Aug. 18, 1964 T. D. SHARPLES 3,145,173

CENTRIFUGE HAVING FORCED SOLIDS DISCHARGE

Filed Nov. 26, 1962 2 Sheets-Sheet 1

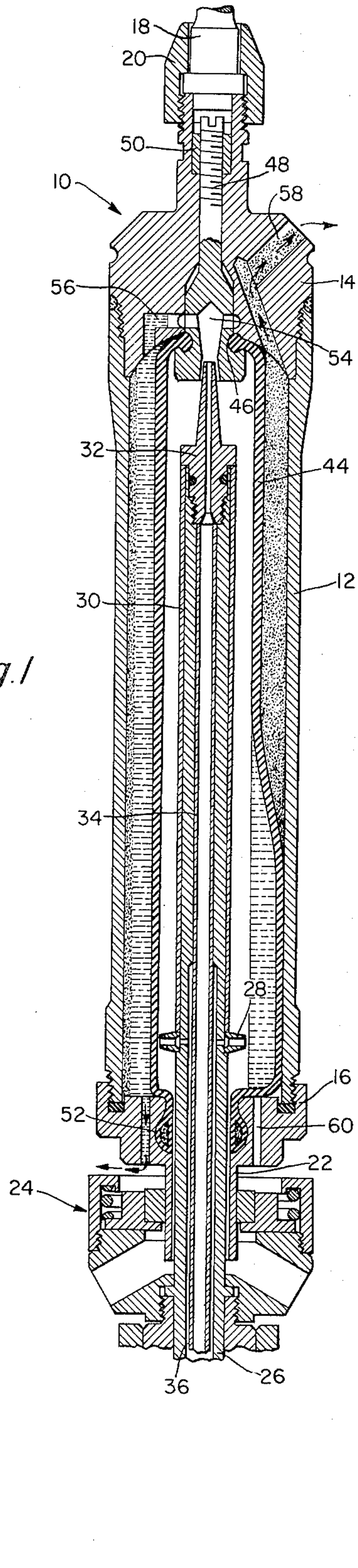
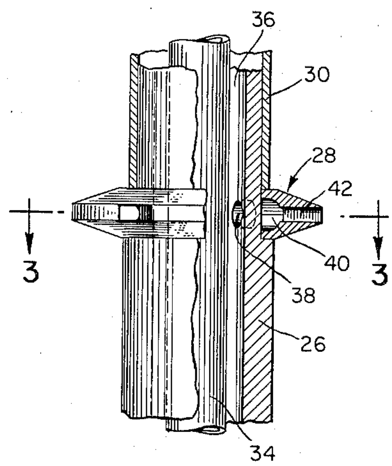


