Oct. 20, 1970 F. W. KEITH, JR 3,534,903

CENTRIFUGE APPARATUS

Original Filed July 9, 1962

Fig. 5

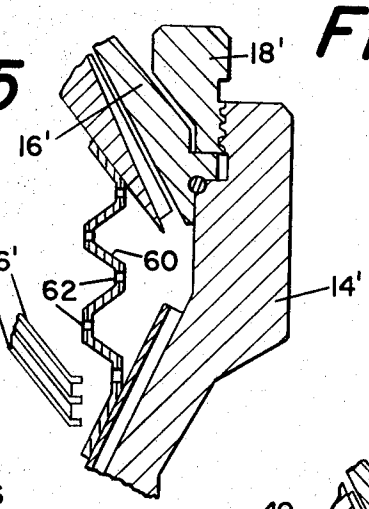


Fig. 2

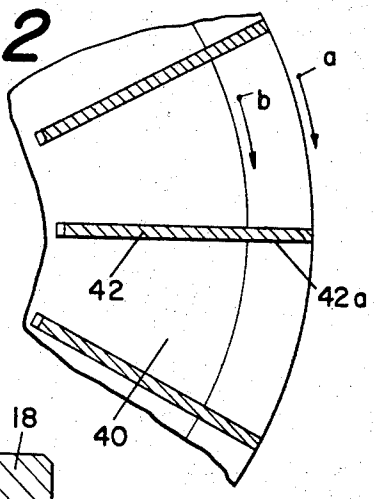


Fig. 1

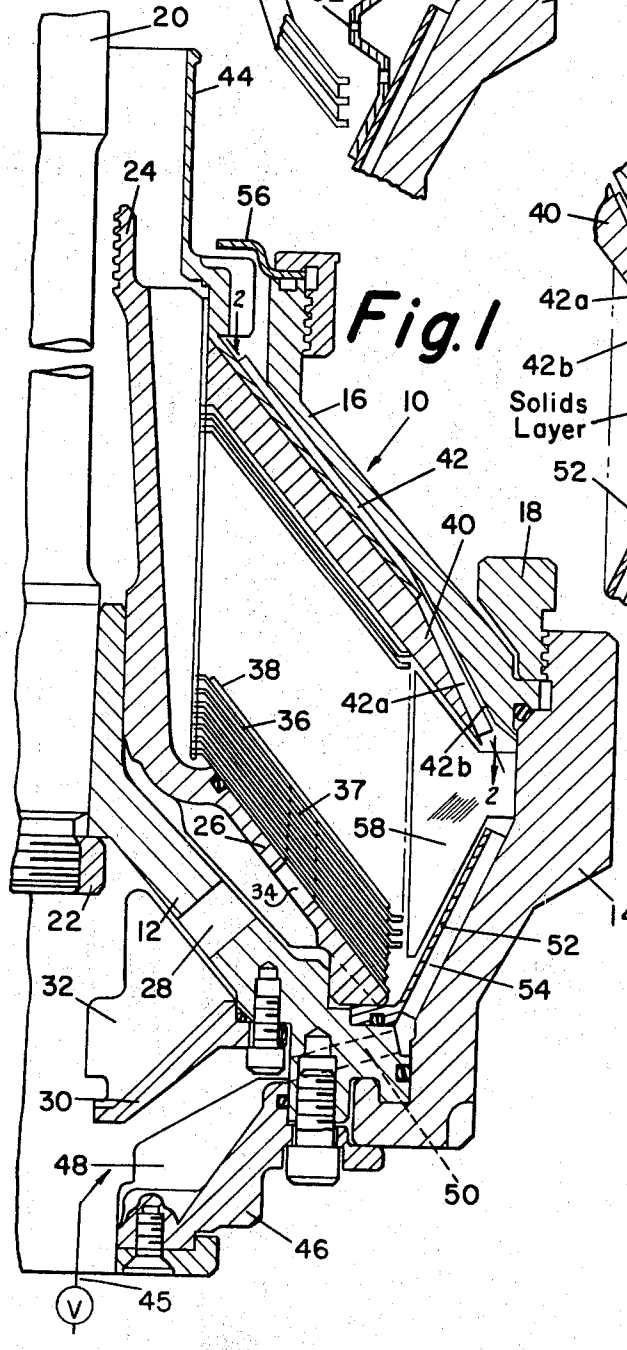


Fig. 3

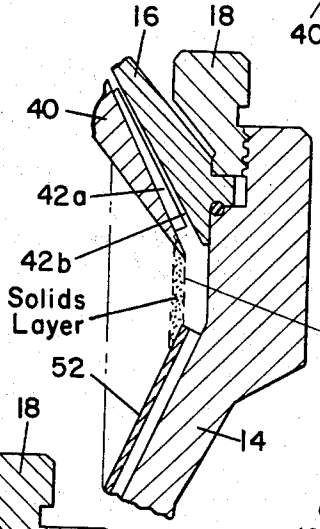
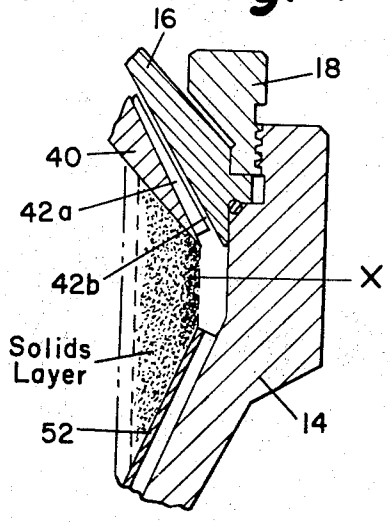


Fig. 4



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CENTRIFUGE APPARATUS

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Original application July 9, 1962, Ser. No. 208,379, now Patent No. 3,388,054, dated June 11, 1968. Divided and this application Sept. 19, 1967, Ser. No. 680,600
Int. Cl. B04b 7/00
U.S. Cl. 233—14 4 Claims

ABSTRACT OF THE DISCLOSURE

The hollow rotor of a centrifuge is provided with a dividing cone spaced from the top wall of the rotor, with at least one radial spacer element disposed between the cone and the top wall and provided with a gap in the path of separated heavy discharge flowing from the interior to the exterior of the rotor.

This is a divisional application of my application Ser. No. 208,379, filed July 9, 1962, now U.S. Pat. No. 3,388,054.

This invention relates to a process for concentrating or compacting solids in a liquid-solids mixture and for separating the solids from the mixture in a condition denuded of the liquid of the mixture to a controlled extent.

The invention finds application in a wide variety of processes, requiring the concentration or compaction of a solid phase in a liquid-solids mixture and the separation from the mixture of the concentrated solids. Since the invention was conceived and perfected in connection with dewaxing of petroleum oil, it will be explained in such enviroment. However, it should be understood that the use of such illustration does not limit the scope of the invention as expressed in the claims.

As is well known, in the processing of a lube oil stock into a commercially acceptable product adapted, for instance, for the lubrication of internal combustion engines, it is conventional to remove from the stock higher melting portions thereof. This step in the process, referred to in the trade as dewaxing, removes from the stock the components which cause the oil to solidify or develop insoluble particles or increase in viscosity at colder temperatures. Such removal is, of course, highly desirable in the processing of the stock into engine oil since solids may plug oil filters and high viscosity characteristics increase friction and make the engine more difficult to start.

It is well known in the art to dewax petroleum oil by the use of centrifugal force. Frequently, to facilitate such centrifugal processing, a solvent or solvent mixture including naphtha or propane or methyl ethyl ketone is added to the lube oil stock. The temperature of the lube oil stock in solvent is then lowered until the higher-melting portions solidify. The oil in solvent with the portions solidified is then introduced into a zone of centrifuging from which the clarified oil in solvent is removed from a locus adjacent the axis of the zone and the solidified wax concentrate with some oil is discharged peripherally or, at least at a locus outside of the first locus. The solvent may subsequently be stripped from both portions.

