United States Patent

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[54] **CENTRIFUGE APPARATUS**
12 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** ..... **233/19 A,** 233/29, 233/47 R, 210/104
[51] **Int. Cl.** **B04b 11/00**
[50] **Field of Search** ..... 233/32, 44, 46, 47 R, 19 R, 19 A, 20 R, 20 A, 9, 27, 28; 210/104, 105, 78, 377

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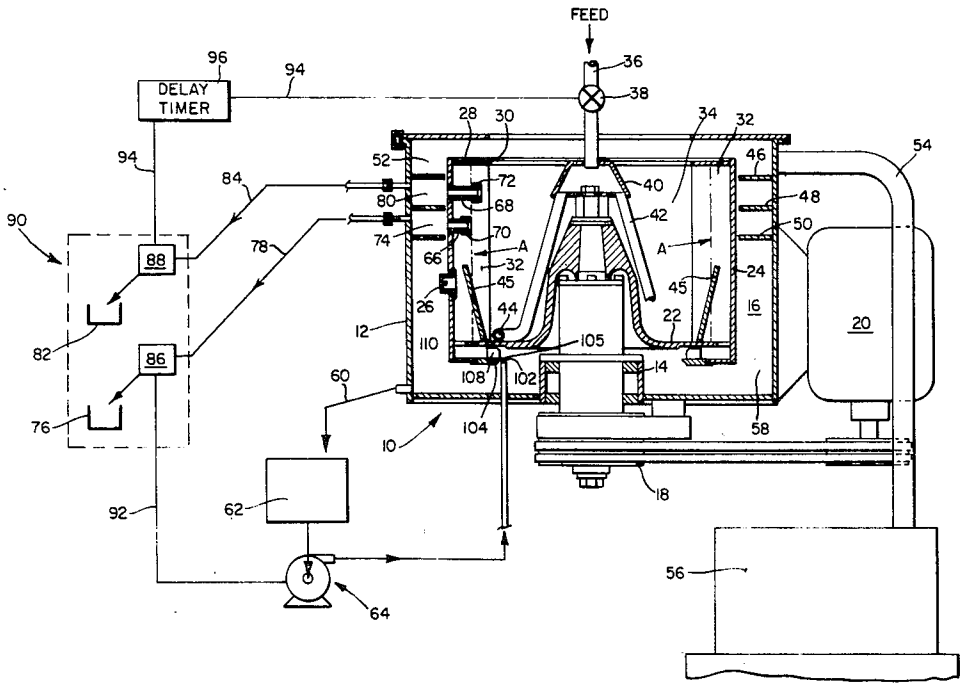
ABSTRACT: A heavy-phase material and a light-phase material separate into two concentric layers, the heavy-phase material accumulating adjacent to the peripheral wall of the bowl. A control device regulates the position of the interface or line of separation between the layers, the control device including a conduit extending inwardly from an opening in the bowl wall to the desired position, and a detecting device. The conduit conducts a sample of the material to the detecting device for sensing a change in specific gravity at that position. Depending upon the direction of change, the detecting device either temporarily closes a feed valve controlling the introduction of feed mixture into the bowl, or actuates a recycle pump for recycling extracted heavy-phase material back into the bowl.