Fig. 1

Fig. 2



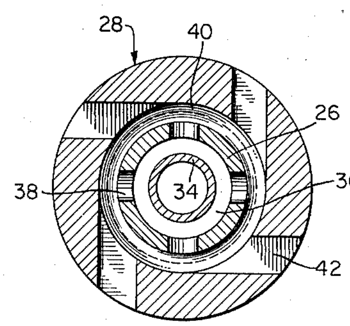


Fig. 3

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CENTRIFUGE HAVING FORCED SOLIDS DISCHARGE

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Fig. 4

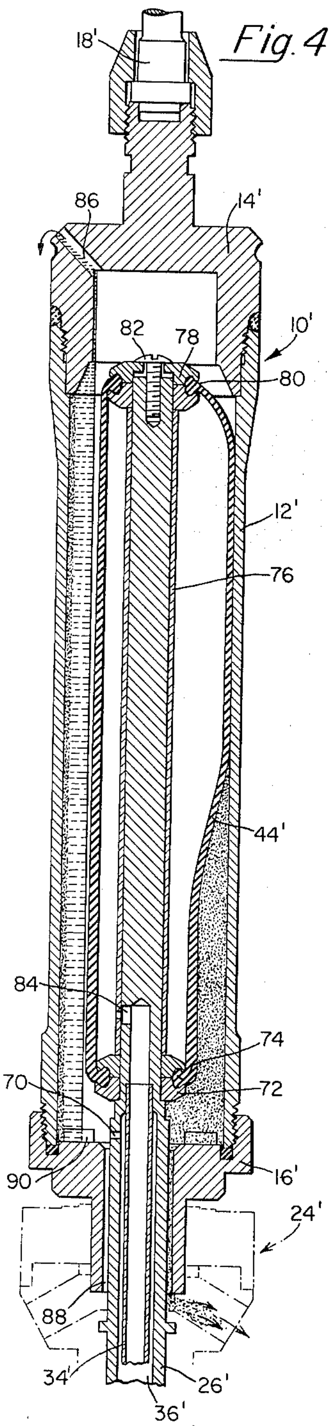
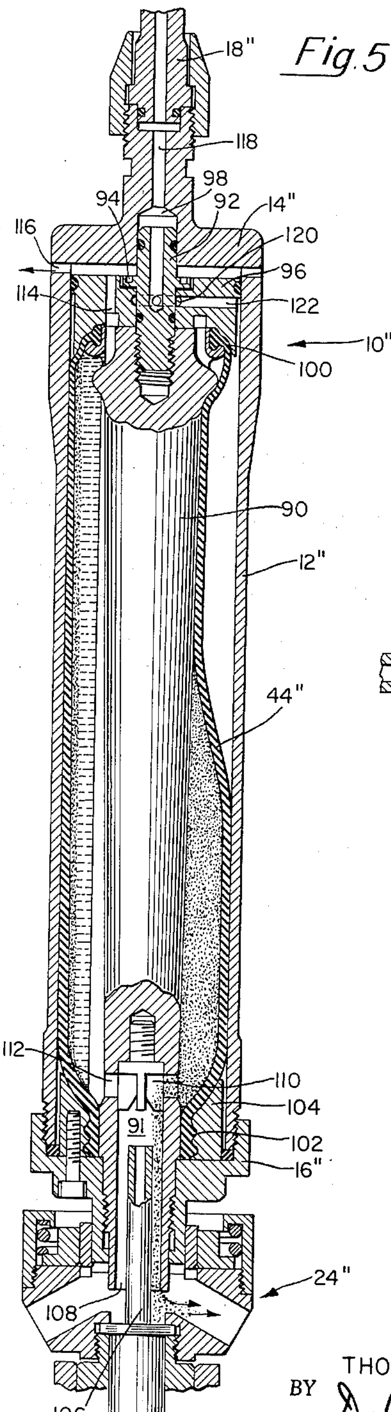


Fig. 5



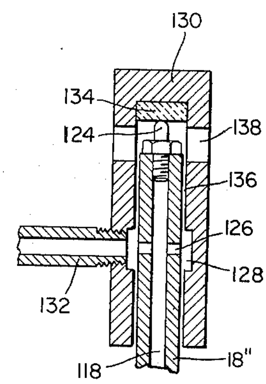


Fig. 6

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CENTRIFUGE HAVING FORCED SOLIDS DISCHARGE

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Filed Nov. 26, 1962, Ser. No. 240,082
16 Claims. (Cl. 233—20)

This invention relates to a centrifuge. More specifically this invention relates to a centrifuge having improved means for discharging separated solids.

In the prior art solid-wall centrifuges have often been made readily disassemblable. Such structure has been necessary to permit the operator periodically to open the machine to remove solids which have accumulated therein. Such has been the normal operating procedure with many liquid-solids centrifuges.

In other machines, nozzles or valves have been provided at the periphery of the centrifuge for discharging the solids while the centrifuge runs. While ideally such nozzle or valve discharges should permit continual discharge of the solids without need for disassembly, as a practical matter high solids flow rates are required to obtain reasonable solids concentrations in the discharge with such machines. Additionally limiting has been the tendency of peripheral discharges to plug, especially in smaller size rotors.

