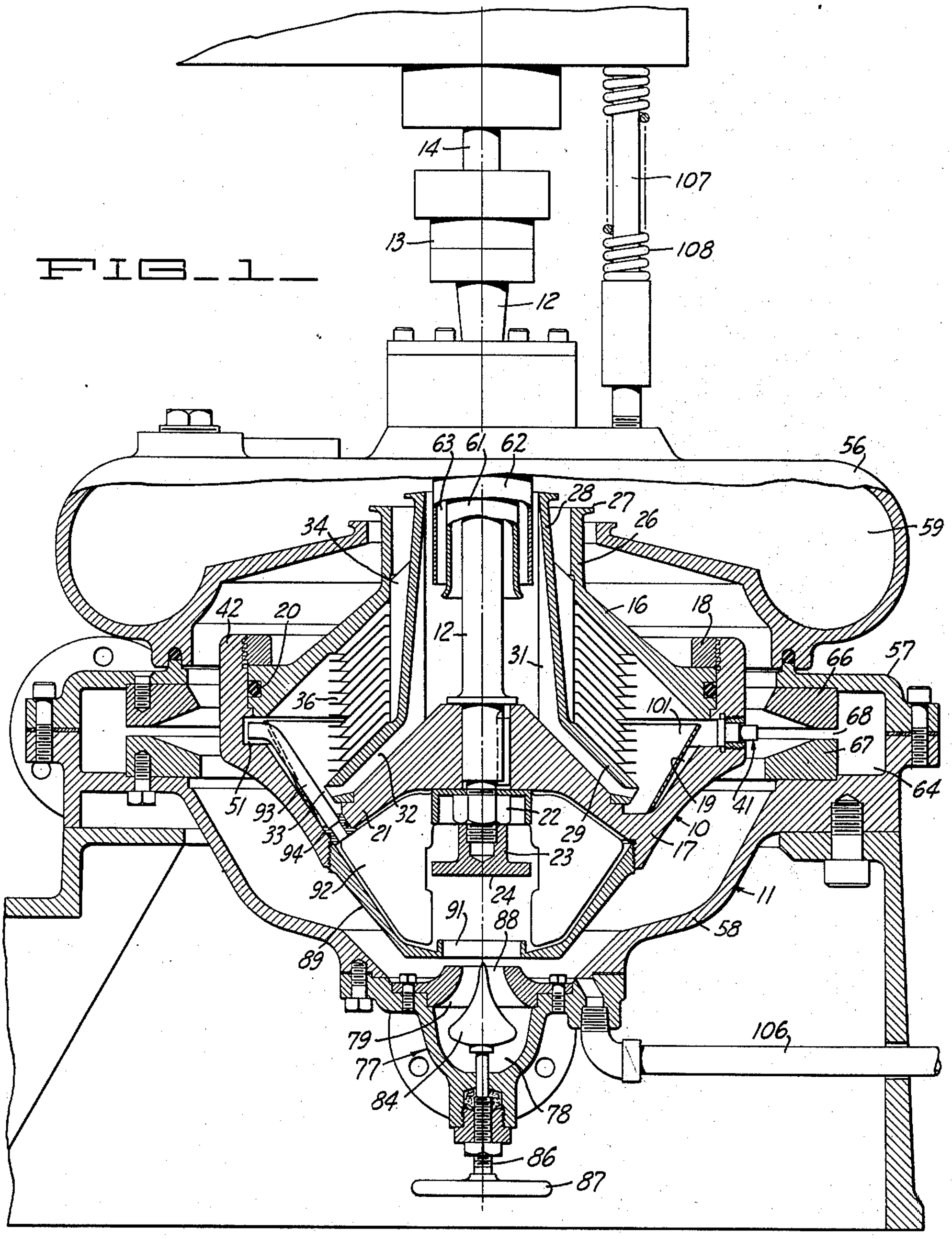
Nov. 1, 1960 **A. PELTZER, SR** 2,958,461

CENTRIFUGE MACHINE

Original Filed July 17, 1951 3 Sheets-Sheet 1

FIG_1_



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Nov. 1, 1960 A. PELTZER, SR 2,958,461