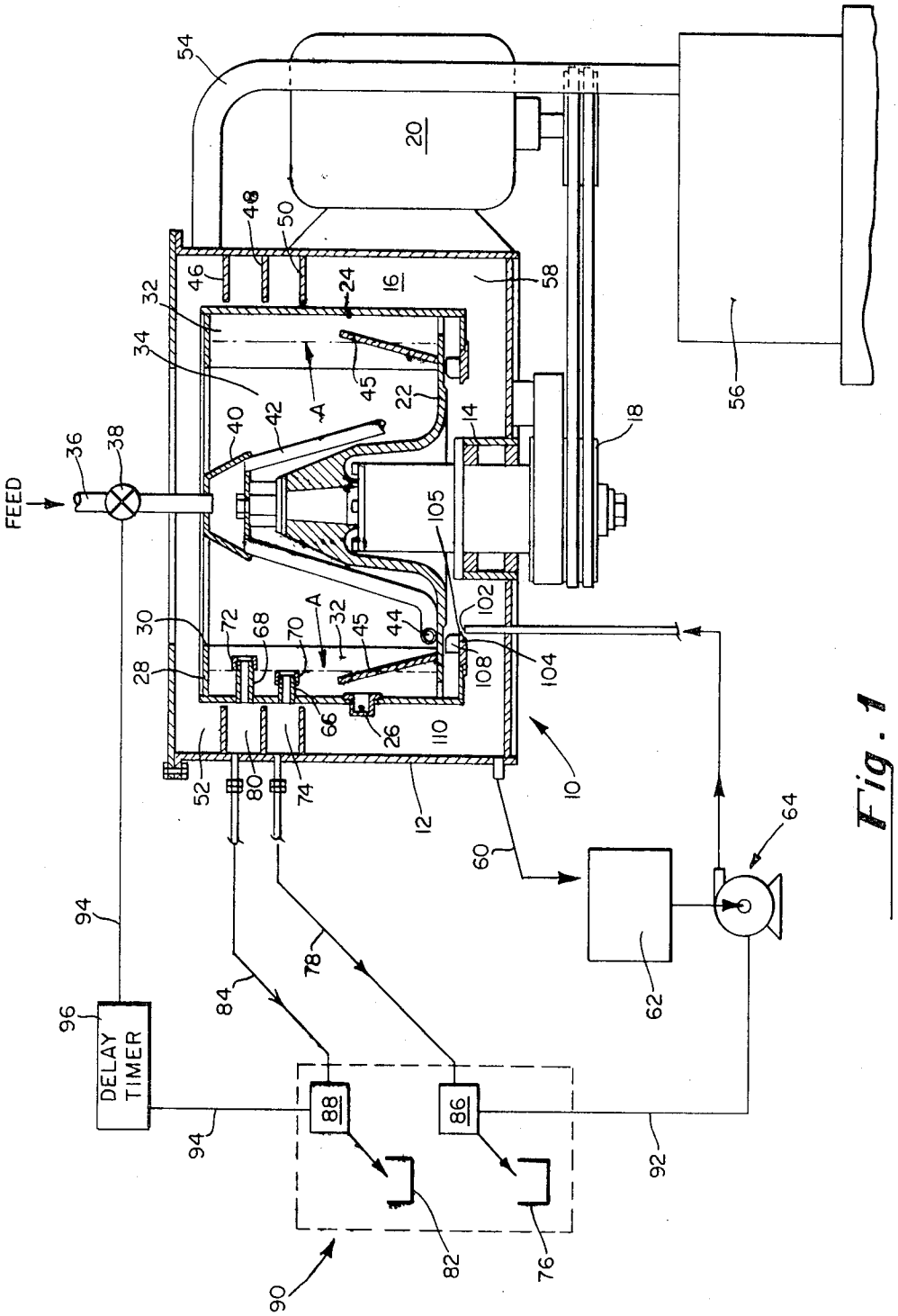


Fig. 1

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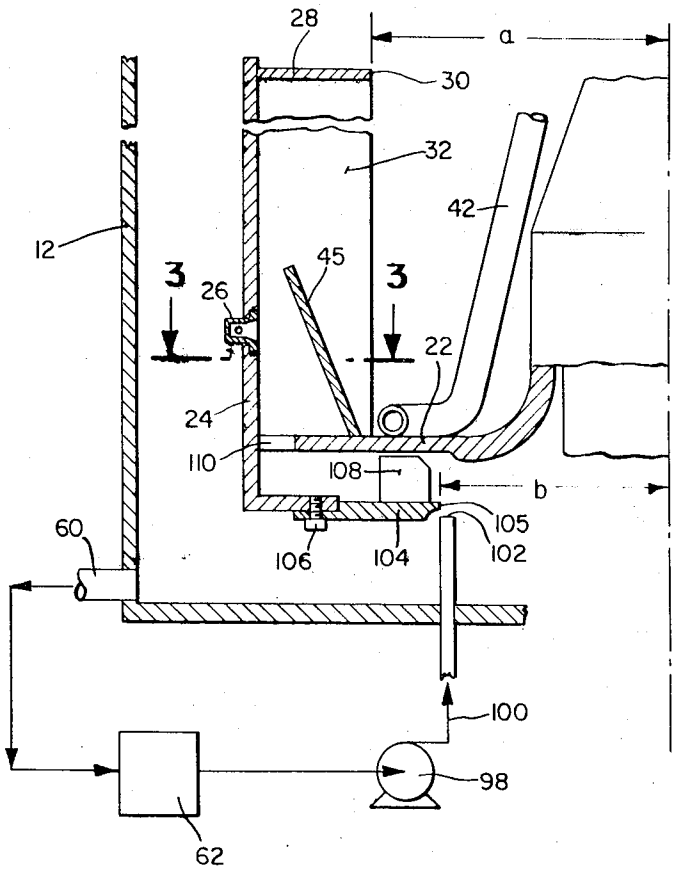