Centrifuges of the "worm" type in which a helical conveyor scrolls the sedimented solids to a diameter less than the liquid level for discharge are similarly unsuitable for discharge of fine solids or for ones sedimenting to form a gel-like paste. Such a conveyor is usually unable to move the solid material through the liquid without redispersing it, defeating the sedimenting action. Furthermore, the agitation of the liquid mixture by the conveyor prevents sedimentation of very fine solids.

While in other machines removal of solids over a ring dam or weir has been attempted, difficulty has been experienced in that fluid pastes or slurries of concentrated solids usually defy discharge by this means.

Therefore, in working with fine solids of the type which pack to form a paste or gel in a continuous centrifuge especially where flow rates are low, it has been necessary to resort to the primitive procedure of shutting down the centrifuge, disassemblying it, and evacuating solids. It is particularly with such solids that the present invention is adapted for use.

The present invention provides means whereby such pasty solids may be extruded or otherwise discharged out of the centrifuge without requiring centrifuge disassembly. This improvement will be recognized as a marked advance, for such disassembly representing inconvenience and lost time has been particularly objectionable where contact with the solids has been a hazard to personnel as, for instance, in the concentration of germ paste.

This invention embodies other novel features, details of construction and arrangement of parts which are hereinafter set forth illustratively in the specification and claims, and illustrating in the accompanying drawings, wherein:

FIGURE 1 is a fragmentary sectional view of a centrifuge embodying the invention. The opposite sides of the pressure element are shown in different conditions;

FIGURE 2 is an enlarged portion of FIGURE 1 shown partly in elevation;

FIGURE 3 is a sectional view taken on the line 3—3 of FIGURE 2;

FIGURE 4 is a fragmentary sectional view of a modified form of the invention. The opposite sides of the pressure element are shown in different conditions;

FIGURE 5 is a fragmentary sectional view of another modified form of the invention. The opposite sides of the pressure element are shown in different conditions; and

FIGURE 6 is a fragmentary sectional view showing a control fluid connection for the modification shown in FIGURE 5.

Very briefly, the invention relates to a centrifuge comprising a hollow rotor having thereinside a first surface, a movable element within the rotor and presenting a second surface opposite said first surface, the element being adapted to move toward the first surface to urge solids between said surfaces toward and out a discharge port and means to move said movable surface.

Referring more specifically to the drawings, the rotor portion of a centrifuge embodying the invention is broadly designated **10** in FIGURE 1. It comprises a peripheral shell **12** having an upper end **14** and a lower end **16**. The upper end **14** terminates in a reduced threaded portion to which is clamped a supporting and drive shaft **18** by a coupling nut **20**. The lower end **16** is formed with a downward axial extension **22** which is received into a conventional guide bushing assembly or drag **24**.

Extending upward from the guide bushing assembly and through a central bore in the lower end **16** is a stationary feed shaft **26**. The shaft is formed with a shoulder to support a skimmer unit **28** which is held against the shoulder by a spacer sleeve **30** in turn held down by feed nozzle **32** threadedly received into the upper end of the feed shaft. The feed shaft **26** incorporates a central feed tube **34** which communicates with the opening in the nozzle **32** and is fed from a feed source not shown. At its lower end the feed shaft **26** is formed with an enlarged axial opening larger than the outer diameter of the feed tube **34** to provide an annular control fluid channel **36**.

The channel **36** which is fed control fluid from a source not shown communicates with the skimmer unit **28** through openings **38** in the feed shaft **26** (FIGURES 2, 3). The unit itself is an annular element having an annular pocket **40** aligned with the openings **38** and having more or less tangential skimmer passages **42**.

