to the heavy phase material in the discharging zone 70. This pressure head, when combined with the pressure applied by the screw conveyor 32, overcomes the oppositely directed centrifugal head of the

heavy phase material in zone 70. The level of the heavy phase material in zone 70 is shown by a broken line identified by the letter "*x*". The level designated "*x*" is slightly inwardly of the weir surfaces of the discharge ports 24, whereby heavy phase material is discharged from ports 24.

The light phase material has a lower specific gravity than the heavy phase material; and therefore a layer of light phase material which is thicker than a layer of heavy phase material is required to provide an equivalent centrifugal pressure head. Consequently, level *x* is more distant from the rotational axis, in radial direction, than is level *a*. An advantage of a so-called deep pond of all materials in the separating zone 68, which the baffle 62 permits, is that larger volumes of feed are accommodated therein, and therefore greater throughput capacities are obtainable. Furthermore, with a deep pond in the separating zone 68 greater centrifugal forces are imposed upon sedimented solids therein, resulting in better solids compaction. The more compact the solids are in the separating zone 68, the clearer will be the separated light phase material. Compact solids also lend themselves to more effective conveying by the screw conveyor 32.

The baffle 62 is disposed between the discharge ports 24 for heavy phase material and the path traveled by feed entering the separating zone 68. This keeps the feed out of the discharging zone 70. Preferably, with a conical baffle 62 the feed passages 54 are disposed radially inward of the baffle 62, for directing feed onto the inner surface of the baffle 62 intermediate the ends thereof. Feed travels outwardly and axially along the inner surface of the baffle 62 and joins the separated materials in the separating zone 68 where it also undergoes separation. This arrangement avoids any splashing introduction of feed which might create turbulence and tend to re-mix separated materials of similar specific gravity.

It is preferred that the inner surface of the baffle 62 be provided with annularly spaced accelerator vanes 76 which extend in generally axial direction. It is the function of the vanes 76 to accelerate incoming feed and thereby bring it up toward the angular velocity of the separated layers already in the zone 68. This also minimizes turbulence in the separating zone and improves clarification.

The screw conveyor 32 and conical baffle 62 of Figure 3 shows that a portion 78 of the baffle 62 adjacent the peripheral edge 72 is cylindrical to provide an additional structural support for the large end of the baffle 62. With this arrangement, such peripheral portion 78 is welded to the screw flights 50, thereby improving the structural integrity of the conveyor 32 and baffle 62 combination.

As shown in Figure 4, the peripheral portion 78 has an axially facing edge 80 which generally follows the trailing edge of the associated helical screw flight 50, except that upon completion of one full turn of such screw flight a short length of the edge 80 extends in axial direction. The significance of this provision is that feed leaving the inner surface of the baffle 62 will join the materials in the separating zone 68 on the trailing side of the closest screw flight 50, the side where the least amount of heavy phase material is present. Since the screw flights 50 and 52 push heavy phase material with the leading side thereof toward the tapered end 30 of the bowl 16 there will be a build-up of heavy phase material on the leading side and very little heavy phase material on the trailing side. Introduction of feed to the separating zone 68 where there is little heavy phase material present minimizes the chance of disturbing settled heavy phase material and thereby improves clarification of light phase material.

The modification of the invention shown in Figure 2 employs an annular baffle 66 which is a flat annular plate carried coaxially by the hub 46.

Where parts in Figure 2 are similar to parts in Figure 1, like reference numerals are employed, and descriptions thereof will not be repeated, for the sake of brevity.

The baffle 66 operates similar to the baffle 62 for creating a restricted passageway 74 for the underflow of heavy phase material. Therefore, the same considerations apply when selecting the radial distance between the peripheral edge 72 and the bowl 16, and when establishing pressure equilibrium between the phases in separating zone 68 and the heavy phase material in discharging zone 70.

It is to be noted that the feed passages 54 in the hub 46 are disposed immediately adjacent the side of the baffle 66 facing the separating zone 68. This is also in keeping with the broad concept of arranging the baffle between the discharging zone 70 and the entering path of the feed entering the separating zone 68.

In the decanter centrifuge of Figure 1 feed is introduced via the feed tube 42, the feed chamber 44, and the feed passages 54. Feed travels radially outwardly into contact with the inner surface of the conical baffle 62, and it is accelerated by the vanes 76 while flowing outwardly and axially along such inner surface. The feed now has an angular velocity approaching that of the contents of the separating zone 68 as it comingles with the phases therein.