Fig. 2

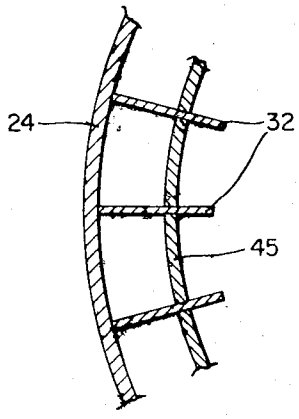

Fig. 3

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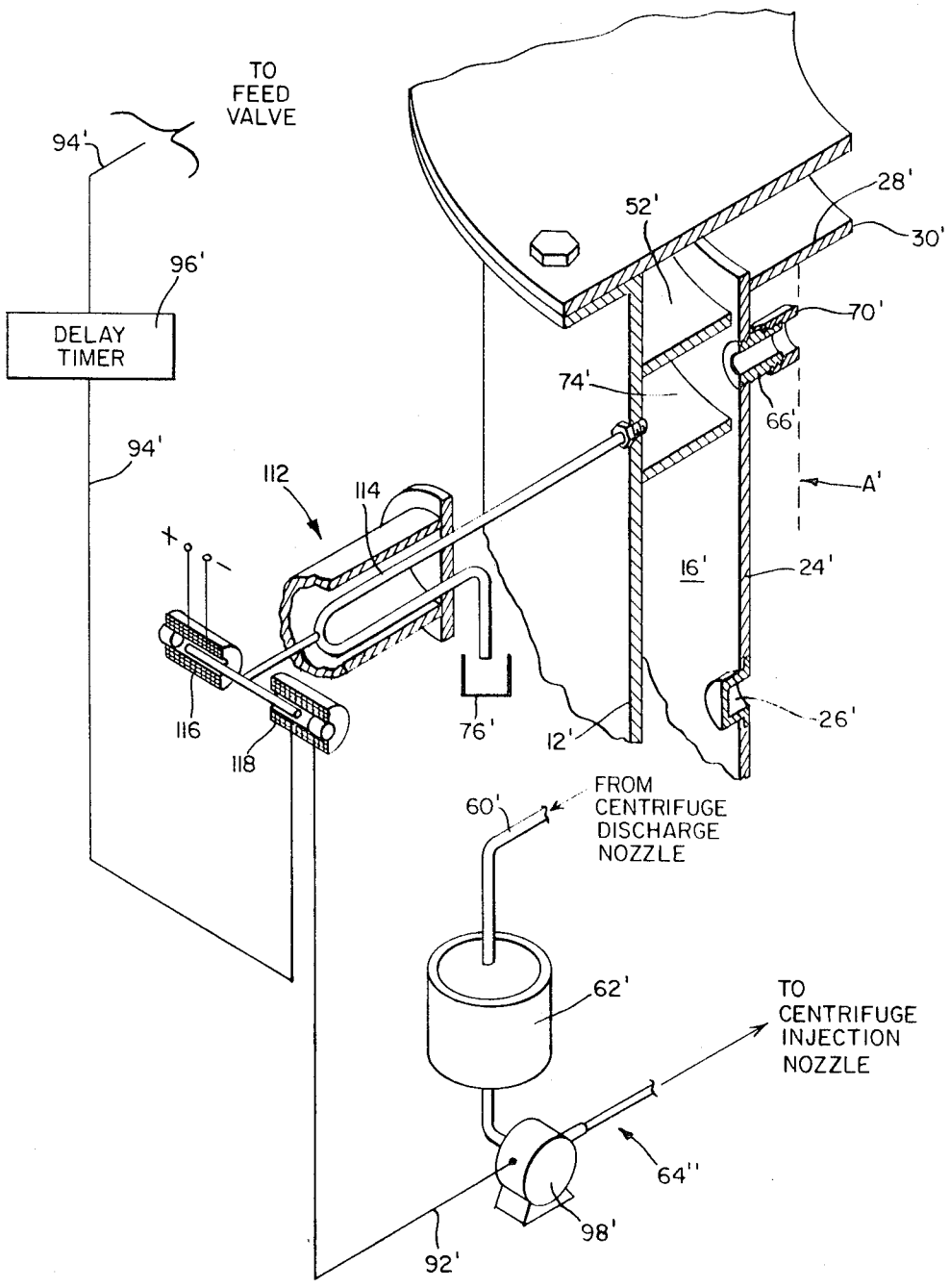

Fig. 4

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CENTRIFUGE APPARATUS

This application is a continuation-in-part of copending application having U.S. Ser. No. 743,075, filed July 8, 1968, now U.S. Pat. No. 3,560,125.

BACKGROUND OF THE INVENTION

This invention relates to centrifuge apparatus having a bowl in which light- and heavy-phase material are separated from one another, the materials forming two concentric layers within the bowl, and the bowl being provided with means for continuously discharging each of the materials. The invention provides for sampling from the interior of the bowl, and depending upon the condition of the sample extracted, either interrupting the feed into the bowl, or automatically recycling heavy-phase material previously extracted.