It has always been the objective in thus dewaxing oil to obtain the lowest oil content wax that is consistent with the clarification of the oil. The oil is usually the more valued discharge, and the production of a low oil content wax is desirable in that it means that more oil is released into the oil discharge. Thus the industry strives to produce this high quality wax and get the benefit of greater oil yield. To the centrifugal processor, the attainment of a high quality wax consistent with clarified oil discharge involves attaining adequate residence time effectively to compact the wax solids and at the same time to avoid the appearance of such wax solids in the oil discharge.

In the past, control of residence time has involved changing the ring dam or adjusting the tube dam of the centrifuge to control the hydrostatic pressure balance within the centrifuge. Obviously the necessity for the step of changing the dam size or adjusting the tube dam to control the wax quality is unsatisfactory, for each such change or adjustment requires stopping of the centrifuge rotor, removing and replacing the ring dam, and once again getting the rotor up to speed. Such a procedure may take as much time as a full hour in accomplishment with consequent loss of time to the processor, and such a procedure may be frequently necessary because of inevitable variances in the densities of the stock mixture and/or wax content and/or temperatures.

I have conceived of a process for controlling the concentration of solids discharged from a centrifuging zone while the centrifuge is operating. My invention is a convenient effective method for achieving its object and it does not involve more than a simple modification to conventional centrifuge equipment.

Other features of my invention will be apparent to those skilled in the art from the following illustrative description and the accompanying drawings in which:

FIG. 1 is a sectional view taken through the axis and showing part of a centrifuge rotor with which the process embodying the invention may be carried out. The supplemental liquid feed and rate control means are shown schematically.

FIG. 2 is a fragmentary sectional view taken on the line 2—2 of FIG. 1;

FIG. 3 and FIG. 4 are simplified fragmentary sectional views adjacent the periphery of the rotor showing the control of solids concentration achieved by the process; and

FIG. 5 is a fragmentary view of a modified form of compaction zone.

Briefly, the invention is the process of concentrating or compacting solids in a liquid-solids mixture and separating the compacted solids from the mixture denuded of the liquid to a controlled extent. The process includes the steps of introducing the mixture to a centrifuging zone, feeding to the zone supplemental liquid of greater density than the first liquid, forming a layer of the solids inward of the supplemental liquid and a layer of the first liquid inward of the solids, withdrawing the separated first liquid from a locus adjacent the axis of the zone, withdrawing together portions of the supplemental liquid and of the layer of concentrated solids from adjacent the solids-supplemental liquid interface by leading the said portions inward through a discharge passage. The process further involves controlling the rate of feed of supplemental liquid to control the desired amount of first-mentioned liquid in the solids concentrate discharge.

Referring more specifically to the drawings, a centrifuge rotor with which the invention is adapted to be

practiced is designated 10 in FIG. 1. The rotor comprises a central hub 12, to the periphery of which is interlocked the shell 14. A cover 16 shoulders against a recess wall in the shell and is held down by a ring element 18. The rotor is driven by a vertical shaft 20 which may extend down from a source of rotary power above and has its tapered lower end secured in a central opening in the hub with a clamping nut 22.

A center tube 24 fits over a central boss of the hub 12 The lower end of the center tube 24 presents a flaring skirt 26 held in place by an annular shoulder on the hub 12.

The hub is formed with an opening 28 for passage of feed to a zone beneath the skirt 26. Secured to the under side of the hub is a concentric downwardly directed feed cone 30 which is provided with radially disposed vanes 32 for accelerating the feed. The skirt 26 is formed with feed holes 34 which permit passage of the feed.

Superposing the skirt 26 is a stack of frusto-conical discs 36. Each disc element is provided with feed opening 37 and with upstanding spacers 38 to space above it the superposing disc element. Superposing the spacers of the uppermost disc element is a dividing cone 40 which carries upward radial spacer element 42. It will be noted that the outer portion 42*a* of the spacer elements do not extend all the way up to the under surface of the cover 16 and provide a gap 42*b* between the spacer and the cover, thus affording a continuous annular space about the top of the dividing cone to permit inwardly flowing discharge to maintain an angular velocity exceeding that of the rotor at all radii of the annular space as will be understood. In practice, the gap 42*b* may be, for instance, 1/16 inch in a rotor such as is shown in FIG. 1 which is approximately 12 inches in diameter. The dividing cone 40 is provided with an axial extension 44 and has its outer periphery complementing the shape of the rotor cover 16.