Separation of the feed into an inner layer of light phase material and an outer layer of heavy phase material takes place by centrifugal action. The *e* line between the phases is at a level with a baffle surface, with the result that no light phase material can flow to the discharging zone 70. Light phase material exits

the bowl 16 from the discharge ports 20; and a level along line *a* is maintained in the separating zone 68.

Heavy phase material in the separating zone 68 is moved by the screw conveyor toward the tapered end 30 of the bowl, there being a small accumulation at the entrance to the restricted passageway 74. Under pressure from the rapidly rotating materials in the separating zone 68, the heavy phase material flows through the passageway 74 and establishes its own level *x* in the discharging zone 70. Level *x* is such that heavy phase material flows out of the discharge ports 24. Heavy phase particles such as coarse solids which offer resistance to flow, frictional or otherwise, are readily conveyed by the screw conveyor 32 to the discharge port 24.

The invention is ideally suited for the separation of secondary sewage, sludge, and other materials wherein the light and heavy phase materials are of similar specific gravity, and wherein the solids may be fine and very slippery when wet. These materials have heretofore defied separation by a decanter centrifuge without polyelectrolytes or additives.

The invention also finds application to the separation of two liquids where solid impurities in the heavy phase liquid would plug other kinds of centrifuges which continuously separate and discharge two liquids. Accordingly, the terms "heavy phase" and "light phase" have been employed to describe the materials which are separable by the centrifuge of the present invention, since the light phase material will usually be a liquid and the heavy phase material will usually be a mixture of solids or a mixture of solids and liquid.

A feature of the present invention is the provision of a discharging zone 70 within the bowl 16, in which the heavy phase material is segregated from the light phase material during the discharging operation. A drier heavy phase discharge results. Furthermore, whereas previous decanter centrifuges required the screw conveyor to move the heavy phase material through and out of the layer of light phase material, tending to cause remixture of the phases, the present invention moves the heavy phase material alone through the discharging zone. This yields a well clarified light phase material, and a separated heavy phase material which contains a commercially acceptable amount of light phase material.

A further modification of the invention is shown schematically in Figure 5. There, the centrifuge bowl 16 also has a heavy phase discharge port 24 in the tapered portion 30. At the opposite end of the bowl 16, light phase discharge ports 20 are provided to maintain level *a* within the bowl. In addition, a circular baffle 86 is carried by the hub 46 of the screw conveyor 32 to seal the separating chamber 68 from the atmosphere via ports 20. A still further addition is an auxiliary baffle 88 of annular shape, carried by the bowl 16. The auxiliary baffle 88 extends radially inward a sufficient distance beyond the *e* line to prevent the flow of heavy phase material toward ports 20.

As in the embodiment of Figure 2, a flat annular baffle 66 is provided in the Figure 5 embodiment. Baffle 66 is carried by the hub 46 and it extends radially outwardly toward closely spaced relationship with the bowl 16, in order to provide a restricted passageway 74 therebetween. Baffle 66 serves the same function described with reference to the embodiment of Figure 2 and it also seals chamber 68 from the ports 24 leading to the atmosphere.

A major distinction between the embodiments of Figure 2 and Figure 5 is that the embodiment of Figure 5 effects pressurization of the heavy phase material in the discharging zone 70 by means of an external pressure source. Such pressure source is preferably a conduit 90, extending from outside the centrifuge bowl 16 through the feed tube 42 to the feed chamber 44. Pressurized gas is delivered through the conduit 90, the chamber 44 and the feed passages 54 to the separating zone or chamber 68, where pressure is applied to the inner surface of the light phase layer and transmitted through the heavy phase material in chamber 68, thence through passageway 74, to the heavy phase material in zone 70.

The pressurized gas is delivered to the separating zone 68 at pressures above the pressure which would be centrifugally developed by any portion of a light phase layer disposed radially outward of the heavy phase port 24. With this arrangement, the inner surface of the light phase material in the separating zone disposed between the baffles 66 and 86 is maintained at a level *b* which is radially outward of the levels *a* and *x*. The pressure from the gas, together with the compressive force applied to the heavy phase material by the screw conveyor 32, plus the centrifugal pressure head of the light phase layer, all combine to overcome the centrifugal pressure head of the heavy phase material having level *x* in the discharging zone 70.