The invention is applied to the separation of a light-phase material, usually liquid, from a heavy-phase material, which may be either a solid material, or another liquid of specific gravity greater than the light phase. Therefore, although the invention will be described herein as applied to the separation of solids or sludge from a mixture with a light-phase liquid, it is to be understood that it is equally applicable for two liquids of different specific gravities that require separation. Also, although the invention is described in connection with an imperforate basket-type centrifuge bowl, it is equally applicable to other types of centrifuge bowls such as a disc-type centrifuge.

In prior art apparatus, feed is delivered to the bowl and clear effluent is discharged over a lip at the upper end of the bowl. Accumulated solids form a cake against the peripheral wall of the centrifuge bowl. After a predetermined period of time, based on experience, which approximates the time required for sludge to build up to the maximum desired level, feed is shut off by a timer, and the sludge is discharged. Sludge discharge may be accomplished by a skimmer which first penetrates the inner layer of effluent, and discharges the same while the bowl is still rotating; and then as the skimmer reaches the sludge effluent interface, the operator manually diverts the discharge to waste so not to comingle the sludge with the effluent already collected. Thereafter, with the sludge removed form the bowl to the extent practicable, the skimmer is returned to its inward rest position and feed to the bowl is resumed.

The foregoing manual or semiautomatic process of the prior art is disadvantageous because the concentration of sludge in the feed is variable, and it is therefor not possible to predict with accuracy the time required to accumulate the maximum desired amount of sludge within the bowl. Thus, if the solids accumulation period is too short, the operation of the machine will be inefficient; and if the same period is too long, sludge will contaminate the effluent. In the interest of efficiency, it is also desired to provide apparatus which discharges solids automatically so that an operator will not be required.

The prior art discloses means for sampling from the interior of the bowl, and in response to the sample obtained, automatically interrupting the feed into the bowl and actuating a skimmer tube to automatically discharge the accumulated solids. While this method has the advantage of automatically interrupting the feed, and actuating the skimmer tube by means responsive to the sample obtained, it still requires the provision of a skimming tube, and requires a considerable period of time to extract the heavy-phase material or solids because the skimmer tube must first extract the light-phase material from within the bowl.

According to the present invention, separate means are provided for discharging in a continuous manner, each of the materials, i.e. the light-phase material and the heavy-phase material. This continuous discharge occurs even after automatic control means has interrupted the feed into the bowl. Thus, after feed is interrupted, both the light-phase and heavy-phase materials continuously discharge simultaneously. This not only eliminates mechanical skimming tubes, but also reduces the mechanical desludging time required to extract heavy-phase material from the interior of the bowl, because both phases are simultaneously discharging.

SUMMARY OF THE INVENTION

According to the present invention, there is provided inwardly of the bowl at least one overflow conduit extending radially inwardly from an opening in the bowl wall to the desired level or position of the interface or line of separation between the separated materials within the bowl. With this arrangement a sample of the material or "control material" within the bowl at that level will flow through the conduit and out of the bowl to a detecting device or apparatus. This detecting device or apparatus senses the specific gravity of the control material and provides the means for automatically maintaining the interface or line of separation at the desired level. Depending upon the direction of change of the specific gravity of the extracted control material, the detecting means will either actuate a delay timer which then closes a feed control valve for a predetermined period of time, or actuate a recycle pump which either returns previously extracted heavy-phase material back into the bowl, or injects a suitable auxiliary liquid into the bowl. If the interface between the separated materials moves inwardly within the bowl, increasing amounts of the heavy-phase material will be conducted to the overflow conduits, thereby increasing the specific gravity of the control material being extracted. The detecting means will then actuate the delay timer to close the feed valve for a predetermined amount of time during which time the heavy-phase material is being continuously discharged, thereby moving the interface outwardly to its desired position. As the interface moves outwardly within the bowl, increasing amounts of light-phase material will be conducted through the overflow conduit to the detecting device, thereby decreasing the specific gravity of the control liquid being extracted. In response to this decrease, the detecting means actuates a recycle pump to recycle extracted heavy-phase material back into the outer region of the separating chamber of the bowl, thereby building up the accumulation of heavy-phase material, and moving the interface inwardly within the bowl to restore it to its desired position. Thus, means are provided for automatically controlling the position or level of the interface within the interior of the centrifuge bowl by either closing the feed valve for a predetermined amount of time during which time the heavy-phase material is being continuously discharged and thereby moving the interface outwardly within the bowl, or by recycling heavy-phase material back into the bowl and thus moving the interface inwardly within the bowl.