Disposed within the hollow rotor **10** (FIGURE 1) is a tubular flexible pressure element **44** which at its upper end is formed with an opening having an enlarged annular lip **46** engaged by the head of a clamping bolt **48** and held thereby against the upper end **14** of the rotor. The bolt **48** is received through an axial bore in the upper end **14** and held in position by a nut **50**. The upper ends of the bolt **48** and nut **50** are radially slotted to provide means for relative turning in assembly or disassembly.

The lower end of the flexible pressure element **44** is similarly provided with a central opening which, however, unlike the opening at the upper end presents a downward flange **52** to surround in spaced relation the feed shaft **26**. The flange **52** is enlarged as shown and weighted, for instance, by heavy metal powder, to be urged outward into the pocket which receives it, thereby securing the flexible pressure element to the lower end **16**.

The flexible pressure element **44** may be of material selected from rubber or any of the resilient synthetic materials. Its density for reasons which will appear must be less than the density of the lightest liquid to be treated. Further, as shown the thickness of the wall of the element in the preferred embodiment tapers, becoming thicker toward the solids discharge region of the rotor. In the embodiment shown this region is at the upper end **14**.

A central feed passage **54** in the head of the clamping bolt **48** communicates with a passage **56** in the upper end **14** to deliver feed to the centrifuging portion of the rotor. On the opposite side of the upper end **14** a solids discharge passage **58** extends upward and inward, then outward to form a weir inward from the liquid discharge.

The liquid discharge in the embodiment shown in FIGURE 1 comprises a series of longitudinally extending openings **60** in the lower end **16**.

In operation, with the rotor turning at high speed, feed mixture is supplied through central feed tube **34** upward through passages **54** and **56** and into the centrifuging zone of the rotor. Clarified liquid discharges through openings **60** in the lower end **16**. The flexible pressure element **44** will "float" on the surface of the liquid as shown in the left-hand side of FIGURE 1, the density of the element being less than the density of the liquid. When the acceptable limit of solids has accumulated in the rotor, and this will be known from experience or by suitable monitoring of the clarified liquid effluent, the feed through the tube **34** is interrupted and control fluid, e.g., liquid, is injected through the channel **36**, and through the skimmer unit **28**. As the rotation of the rotor **10** continues, centrifugal force acting on the control liquid which is disposed against the inside wall of the element **44** urges the element outward. The outward urging is first manifest by movement outward of the thinner-walled portion of the element at its lower end and the manifestation progresses upwardly as shown on the right-hand side of FIGURE 1. The movement of the element **44** toward the shell **12** urges the solids between the opposing surfaces toward and out the solids discharge passage **58**.

When the centrifuging zone has been evacuated of solids in this manner, the supply of control fluid is shut off, the control fluid line is vented, and feed of mixture through central feed tube **34** is resumed, floating the rotating flexible element inward. Since the skimmer unit **28** is submerged when the mandrel is expanded, the venting of the control fluid line is alone sufficient to initiate the skimming action. The inward movement of the element continues to force the level of control fluid into the skimmer unit **28** and allows it to skim out virtually all of the control fluid and discharge it out the annular channel **36** through which it was introduced. This cyclic operation may be continued indefinitely, without interrupting rotation of the rotor **10**.

Modifications

The rotor of the modification shown in FIGURE 4 is generally designated **10′**. It comprises the peripheral shell **12′** having the upper end **14′** and the lower end **16′**. The rotor is supported from its upper end and driven by drive shaft **18′**, while the lower end **16′** is engaged by the guide bushing assembly **24′**. Extending upward from the guide bushing assembly **24′** is the feed shaft **26′** which carries within it a central control fluid tube **34′**. The outer diameter of the latter is less than the inner diameter of the feed shaft **26′** and provides an annular feed passage **36′**. The annular feed passage **36′**, supplied from a source not shown communicates to the bowl through the radial opening **70**.