CENTRIFUGE MACHINE

Original Filed July 17, 1951 3 Sheets-Sheet 2

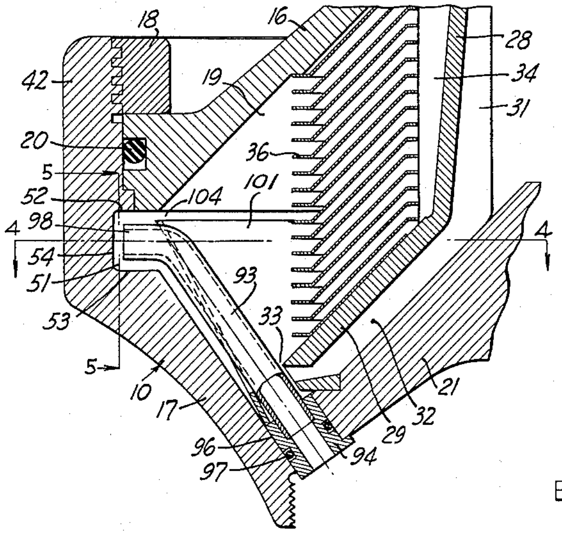


FIG_3_

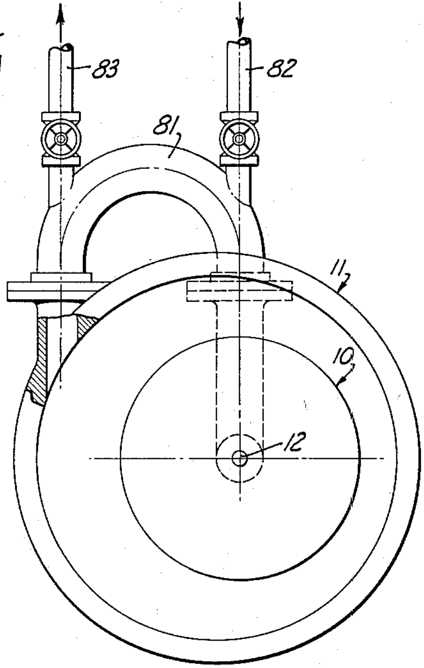


FIG_2_

FIG_5_

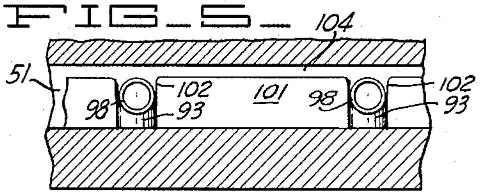
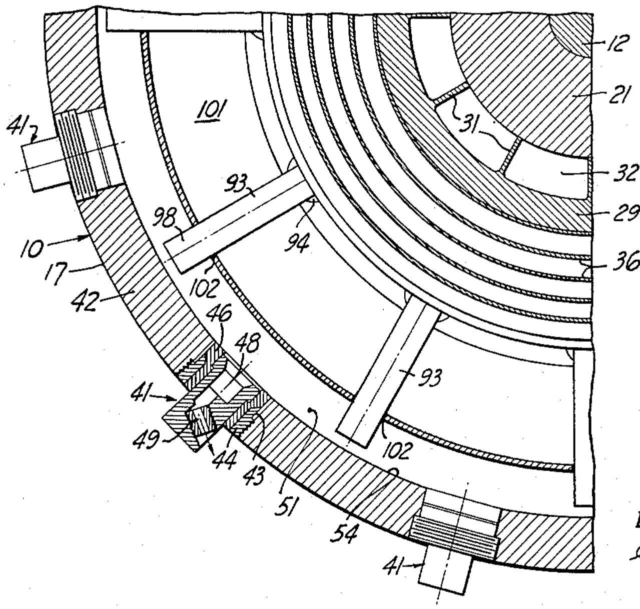