An annular ring dam is provided at the bottom of the bowl, the ring dam being formed about the axis of rotation. The recycled or injected material is directed over the ring dam to the outer regions of the separating chamber. The recycled material may also be injected into the top of the bowl and appropriately channeled to the outer region of the separation chamber. When used as a liquid-liquid separator wherein he heavy-phase material is a liquid having a specific gravity greater than that of the light-phase material, recycled material which is not accepted by the bowl will be discharged downwardly over the inner edge of this ring dam. On the present embodiment there may be only a few nozzles discharging the heavy-phase material around the periphery of the bowl, and thus incoming feed material will tend to be channeled toward these nozzles before separation. To prevent the same an annular wall is located within the separation chamber between the outlets of the feed tubes and the nozzles. By providing a plurality of generally radially extending accelerator vanes, the feed introduced into the bowl is quickly brought up to the peripheral speed of the bowl. Thus, the feed mixture is more efficiently separated into its component parts, and any channeling effect would then occur after separation and beneath the annular wall structure en route to the nozzles.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of the centrifuge embodying the invention, and showing in schematic form some of the controls thereof;

FIG. 2 is an enlarged sectional view of the bottom portion of the centrifuge shown in FIG. 1, and illustrating the form of the recycling arrangement;

FIG. 3 is a transverse sectional view taken through line 3—3 of FIG. 2 showing the radially extending accelerator vanes;

FIG. 4 is a sectional view of a modification of the present embodiment and showing the controls in schematic form.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, the centrifuge is designated generally by the numeral 10, the centrifuge including a base with a plurality of upright standards (not shown) for supporting or suspending the centrifuge housing. At the lower end of the housing 12 is a bearing 14 which is mounted with a centrifuge bowl 16 on a shaft, the latter having a lower end extending downwardly through the bearing for reception in a pulley 18 driven by motor 20 by suitable pulley means.

Preferably, the centrifuge bowl is a cylindrical shell, including an imperforate bottom wall 22 and a peripheral wall 24, the peripheral wall having a plurality of circumferentially spaced outlets or nozzles 26, each of these nozzles being formed to discharge in a tangential direction. The centrifuge bowl includes an upper end wall 28, this upper end wall having an inner annular liquid overflow lip 30. The radial position of this lip may be made adjustable if desired. Arranged within the centrifuge bowl is a plurality of radially extended accelerator vanes 32 utilized for bringing the mixture introduced into the bowl up to the peripheral speed of the bowl.

A feed slurry or mixture is introduced into the separation chamber 34 of the bowl through feed means comprising a stationary feed tube 36 having valve means 38 therein. The feed tube is mounted and spaced in coaxial relationship with the upper end of the bowl. At the top of the bowl is provided a feed-receiving cup 40 which rotates with the bowl, and receives the feed mixture for distribution downwardly and outwardly toward the bottom of the bowl through a plurality of feed conduits 42 each having feed outlet means 44 at the remote ends thereof. Located between the outlet ends 44 and the peripheral nozzles 26 is an annular inner wall extending around the interior of the bowl. As the feed mixture is introduced into the bowl through the feed means, it is quickly brought up through the speed of the bowl, thus separating the mixture into two concentric layers, the heavy-phase or sludge material being that layer immediately adjacent to the inner annular surface of the bowl. This sludge or heavy-phase material will be continuously discharged through discharge nozzles 26 disposed about the periphery of the bowl. The inner or liquid layer will be discharged from the bowl over liquid overflow lip 30. Where there are only a small number of discharge nozzles 26, feed mixture being introduced into the separation chamber 34 will tend to be channeled toward these nozzles before the mixture can separate into its respective concentric layers. To prevent this, the inner annular wall 45 is located between outlets 44 and nozzles 26, the accelerator vanes 32 serving to quickly bring the mixture up to the rotating speed of the bowl. Thus, any channeling effect would occur underneath this annular wall in route to the nozzle 26 after the material or mixture has separated into its heavy and light phases.

Between the housing 12 and the peripheral wall 24 of the bowl, there are plurality of annular spaces partially defined by annular partitions 46, 48, and 50.

With this arrangement the upper annular space 52 receives the liquid or light-phase material flowing over the overflow lip 30, the material being conducted away from the space by a conduit 54, and into an effluent-receiving tank 56. The sludge or heavy-phase material is discharged through nozzles 26 into the lower annular space 58, and is conducted out of housing 12 through a conduit 60, and into a sludge-receiving means or tank 62. Connected between the sludge-receiving tank 62 and the bottom of the centrifuge bowl, is a recycle or injection means for recycling extracted sludge or heavy-phase material back into the bowl in response to conditions to be hereinafter described.

Referring more particularly to the inventive subject matter, it can be seen that the feed mixture separates into two concentric layers having an interface A between the layers. It is particularly important that this interface or line of separation be maintained at a desired level or position, or at least maintained within a desired range for efficient separation.