WHAT WE CLAIM IS:—

1. A decanter centrifuge comprising an elongated bowl mounted for rotation about its longitudinal axis, said bowl having at one end thereof an inwardly tapering end section in which is located a heavy phase discharge port and, at the opposite end, a light phase discharge means having a lip or weir over which separated light phase material flows prior to discharge from the bowl through said means, a screw conveyor coaxially mounted within the centrifuge bowl for rotation relative thereto and effective upon rotation thereof relative to the bowl to convey separated heavy phase

the bowl 16 from the discharge ports 20; and a level along line *a* is maintained in the separating zone 68.

Heavy phase material in the separating zone 68 is moved by the screw conveyor toward the tapered end 30 of the bowl, there being a small accumulation at the entrance to the restricted passageway 74. Under pressure from the rapidly rotating materials in the separating zone 68, the heavy phase material flows through the passageway 74 and establishes its own level *x* in the discharging zone 70. Level *x* is such that heavy phase material flows out of the discharge ports 24. Heavy phase particles such as coarse solids which offer resistance to flow, frictional or otherwise, are readily conveyed by the screw conveyor 32 to the discharge port 24.

The invention is ideally suited for the separation of secondary sewage, sludge, and other materials wherein the light and heavy phase materials are of similar specific gravity, and wherein the solids may be fine and very slippery when wet. These materials have heretofore defied separation by a decanter centrifuge without polyelectrolytes or additives.

The invention also finds application to the separation of two liquids where solid impurities in the heavy phase liquid would plug other kinds of centrifuges which continuously separate and discharge two liquids. Accordingly, the terms "heavy phase" and "light phase" have been employed to describe the materials which are separable by the centrifuge of the present invention, since the light phase material will usually be a liquid and the heavy phase material will usually be a mixture of solids or a mixture of solids and liquid.

A feature of the present invention is the provision of a discharging zone 70 within the bowl 16, in which the heavy phase material is segregated from the light phase material during the discharging operation. A drier heavy phase discharge results. Furthermore, whereas previous decanter centrifuges required the screw conveyor to move the heavy phase material through and out of the layer of light phase material, tending to cause remixture of the phases, the present invention moves the heavy phase material alone through the discharging zone. This yields a well clarified light phase material, and a separated heavy phase material which contains a commercially acceptable amount of light phase material.

A further modification of the invention is shown schematically in Figure 5. There, the centrifuge bowl 16 also has a heavy phase discharge port 24 in the tapered portion 30. At the opposite end of the bowl 16, light phase discharge ports 20 are provided to maintain level *a* within the bowl. In addition, a circular baffle 86 is carried by the hub 46 of the screw conveyor 32 to seal the separating chamber 68 from the atmosphere via ports 20. A still further addition is an auxiliary baffle 88 of annular shape, carried by the bowl 16. The auxiliary baffle 88 extends radially inward a sufficient distance beyond the *e* line to prevent the flow of heavy phase material toward ports 20.

As in the embodiment of Figure 2, a flat annular baffle 66 is provided in the Figure 5 embodiment. Baffle 66 is carried by the hub 46 and it extends radially outwardly toward closely spaced relationship with the bowl 16, in order to provide a restricted passageway 74 therebetween. Baffle 66 serves the same function described with reference to the embodiment of Figure 2 and it also seals chamber 68 from the ports 24 leading to the atmosphere.

A major distinction between the embodiments of Figure 2 and Figure 5 is that the embodiment of Figure 5 effects pressurization of the heavy phase material in the discharging zone 70 by means of an external pressure source. Such pressure source is preferably a conduit 90, extending from outside the centrifuge bowl 16 through the feed tube 42 to the feed chamber 44. Pressurized gas is delivered through the conduit 90, the chamber 44 and the feed passages 54 to the separating zone or chamber 68, where pressure is applied to the inner surface of the light phase layer and transmitted through the heavy phase material in chamber 68, thence through passageway 74, to the heavy phase material in zone 70.

The pressurized gas is delivered to the separating zone 68 at pressures above the pressure which would be centrifugally developed by any portion of a light phase layer disposed radially outward of the heavy phase port 24. With this arrangement, the inner surface of the light phase material in the separating zone disposed between the baffles 66 and 86 is maintained at a level *b* which is radially outward of the levels *a* and *x*. The pressure from the gas, together with the compressive force applied to the heavy phase material by the screw conveyor 32, plus the centrifugal pressure head of the light phase layer, all combine to overcome the centrifugal pressure head of the heavy phase material having level *x* in the discharging zone 70.