Secured ot the bottom of the bowl hub downward of the feed cone is a supplemental feed cone 46 having upwardly extending vanes 48. The hub is formed with a passage 50 upward of the cone 46, and a frusto-conical distributor 52 extends upward along the rotor shell 14 spaced therefrom by spacer elements 54. The distributor 52 may be clamped between the skirt 26 and the rotor hub 12 and its outer periphery extends somewhat beyond the outer periphery of the dividing cone 40.

The rotor cover 16 is provided with a conventional ring dam or weir 56. Planar radial vanes 58 are provided to assure acceleration of material in the zone outside the disc stack.

FIG. 5 using the primed form of numerals already used to designate corresponding parts discloses a modified form of rotor in which the stack of discs 36' is surrounded by a number of stacked frusto-conical baffles 60 arranged in zig-zag fashion and having openings 62 in between to permit outward passage of the solids and inward passage of liberated liquid. The action of the solids in such baffle structure is more fully disclosed in co-pending U.S. application Ser. No. 176,355, filed Feb. 28, 1962, now U.S. Pat. No. 3,328,282 which issued June 27, 1967.

In operation in accordance with the invention, the mixture which may, for instance, comprise lube oil stock in solvent chilled to an appropriate temperature to solidify some of its higher melting components is introduced through an appropriate feed tube to the rotating machine at the feed pocket defined by the feed cone 30 and the rotor hub 12. The feed fiinds its way through opening 28 and through holes 34 and 37 into the stack of discs. The lighter portion of the mixture, i.e. the oil in solvent, moves inwardly through the disc elements 36, and discharges over the extension 44. The solids particles sediment outwardly toward the periphery of the rotor.

Preferably prior to the introduction of feed, a supplemental liquid such as brine or other heavy liquid with which the main feed is immiscible is introduced by suitable feed tubes 45 with rate control V to the supplemental liquid pocket defined by the cones 46 and 30 and the supplemental liquid moves through passage 50 about the outside of the distributor 52 to the periphery of the rotor. The solids in the feed compact against the supplemental liquid layer. Subsequently the supplemental liquid carrying some of the compacted solids moves inwardly over the cone 40 between the spacer elements 42 and over the ring dam or weir 56. The light phase oil in solvent is collected separately. The heavy discharge may be settled and the supplemental liquid may be drained off for reuse. The wax solids and oil discharge are then treated as desired or necessary.

Obviously the supplemental liquid may be wholly or partially incorporated in the mixture fed into the rotor through the feed pocket defined by the feed cone 30, for being heavier than the mixture it will move to the outside of the rotor. However, the preferred method of operating is as described above using the supplemental feed pocket and distributor 52.

In accordance with the invention, the degree to which the discharge concentrated solids are denuded of the liquid phase (e.g. oil) in the centrifuge may be controlled by the rate at which the supplemental liquid is fed to the centrifuge. For instance, if the supplemental liquid is fed at a slow rate the discharge solids will have a relatively high content of the light liquid phase, while if the auxiliary liquid is fed at a rapid rate the light liquid content of the discharge solids will be lower. The auxiliary liquid feed rate may be controlled, for instance by means V.

My invention is hence predicated on my discovery of a control of the residence time of the solids in the centrifuging zone which control may be exercised while the centrifuging zone is operating. Hence according to my invention it is not necessary to stop the centrifuge rotor and make adjustment in order to vary the residence time of the solids.