To accomplish this, the centrifuge includes two control tubes 66 and 68, each leading from an opening in the peripheral wall 24 in which it is sealed, securely mounted as by a threaded connection, and oriented in a radial and horizontal direction to extend inwardly of the bowl 16. The inner end of each tube may be threaded and fitted, as shown, with nozzles 70 and 72 respectively. It is contemplated that nozzles 70 and 72 will be provided in various lengths and orifice sizes so that the peripheral radial extent of the tubes 66 and 68, and also their flow areas, can be accurately adjusted.

There may be one or a plurality of each of these control tubes located around the peripheral wall of the centrifuge bowl. As will appear more fully, adjustment of the radial inward extent of each of the tubes 66 and 68 is to a level setting the maximum desired range which is desired for the interface A. Since such maximum range can vary from application to application, this means of adjustment is believed to be economical, convenient, and effective. Thus, each of these tubes 66 and 68 acts as an indicating means to indicate the position of the interface A within the separation chamber. With this arrangement, tube 66 conducts a sample of material taken from the inner end of nozzle 70 and discharges it into annular space 74. This sample material, which may also be termed "control material," is conducted to control tank 76 by means of a conduit 78 connected between the centrifuge housing 12 and the tank 76. Tube 68 will conduct the sample material into annular space 80 from which it is ultimately conducted to a control tank 82 via conduit 84 extending between the housing 12 and the control tank 82.

Each of the control tanks 76 and 82 can be provided with a valve opening in the bottom thereof (not shown) which may be used to recover the samples of material deposited within each of these tanks. The samples may then be returned to the feed supply tank (not shown), or to a sludge-receiving tank 62 as desired.

Connected between the annular space 74 and tank 76, and between annular space 80 and control tank 82 are two detecting devices 86 and 88 respectively. Each of these detecting devices is identical to the detecting device 72 set forth in the drawing of the above-mentioned patent application having U.S. Ser. No. 743,075, filed July 8, 1968. Each of these detecting devices 86 and 88 and their respective control tanks 76 and 82 comprise a detecting means represented by the dotted line, and designated generally by the numeral 90.

Each of the detecting devices 86 and 88 are responsive to changes in specific gravity of the control liquid flowing therethrough. With the appropriate change in specific gravity, detecting device 86 will transmit an electrical signal through line 92 to actuate the recycle means 64, thus returning extracted heavy-phase material from receiving tank 62 back into the outer region of separation chamber 34. Upon the appropriate change in specific gravity for detecting device 88 an electrical signal will be transmitted through the line 94, and through a relay timer 96 to close the feed valve 38, the feed valve automatically reopening after a predetermined time has elapsed. The relay timer is adjusted so that the sludge or heavy-phase material will not be completely removed from the bowl through discharge nozzles 26 before valve 38 is reopened. Thus, as interface A moves inwardly beyond the end of tube 68, increasing amounts of heavy-phase material will be conducted through tube 68 to detecting device 88 which in turn temporarily closes the feed valve 38 in response

to the increase in specific gravity of the control material. Thus, the fee is momentarily stopped allowing the nozzles 26 to lower the sludge or heavy-phase level, thus moving the interface A outwardly. If the interface A moves outwardly beyond the end of tube 66, increasing amounts of light-phase material will be conducted through detecting device 86. Density detection device 86 senses the decrease in specific gravity of the control material being transmitted therethrough, thus, actuating recycle means 64 to recycle discharged sludge or heavy-phase from the receiving tank 62 back into the outer region of separation chamber 34. This recycled material would then enrich the content of the bowl, thus satisfying the nozzles 26. To satisfy the nozzles means to supply sufficient discharged sludge or heavy phase material on a recycled basis, so that the flow through the nozzles, determined by the size of the nozzle and the pressure at the same, will be satisfied by heavy-phase material rather than light-phase material. As the interface A begins to move inwardly once more, the flow of heavy-phase material through tube 66 would deenergize the recycle means 64 via the detecting device 86. By adjusting the length of each of the tubes 66 and 68 it is possible to control the location of the interface A within the separation chamber under all conditions of feed concentration. This applies whether or not separation involves liquid-solids or liquid-liquid separation. Thus, as can be seen, detection device 88 senses high specific gravity, and device 86 senses low specific gravity to actuate the valve 38 and recycle means 64 respectively.