WHAT WE CLAIM IS:—

1. A decanter centrifuge comprising an elongated bowl mounted for rotation about its longitudinal axis, said bowl having at one end thereof an inwardly tapering end section in which is located a heavy phase discharge port and, at the opposite end, a light phase discharge means having a lip or weir over which separated light phase material flows prior to discharge from the bowl through said means, a screw conveyor coaxially mounted within the centrifuge bowl for rotation relative thereto and effective upon rotation thereof relative to the bowl to convey separated heavy phase

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material axially along the interior wall of the centrifuge bowl towards said heavy phase discharge port, and means for feeding materials to be separated into said centrifuge bowl along the axis thereof, to a feed entry point located intermediate the ends of the bowl, said screw conveyor comprising an elongated cylindrical hub extending substantially the length of the centrifuge bowl and having over its own length between said feed entry point and said heavy phase discharge port, an external radius less than the spacing of said lip or weir from the axis of the centrifuge bowl, and a helical screw flight mounted externally on the hub, and wherein there is also mounted externally on said hub a baffle, said baffle being positioned between said feed entry point and the heavy phase discharge port, thereby to divide the interior of the bowl into a discharge section communicating with said heavy phase discharge port and a separating section communicating with said feed entry point and with the light phase discharge means, and wherein the baffle extends radially a distance such that the outer edge thereof, in use, projects into the separated layer of heavy phase material, thereby to prevent the passage of separated light phase material from the separating section into the discharge section and forming with the adjacent internal wall of the centrifuge bowl a restricted passageway through which the separated heavy phase material passes on its way towards the heavy phase discharge port, and wherein means are provided, operable independently of the conveyor, to apply a pressure head to the separated heavy phase material located on the side of the baffle remote from the heavy phase discharge port, thereby to assist the passage thereof through the restricted passageway.

2. A centrifuge according to claim 1, wherein the baffle comprises a flat annular plate mounted about the conveyor.

3. A centrifuge according to claim 2, wherein the baffle is perpendicular to the longitudinal axis of the centrifuge bowl.

4. A centrifuge according to claim 1, wherein the baffle comprises a frusto-conical member mounted about the conveyor.

5. A centrifuge according to claim 4, wherein the baffle tapers in the same direction as the tapering end section of the centrifuge bowl.

6. A centrifuge according to claim 5, wherein the baffle is positioned within the tapering end section of the centrifuge bowl and is provided on its external surface with a helical flight adapted, when the conveyor is rotated relative to the centrifuge bowl, to convey separated heavy phase material along the inwardly tapering section of the centrifuge bowl towards the heavy phase discharge port.

7. A centrifuge according to any one of claims 4—6 wherein the point of introduction of the feed material into the centrifuge bowl is positioned within the frusto-conical baffle.

8. A centrifuge according to claim 7, wherein the internal surface of the baffle is provided with accelerator vanes aligned with the longitudinal axis of the centrifuge bowl.

9. A centrifuge according to claim 7 or 8, wherein the frusto-conical baffle is formed with a substantially cylindrical portion at the end of largest diameter.

10. A centrifuge according to claim 9, wherein the baffle is positioned within the tapering end section of the centrifuge bowl and has a helical flight formed on the external surface thereof, the said cylindrical portion of the baffle being formed with a trailing edge aligned with the longitudinal axis of the centrifuge bowl and positioned immediately behind a flight formed on the external surface of the baffle when considered in the direction of advance of the heavy phase material towards the heavy phase discharge port.

11. A centrifuge according to any one of the preceding claims, wherein the lip of the heavy phase discharge port is positioned at a radial distance from the longitudinal axis of the centrifuge bowl greater than the radial distance of the lip or weir of said light phase discharge means from said axis, thereby to provide, in use, a substantial depth of separated light phase material within said separating section of the centrifuge bowl, the separated light phase material thereby supplying the pressure head to the separated heavy phase material in said separating section.

12. A centrifuge according to any one of claims 1—10, wherein the means for applying a pressure head to the separated heavy phase in the separating section comprise a conduit for supplying a gas under pressure to said separating section.

13. A centrifuge according to claim 12, wherein the gas conduit is coaxially mounted within the feed conduit.

14. A centrifuge according to any one of the preceding claims, wherein the light phase discharge means comprise an aperture in the end wall of the centrifuge bowl opposite the end having the tapering end section.

15. A centrifuge according to claim 14, wherein the position of said aperture in said end wall is radially adjustable.

16. A centrifuge according to claim 1, substantially as hereinbefore described with reference to the accompanying drawings.

* C L M S *

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