The reason for the operation of the process embodying my invention is not readily attributed to a single phenomenon acting without additional effect from other contributory factors. A possible explanation of the controlling feature may be made with reference to FIG. 2. It is well known that an element at the periphery of a zone of centrifuging and moving at an angular velocity substantially the same as that of the zone has also a given attendant tangential velocity and under the principles of inertia will tend to maintain that tangential velocity. In FIG. 2 this velocity is diagrammatically indicated at the periphery of the dividing cone 40 by an arrow extending from an element at position *a*. If now the element is brought inwardly over the dividing cone, for instance, by some pressure differential to a position *b*, the tangential velocity of the element at point *b* will tend to be the same (as diagrammed by the arrow from the point *b*) due to the inertia built up by the element in traveling at its speed at *a*. The angular velocity of the unrestrained or partially restrained element at *b* is therefore actually greater than that of the rotor at *b* and hence the centrifugal pressure on the liquid at point *b* and all points outward thereof will be greater than it would be if the particle at *b* had only the angular velocity or rotation of the rotor. At the radius of the periphery of the dividing cone this increase in pressure must be balanced on the underside of the cone by a pressure increase. From its position shown in FIG. 3 there is consequently a compensating inward shift of the solids-supplemental liquid interface X causing a temporary additional discharge of oil over the extension 44. However, as solids build up inwardly of the radius of the interface, the interface X between the solids and the supplemental liquid moves outwardly to assume somewhat the disposition shown in FIG. 4 wherein the interface between the solids and supplemental liquid layer is about at the radial position of the periphery of

the dividing cone. Solids will again start discharging with the supplemental liquid.

It will be understood, referring once again to FIG. 2, that in order to create the condition in which the element at *b* located radially inward from *a* has substantially the same tangential velocity, the movement of the element inward must be accompanied by no tangential deceleration. In practice better control is achieved by partial deceleration by restricting the size of gap **42***b*. Since deceleration is also proportional to the rate of radial movement of the element, it is partially controlled by the radial flow rate and thus the total flow rate of the supplemental liquid. If the rate is low before the position of the element changes from *a* to *b*, considerable deceleration of the element will occur due to the action of the vane **42***a* which comprises a partial barrier. At low supplemental liquid rates, therefore, the tangential velocity of the particle as it moves from *a* to *b* will be only slightly greater than that of the rotor surface; at higher supplemental liquid rates, the tangential velocity of the element will be proportionately greater than that of the rotor surface and the pressure increase exerted at the radius of the periphery of the dividing cone **40** will also be proportionately greater.

Reference once again is made to FIGS. 3 and 4 wherein the condition in the rotor during both low and high feed rates of the supplemental liquid are characteristically shown respectively. It is diagrammatically indicated in FIG. 4 that the solids layer is thicker at the higher rate and therefore the solid particles toward the periphery of the rotor are packed to a greater extent than those toward the axis or those in FIG. 3.

Previous reference was made to other factors that contribute to an unknown degree to the supplemental liquid flow rate control of solids quality. For instance, increasing the flow rate of supplemental liquid increases its radial velocity through channels formed by spacer elements **42**. It is well known that this will require additional pressure at the periphery of dividing cone **40** to overcome the additional pressure drop due to friction in the channels, but it is readily shown by the usual fluid flow calculations that this increase in pressure is but a small fraction of that needed to increase the solids residence time by increasing the depth of the solids layer to the extent observed in practice.

Similarly, increasing the supplemental liquid flow increases the "cresting" or height of liquid necessary to create a discharge head pressure over the ring dam or tube dam acting as a discharge weir for this flow. This feature becomes more effective as the tube dams are reduced in diameter, although the latter are always maintained at sufficient size that partially free-surface flow exists within the tube and the tube diameter is several times larger than the largest solids particle to be encountered. Again, however, reference to the usual hydraulics calculations for weirs shows insufficient pressure increase due to cresting to account for the observed changes in solids layer depth by at least one order of magnitude.

The annular space formed by gaps **42***b* is not the only zone in the rotor in which the supplemental liquid moves radially inward and has some opportunity for partial rather than complete deceleration to the angular velocity of the rotor at each radius. Due to radial baffling and very restricted gaps, however, these additional zones probably contribute relatively small but unknown portions of the increased peripheral pressure due to partial deceleration in gaps **42***b*.