Referring to FIG. 2, the recycle or injection means 64 will be described in more detail. Upon actuation of the recycle means 64, the recycle pump 98 will begin to remove discharged sludge or heavy-phase material from the tank 62 returning it to the bottom of the centrifuge bowl via injection conduit 100 having an injection outlet 102. Mounted to the bottom of the centrifuge bowl 16 beneath the imperforate bottom 22 is an annular ring dam 104 formed about the axis of rotation, and secured to the centrifuge bowl by means of bolts 106. Attached to the upper surface of the ring dam 104, is a plurality of radially positioned accelerator vanes 108 which serve to pick up and accelerate material being injected into the bowl via injection outlet 102. The position of the inner edge of the annular ring dam 104 with respect to the overflow lip 30 is important, and dependent upon the materials being separated. Overflow lip 30 has an inner circular opening having a radius, or in other words, a radial distance from the axis of rotation indicated by the letter *a*. This distance may be made adjustable if desired. Annular ring dam 104 has an inner circular opening or edge 105 having a radius, or in other words, a radial distance from the axis of rotation indicated by the letter *b*. It is contemplated that ring dams will be made available in various sizes so that the radial distance *b* can be varied between being something less than *a* to being something greater than *a*. Thus material injected into the bottom of the bowl via injection openings 102 will be accelerated by accelerator vanes 108, and directed toward the outer peripheral wall 24 of the centrifuge bowl. The recycled or injected material will enter the outer region of the separation chamber 34 via openings 110 in the bottom 22 of the bowl.

Since a plurality of ring dams will be made available in various sizes the present invention can be used for liquid-solids separation as in the present example where the dimension *b* is less than dimension *a*, or in a liquid-liquid separation where dimension *b* may be somewhat greater than dimension *a*.

When utilizing the present invention for a liquid-liquid separation, the inner edge 105 of the ring dam 104 is located outwardly of the liquid overflow lip 30, i.e., the *b* dimension is greater than the *a* dimension. All other factors remaining constant, the interface A moves radially inwardly or outwardly depending upon the *a* and *b* dimensions. A skilled centrifuge engineer can resort to simple calculations to determine the exact dimensions. When using the centrifuge as a liquid-liquid separator, recycled material not accepted by the bowl flows downwardly over the inner edge 105 of the annular ring dam and back to the recycle tank 62. When the nozzle demand has been satisfied, the bowl automatically rejects recycled material.

Referring to FIG. 4, a modification of the present embodiment is illustrated. The centrifuge is alike in all respects except as to the means utilized for detecting changes in specific gravity of the control material. This can be seen in FIG. 4. A single control tube 66' having an adjustable nozzle 70' on the end thereof extends inwardly to the desired level or position of the interface A'. A sample of the material within the bowl 16' is conducted through tube 66', into annular area 74', to a detecting means designated generally by the numeral 112. In the embodiment illustrated in FIG. 1 it was necessary to have two detecting devices, 86 and 88, the first being utilized to detect low specific gravity, the second or latter being used to detect high specific gravity. The present detecting means 112 can be utilized to detect either high or low densities or specific gravities. This device is commercially available from Automation Products, Incorporated, and as described in their Bulletin No. J–8/D is responsive to changes in specific gravity of the sample material flowing therethrough. The product or sample to be measured flows through U-tube 114 and is ultimately conducted to a control tank 76', from which tank the sample liquid or material may be later recovered if desired. A driver coil 116 is electrically excited by a pulsating current which drives the U-tube 114 into mechanical vibration. The vibration becomes a function of the mass of the material contained in the U-tube. If the density or specific gravity of this sample is increased the effective mass of the U-tube increases, if the density decreases the effective mass of the U-tube decreases.

The vibration is sensed in a pickup coil 118 which consists of an armature and coil arrangement similar to that of the driver coil 116. The vibration of the pickup armature induces an AC voltage in the pickup coil, the output in the pickup coil 118 being a function of the density or specific gravity of the material being conducted therethrough. Thus, depending upon the direction of change the specific gravity being conducted through the U-tube either the delay timer 96' and ultimately the feed valve is actuated, i.e., closed, or the recycle means 64' is actuated to return heavy phase material from the receiving tank 62' back into the centrifuge bowl 16'.

Thus as the interface A' moves inwardly or outwardly of the end of tube 66' more or less of heavy-phase material will be conducted through the U-tube 114. Thus, as stated, depending upon the direction of the change, i.e., an increase or a decrease in the specific gravity, either the feed valve will be temporarily closed, or the recycle means 64' will be actuated.

In either of the above-described embodiments, multipositioning or fully variable control adjustments on either the feed valve or the recycle means to smooth out the operation permits the system to be finely tuned. It is also within the scope of the resent invention to inject a suitable auxiliary material to control the position of the interface, rather than recycle discharged heavy-phase material. Thus, pumps 98 or 98' would be connected to a separate supply of the auxiliary material rather than tanks 62 or 62'. The means for controlling the injection of the auxiliary material would be identical to that disclosed herein for controlling recycled material.