In the FIGURE 4 embodiment the feed shaft **26′** is formed with a shoulder against which are clamped a pair of lower sandwich plates **72**. A tubular flexible pressure element **44′** within the rotor is stationary and is formed at its lower end with an opening having an enlarged annular lip **74** held between the plates **72** as shown. A spacing tube **76** snugly surrounds the feed shaft **26′** and supports at its upper end a pair of upper sandwich plates **78**. The upper sandwich plates **78** hold between them the enlarged annular lip **80** of the upper end of the flexible pressure element **44′**. The sandwich plates **72** and **78** as well as the spacing tube **76** are held under compression by the bolt **82** received into the upper end of the shaft **26′**. The pressure element **44′** has tapering walls thinning as the upper end is approached.

Passage of control fluid between the tube **34′** and the pressure element **44′** is provided by the passages **84** in the shaft and spacing tube **76**. Separated liquid discharge is provided through opening **86** and solids discharge is provided through the annular opening **88** between the shaft **26′** and the lower end **16′**.

Vanes **90** may be provided in the lower end **16′** to help accelerate the mixture.

In operation, feed mixture is delivered to the centrifuge zone of the rotor **10** through the passages **36′** and **70**, and clarified liquid discharges through opening **86**. As in all embodiments of the invention separate collectors (not shown) are provided for the liquid and solids discharges. When solids have accumulated, the rotation of the rotor is stopped and control fluid, e.g., air, is injected under pressure through the tube **34′** and passages **84** to expand the pressure element **34′** outward progressively from top to bottom as shown on the right-hand side of FIGURE 4. When the solids have been discharged from opening **88**, control fluid may be vented to return the element to its original position as shown in the left side of FIGURE 4, and the centrifuging operation resumed.

In the FIGURE 5 modification the rotor is generally designated **10″** and comprises a peripheral shell **12″** shown integral with the upper end **14″**, and a lower end **16″**. The upper end of **14″** is engaged by and the rotor is driven and supported by the drive shaft **18″**.

As shown, the rotor **10″** is provided with an axial mandrel **90**. The mandrel **90** is tapered, narrowing as its lower end is approached. The lower end is formed with an axial bore **91** and is exteriorly threaded to engage corresponding threads in the end **16″** which fits into the guide bushing assembly **24″**. The upper end of the mandrel **90** is formed with an axial opening interiorly threaded to receive a stud **92** which carries cooperant threads and is formed with an outward annular flange **94** which clamps the mandrel cap **96** downward against the upper end of the mandrel. The stud extends on upwardly into an axial recess **98** in the upper end **14″**. O-rings are provided in grooves in the stud to seal the clarified liquid passage from the control fluid passage as will be explained. An O-ring is also provided in the cap **96** to avoid leakage of clarified liquid discharge into the space between the element **44″** and the rotor wall.

Surrounding the mandrel **90** is the tubular flexible pressure element **44″** which has walls thicker at the lower end adjacent the solids discharge port. The upper end of the flexible pressure element **44″** is formed with an opening having an enlarged annular lip **100** which is clamped in aligned annular grooves in the upper end of the mandrel and in the mandrel cap **96**, respectively, as shown. The lower end of the flexible pressure element **44″** is formed with an opening having a downward flange **102** with outward peripheral ribs fitting into grooves in the clamping ring **104**. As shown, the clamping ring **104** is bolted to the lower end **16″** and the flange **102** is held outward in compression against the ring by the lower end of the mandrel **90**. For this purpose the appropriate area of the mandrel **90** may be tapered.

A mixture feed nozzle **106** is mounted in the guide bushing assembly **24″** and extends upward in the opening **91** in the lower end of the mandrel **90**. The outer diameter of the nozzle **106** is of size to permit an annular discharge passage **108** thereabout. An accelerator **110** is provided at the upper end of the mandrel opening, and radial passages **112** communicate to the inside of the rotor.

Passages **114** are provided in the upper end of the mandrel **90** and in the mandrel cap **96** to permit discharge of clarified liquid into the space between the mandrel cap **96** and the upper end **14″** from whence the liquid may discharge from the rotor through radial passages **116**.