The following table meant by way of illustration rather than limitation demonstrates the effectiveness of the process according to my invention. The table was drawn from experiments operating on a centrifuge rotor as shown in FIG. 1 wherein the diameter of the rotor was 12 inches and the rotor operated at a speed of 10,000 r.p.m. Four radial vanes such as **58** were uniformly spaced about the disc stack. A mixture of lube oil stock in solvent chilled to precipitate the higher melting portions thereof was uniformly introduced as described above. Clarified oil discharged over the extension **44** and concentrated solids discharged with supplemental liquid over the ring dam or weir **56**. The table below sets forth the percentage of oil in the solids or wax after stripping off the solvent for various supplemental liquid feed rates. The supplemental liquid in this case was brine, and it was fed over cone **46**.

Brine rate:	Percent oil in wax
1.9	44
1.6	46
0.65	58

I have also discovered that the effectiveness of my process may be enhanced by placing in the centrifuge zone outwardly of the disc stack a number of perforated peripheral baffles similar to those disclosed in FIG. 5. With the rotor having a diameter of 12 inches and operating at a speed of 7100 r.p.m., the table below indicates the effectiveness of the control.

Brine rate:	Percent oil in wax
1.6	27
1.2	41
0.9	46
0.65	57

From the above it will be clearly understood that by controlling the feed rate of supplemental liquid, e.g. brine, the quality of the wax may be correspondingly controlled. This eliminates the requirement of stopping the centrifuge and replacing ring dams or tube dams. It will be understood, as with the older means of adjusting quality of the wax, the optimum operating conditions are those at which the wax quality is highly consistent with suitable clarification of the oil. For this reason as the supplemental liquid rate is adjusted in accordance with the present process, the discharging light phase is observed. Should the oil become visually foamy and/or cloudy there is indication that clarification is probably inadequate and accordingly downward adjustment of the brine rate must be made. Additionally to assure that the lighter phase is properly clarified, periodic pour point checks are made on the light phase discharge.

It will be obvious to those skilled in the art that reasonable variations from the above disclosure may be made. For instance, it would be possible to feed the mixture around the skirt and to the outside of the disc stack if desired. The rotor disclosed is the embodiment I prefer.

Therefore, having particularly described my invention, 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. In a centrifuge suitable for the separation of a liquid-solids mixture where a liquid-liquid interface is established with a second liquid of greater density than the first liquid and said solids are passed outwardly across said interface into said second liquid to form a second liquid-solids mixture, said centrifuge comprising a frustoconical disc stack and a bowl shell having a top wall, bottom wall and a circular sidewall, said frustoconical disc stack and bowl shell being rotatably mounted about a central axis, said bowl shell containing a separating chamber and an annular pssageway extending radially outward from said separating chamber to said sidewall, said annular passageway communicating with said separating chamber through a peripheral opening, said centrifuge having a first inlet means, including an air gap, for the first liquid-solids mixture, said first inlet means communicating with said separating chamber, a second

inlet means, including an air gap, for said second liquid, said second inlet means communicating with said passageway, a first outlet means for said first liquid communicating with said separation chamber and a second outlet means for the said second liquid-solids mixture communicating with said passageway, the improvement consisting of a system for accurately positioning the location of the liquid-liquid interface without stopping operation of the centrifuge, said system comprising in combination:

(1) control means for adjusting the feed rate of said second liquid;

(2) an overflow weir located in said second liquid-solids mixture outlet means, said weir being so constructed and arranged as to produce a horizontal crest in the second liquid-solids mixture overflowing said weir

whereby an increase in the feed rate of said second liquid results in moving said liquid-liquid interface radially inward while a decrease in said feed rate resulting in moving said interface radially outward; and

(3) a dividing cone in said bowl between said disc stack and said top wall of the bowl shell, with at least one radially disposed spacer element intermediate said dividing cone and said top wall maintaining them in spaced relationship to define at least a portion of said second outlet means.

2. Apparatus according to claim **1** wherein said spacer element has a gap therein to provide a free annular zone about said dividing cone, between said dividing cone and said top wall, in the flow path of the second liquid-solids mixture.

3. Apparatus according to claim **2** comprising a plurality of such spacer elements, with the respective gaps therein being at substantially the same radii relative a rotational axis of said bowl.

4. Apparatus according to claim **1** further including non-radial baffles located radially outwardly of the disc stack and inwardly of the circular sidewall of said bowl shell.

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U.S. Cl. X.R.

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