It can be seen that with the present invention skimming pipes or tubes are eliminated and mechanical desludging time is greatly reduced. With relatively solids in the feed, this can multiply the effective rate of the centrifuge by two to 10 times while at the same time providing maximum concentration of sludge or heavy-phase material, as this is removed from the maximum diameter of the bowl. Sizing of the nozzles, and the number of nozzles is determined by the feed perimeters, and approximate prestraining can be provided to preclude possible pluggage of the nozzles.

Although I have described my invention with a certain degree of particularlity, it is understood that the present disclosure has been made only by way of example, and that numerous changes in the details of construction and combination and arrangement of parts may be resorted to without de-

parting from the spirit and scope of the invention as hereinafter claimed.

What is claimed is:

1. A centrifuge including a rotatably mounted centrifuge bowl having a separation chamber therein, said bowl having an annular liquid overflow lip formed about the rotational axis at the upper end of said bowl, means including valve means, for feeding a mixture of at least two materials into said separation chamber wherein the first material thereof has a higher specific gravity than the second material thereof, and whereby said first material builds up against the peripheral wall of said bowl, means for continuously discharging said first material, means for receiving said first material upon discharge, means including pump means, operatively associated with said receiving means for recycling said first material into the outer region of said separation chamber, means for indicating when the line separation between said materials has reached a predetermined level inward of said peripheral wall and outward of said lip, said indicating means including detecting means operatively associated with said valve means and said pump means, said detecting means being adapted to detect an increase above the specific gravity of said second material for closing said valve means, and adapted to detect a decrease in specific gravity below the specific gravity of said first material for actuating said pump means.

2. A centrifuge according to claim 1 wherein said indicating means includes a tubular passageway extending through the peripheral wall of said bowl inwardly of the bowl to said predetermined level for conducting material out of said bowl to said detecting means.

3. A centrifuge according to claim 1 wherein said bowl further includes an annular ring dam formed about the rotational axis at the bottom end of said bowl, and a passageway extending between the inner edge of said ring dam and the outer region of said separation chamber.

4. A centrifuge according to claim 3 wherein said means for discharging said first material comprises a plurality of circumferentially spaced peripheral outlets.

5. A centrifuge according to claim 4 wherein said recycling means includes injection outlet means for recycling said first material over said ring dam, and into the outer region of said separation chamber.

6. A centrifuge according to claim 4 wherein the radius of the inner edge of said ring dam is larger than the radius of said lip.

7. A centrifuge according to claim 4 wherein the radius of the inner edge of said ring dam is equal to or less than the radius of said lip.

8. A centrifuge according to claim 5, and further including delay timer means operatively associated with said valve means and said detection means, said delay timer means being adapted to reopen said valve means after being closed a predetermined time.

9. A centrifuge according to claim 8 wherein said feed means includes outlet means disposed within said separation chamber, and further including annular wall structure formed about the rotational axis, said wall structure being disposed between said peripheral outlets and said outlet means.

10. A centrifuge including a rotatably mounted centrifuge bowl having a separation chamber therein, said bowl having an annular liquid overflow lip formed about the rotational axis at the upper end of said bowl, means including valve means, for feeding a mixture of at least two materials into said separation chamber wherein the first material thereof has a higher specific gravity than the second material thereof, and whereby said first material builds up against the peripheral wall of said bowl, said bowl having a plurality of circumferentially spaced peripheral outlets for continuously discharging said first material, means including pump means for injecting auxiliary material into the outer region of said separating chamber, means for indicating when the line of separation between said first and second materials has reached a predetermined level inward of said peripheral wall and outward of said lip, said indicating means including detecting means operatively associated with said valve means and said pump means, said detecting means being adapted to detect an increase above the specific gravity of said second material for closing said valve means, and adapted to detect a decrease in specific gravity below the specific gravity of said first material for actuating said pump means.

11. A centrifuge according to claim 10 wherein said bowl further includes an annular ring dam formed about the rotational axis at the bottom end of said bowl, a passageway extending between the inner edge of said ring dam and the outer region of said separation chamber, said injection means having injection outlet means disposed adjacent to the inner edge of said ring dam for injecting said auxiliary material over said ring dam and into the outer region of said separation chamber, and wherein the radius of the inner edge of said ring dam is larger than that of said lip.

12. A centrifuge according to claim 10 wherein said bowl further includes an annular ring dam formed about the rotational axis at the bottom end of said bowl, a passageway extending between the inner edge of said ring dam and the outer region of said separation chamber, said injection means having injection outlet means disposed adjacent to the inner edge of said ring dam for injecting said auxiliary material over said ring dam and into the outer region of said separation chamber, and wherein the radius of the inner edge of said ring dam is equal to or less than that of said lip.

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