The drive shaft **18″**, the upper end **14″**, and the stud **92** are provided with axial passages **118** as shown for flow of control fluid. The stud **92** at the lower end of its axial opening is formed with a radial passage which communicates with an annular opening **120** on the inside of the axial bore of the mandrel head **96**. The annular opening **120**, in turn, joins a radial passage **122** through the mandrel head 96 to the periphery of the mandrel head which is reduced as shown to permit passage into the hollow portion of the rotor.

Control fluid, e.g., air, may be supplied to the hollow drive shaft 18″ through the connection shown in FIGURE 6. In FIGURE 6 the upper portion of the drive shaft 18″, above the engagement with the driving means is capped by a screw having a hard steel hemisphere 124. Radial openings 126 in the shaft extend outward from the central bore 118 and are in registry with an annular enlargement 128 of the connection cap 130. To the cap at the annular enlargement 128 is attached the control fluid feed tube 132 connected to a source not shown. The hemisphere 124, rotating with the spindle supports the cap 130 by engagement with a sapphire or the like disc 134 on the underside of the cap top. Journal clearance 136 is permitted between the periphery of the drive shaft 18″ and the inner surface of the cap, and radial exhaust openings 138 for control fluid permit escape of the control fluid from the upper end of the stationary cap.

In operation, with the rotor of FIGURE 5 rotating at high speed, centrifugal force and the weight of the mixture being separated normally holds the flexible pressure element 44″ against the peripheral shell 12″ as shown on the left of the figure. Feed mixture is introduced through the nozzle 106 through openings 91 and 112 into the centrifuging zone of the rotor. Clarified liquid discharges outward through passages 114 and 116. After solids have accumulated, the feed is interrupted. Control fluid, e.g., air, which may be supplied normally at low volume to lubricate the connection shown in FIGURE 6 is increased in volume and urges the flexible pressure element 44″ inward progressively from the upper end to the lower end of the rotor as at the right of the figure. Solids are extruded or otherwise discharged outward through opening 112, opening 46 and annular opening 108.

When the bowl has thus been evacuated, introduction of the feed mixture is resumed and control fluid is reduced to allow the flexible pressure element 44″ to return to its position shown on the left side of FIGURE 5, being urged outward by the weight of the incoming mixture and backing the control fluid to escape through the cap 130 clearances. This cyclic operation may be continued indefinitely without interrupting rotation.

From the above description it may be seen that I have developed a centrifuge particularly adapted for use in clarifying liquid-solid mixtures in which the solids tend to accumulate in the rotor and form a paste or gel against the peripheral wall. Whereas before such solids could be evacuated only by stopping and disassembling the rotor, under the present invention, such disassembling is not necessary and moreover in the embodiments such as in FIGURES 1 and 5, the rotor need not ever be stopped to effect the evacuation. The rotors of the embodiments of the invention disclosed herein are particularly adapted for extremely high speed operation and concomitant multiples of the acceleration of gravity in the neighborhood of 15,000, for instance, and well above. Obviously, however, rotors embodying the invention may find application at lower speeds of operation.

It should be understood that centrifuges embodying the present invention may be used in a vast number of different clarifications. They are especially adapted to the dewaxing of petroleum oil, the destearination of vegetable oil and other operations involving pasty-type solids. The benefits of the invention will be especially appreciated in the clarification of such pasty solids, contact with which represents a hazard to personnel. The apparatuses embodying the invention are also useful in the separation of extremely valuable and expensive solids produced at rates too low for nozzle-type centrifuges, as well as the recovery of solids which cannot withstand the rough treatment of removal by conveyor centrifuges.

It should be understood that while the invention has

been described in a clarification operation involving the removal of solids from a single liquid, the description has been illustrative and the centrifuge of the invention, especially the embodiments of FIGURES 1 and 5, may, with the addition of a single dividing cone or the like, be adapted for the separation of two or more liquids in the liquid-solid feed. This adaptation as well as limitless possible changes in design which will be obvious to those skilled in the art are contemplated as reasonable variations of the invention.

Therefore, it is to be understood that this is by way of illustration, and that changes, omissions, additions, substitutions, and/or other modifications may be made without departing from the spirit thereof. Accordingly it is intended that the patent shall cover, by suitable expression in the claims, the various features of patentable novelty that reside in the invention.

I claim:

1. A centrifuge for concentrating solids into pasty consistency from a suspension, comprising a hollow imperforate-walled rotor having a solids discharge port spaced inward from the imperforate wall, means to discharge clarified liquid, a pair of coextensive radially spaced surfaces in said rotor extending from a region in the rotor remote from the solids discharge port and generally toward the solids discharge port, means for rotating the rotor, means for delivering the suspension to a zone in the rotor between the surfaces for centrifugation, means to move one of the surfaces in a substantially radial direction toward the other and substantially into contact therewith in a movement which progresses from said region and toward the solids discharge port, whereby concentrated pasty solids between the surfaces may be extruded inward to the solids discharge port for discharge.

2. A centrifuge as described in claim 1 wherein the said one surface is presented by a movable element of flexible material which is moved toward the other surface by fluid under pressure.

3. A centrifuge as described in claim 2 wherein portions of said movable element are of tapering thickness, thicker adjacent the discharge port.

4. A centrifuge for concentrating solids into a paste, comprising an imperforate-walled hollow rotor, a rigid surface in the rotor, a flexible pressure element mounted in the rotor, means to supply feed mixture into said rotor between the flexible pressure element and the rigid surface, means to discharge clarified liquid from the rotor, means inward of the imperforate wall to permit discharge of concentrated solids from said rotor, and means to supply control fluid into said rotor on the other side of said pressure element from the rigid surface to move the element toward the rigid surface and substantially into contact therewith to extrude concentrated solids toward and out of said means to permit discharge of concentrated solids.

5. A centrifuge as described in claim 4 wherein the flexible pressure element is tubular and disposed about the axis of the rotor and has a wall of tapering thickness becoming wider as the means to permit discharge of concentrated solids is approached.

6. A centrifuge as described in claim 5 wherein the flexible pressure element is mounted for rotation with the rotor.

7. A centrifuge as described in claim 6 wherein the means to supply feed mixture into the rotor supplies it to the outside of the flexible pressure element, and skimmer means are provided adjacent the axis to remove such control fluid.

8. A centrifuge as described in claim 6 wherein the means to supply feed mixture into the rotor supplies it to the inside of the flexible pressure element, and a central mandrel comprising the rigid surface is positioned inside the flexible pressure element.

9. A centrifuge as described in claim 5 wherein the flexible pressure element is stationary.

10. A centrifuge particularly adapted for concentrating solids from a suspension into a pasty consistency, comprising a hollow rotor having an imperforate peripheral wall and upper and lower end walls, the lower end wall having an opening therein, means to rotate the rotor, a rigid mandrel mounted within the rotor along the axis thereof and having a lower portion extending through the opening to the outside of the rotor, a tubular flexible pressure element circumposing the mandrel and means mounting the flexible pressure element at either end, one said means attached to the upper end of the mandrel, the other means attached to the lower end wall of the rotor, the mandrel having a first passage including a bore on the axis of the rotor from the outside of the rotor and an opening from the bore to the inside of the flexible pressure element, the rotor having a control liquid passage communicating from the outside of the rotor to a space between the rotor wall and the flexible pressure element, a stationary feed tube extending into the bore in the mandrel, the feed tube being of smaller outside dimension than the bore, and liquid discharge port means inward from the peripheral wall of the rotor and at a radius greater from the axis of the rotor than the radius of the bore and permitting escape of clarified liquid from inside the flexible pressure element, whereby the suspension may be injected through the feed tube and the first passage into the flexible pressure element for centrifugation, the clarified liquid may pass out the liquid discharge port means, and upon accumulation of solids the feed may be interrupted and control liquid supplied to the control liquid passage to urge the flexible pressure element inward toward the mandrel extruding the concentrated solids out the first passage and about the stationary feed tube to discharge.

11. A centrifuge as claimed in claim 10 wherein the mandrel has a tapered portion narrowing toward the opening in the first passage.

12. A centrifuge as claimed in claim 10 wherein the wall of the flexible pressure element tapers narrowing away from the opening in the first passage.

13. A centrifuge especially adapted for the concentration of solids from a suspension into a pasty consistency, comprising a hollow rotor having an imperforate peripheral wall and an upper end wall and a lower end wall, the lower end wall having a central opening, the upper end wall having a solids discharge port spaced inward from the imperforate peripheral wall, a clarified liquid discharge port in the rotor disposed at a radius from the axis of the rotor between that of the imperforate peripheral wall and the solids discharge port, means to rotate the rotor, a tubular flexible pressure element disposed about the axis of the rotor inside the rotor, clamping means holding the upper end of the flexible pressure element to the upper end wall of the rotor, means holding the lower end of the flexible element in the central opening of the lower end wall, the clamping means and the upper end wall having a passage extending from an opening in the clamping means inside of the flexible pressure element to a space between the flexible pressure element and the imperforate peripheral wall of the rotor, a stationary suspension feed tube extending upward from the outside of the rotor through the central opening of the lower end wall and terminating in a nozzle directed toward the opening in the clamping means, a skimming unit disposed about the suspension feed tube and extending outward to a radius less than that of the clarified liquid discharge port, a stationary control liquid conduit circumposing the suspension feed tube and also extending up through the central opening in the lower end wall and communicating with the skimming unit, whereby suspension may be fed into the rotor through the suspension feed tube and passage in the clamping means and upper end wall of the rotor, clarified liquid discharging from the clarified liquid discharge port, and after solids have accumulated the suspension feed may be interrupted and control liquid supplied to the inside of the flexible pressure element through the control liquid conduit and skimmer unit to urge the flexible element toward the rotor wall and extrude concentrated solids out through the solid discharge port whereupon the control liquid conduit may be vented and the skimmer unit may pump control liquid out of the flexible pressure element to restore it to a relatively inward disposition as rotation of the rotor continues.

14. A centrifuge as described in claim 13 wherein the wall of the flexible pressure element is tapered narrowing away from the solids discharge port.

15. A centrifuge especially adapted for the concentration of solids from a suspension into a pasty consistency, comprising a hollow rotor having an imperforate peripheral wall having upper and lower end walls, the upper end wall having a clarified liquid discharge port at a radius inward from the imperforate peripheral wall, means to rotate the rotor, the lower end wall having a central opening of radius less than the radius from the axis of the rotor at which the clarified liquid discharge port is located, a stationary shaft extending freely through the central opening in the lower end wall and up into the rotor, the stationary shaft having a suspension feed passage therein with a feed opening into the rotor, a tubular flexible pressure element having its upper and lower ends secured to the shaft at vertically spaced positions both being above the feed opening in the shaft, the shaft having a second opening intermediate the positions, control liquid passage means in the shaft communicating with the second opening, whereby feed suspension may be delivered to the rotor through the suspension feed passage and opening, and after solids have accumulated the feed may be interrupted and the rotor may be brought to rest and the flexible pressure element expanded by control liquid supplied through the control liquid passage means, the expanding element urging the concentrated solids out the central opening in the lower end wall whereupon the flexible pressure element may be vented of control liquid through the control liquid passage means to return it to smaller size and the rotation and suspension feed may be resumed.

16. A centrifuge as described in claim 15 wherein the wall of the flexible pressure element tapers, narrowing away from the central opening in the lower end wall of the rotor.

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