FIG_4_



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3 Sheets-Sheet 3

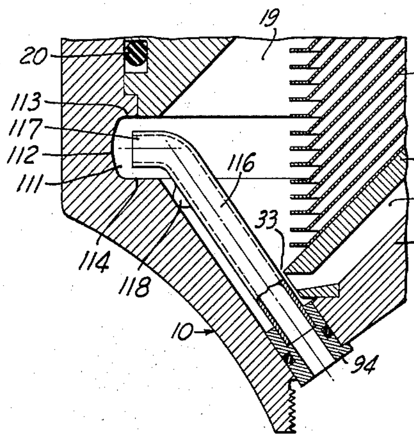


FIG_6_

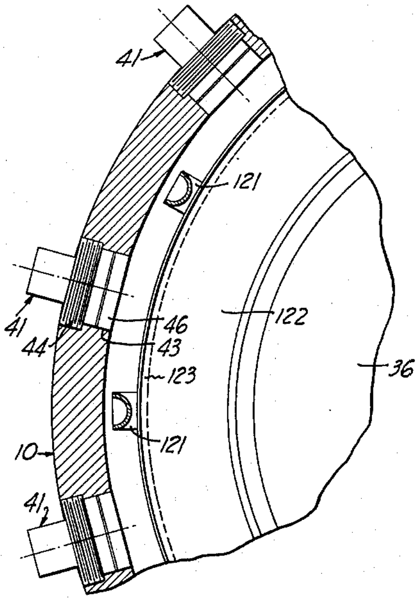


FIG_8_

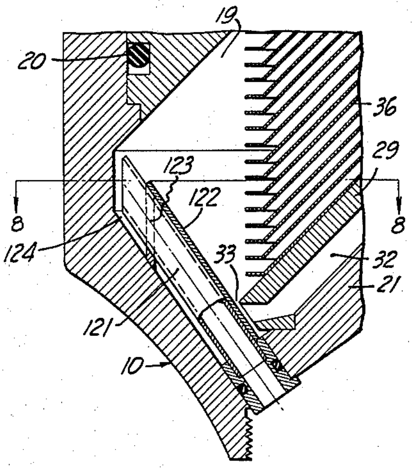


FIG_7_

FIG_9_

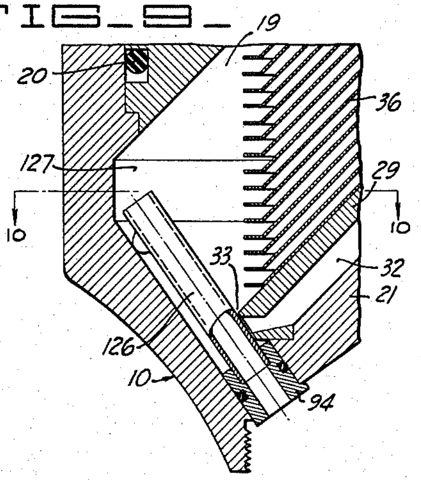
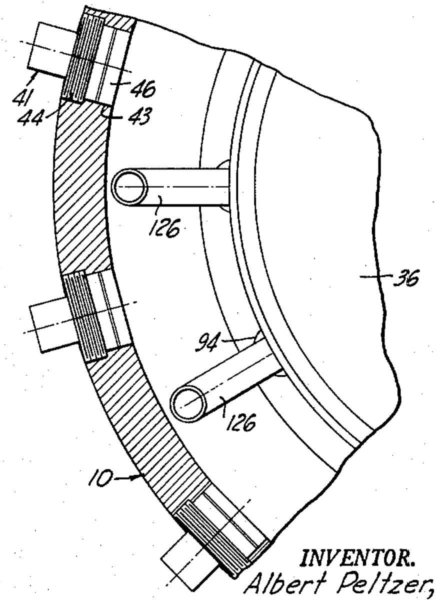


FIG_10_



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2,958,461
Patented Nov. 1, 1960

2,958,461

CENTRIFUGE MACHINE

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Continuation of abandoned application Ser. No. 237,236, July 17, 1951. This application Feb. 19, 1959, Ser. No. 794,464

13 Claims. (Cl. 233—14)

My present invention relates generally to centrifuges of the type adapted for the continuous separation and discharge of solid components from a fluid feed material containing suspended solids. My invention also relates to centrifugal separating methods which may be carried out by such machines, and the present application is a continuation of my copending application Serial No. 237,236 filed July 17, 1951, and now abandoned, which in turn is a continuation-in-part of my then copending application Serial No. 100,488, filed June 28, 1949, now abandoned.

More particularly my invention relates to continuous return circuit centrifuges in which part of the separated underflow is continuously returned into the centrifuge rotor for redischarge through the underflow nozzles with provision for the efficient recovery of solubles of the feed liquid, as well as for the separation of solids.

The first presently known proposals for centrifuges providing for return of underflow are disclosed in Swedish Patent No. 25,442 of 1907 and in the corresponding British Patent No. 10,314 of 1908. In each of these patents, one embodiment is shown with relatively large tapering return tubes discharging at the rotor nozzle entries, and in another embodiment such tubes are shown discharging between the nozzles. No effort was made to recover solubles in the feed liquid, and the stated object of these patents was the provision of centrifugal machines for separating solids from liquids provided with means for preventing obstruction of the discharge nozzles. These structures are such that mixing of feed liquid with the returned underflow necessarily results in causing substantial loss of solubles as well as inefficient separation of solids. The sole control mentioned, but with no disclosure of method, is the maintenance of the total amount of discharged solids and return fluid nearly constant, independently of variations in the amounts of solids separated. Tests have shown that large tapering return feed tubes clog readily, particularly with heavy underflow return feed. No settling zone is disclosed between the discs and bowl periphery, and the general arrangement is very inefficient, although the patents were owned by the oldest highly skilled manufacturer of continuous non-return centrifuges. If any such machines were built, they were not put into general commercial use, and the owner until recently has manufactured only non-return types of continuous centrifuges.

The first commercially successful return type centrifuges providing for fairly efficient recovery of solubles and separation of solids appeared on the market years later. They were manufactured under U.S. Patents 1,847,751; 1,923,454 and 1,945,786. In these machines fairly successful control of the important function of separating the original feed liquid from the discharging solids to effect soluble recovery was provided. U.S. Patent No. 1,847,751 illustrates the earliest such commercial machine utilizing return circuit tubes which discharged only at the rotor bowl nozzle entries. The return tubes were improved upon at an early date by a cone shaped return impeller provided with impeller vanes extending from the lower conical surface of the impeller to the lower conical bowl section and which distribute the return feed around the discharge periphery of the bowl as illustrated for example in U.S. Patent No. 1,945,786. These and later tubeless centrifugal machines such as shown in U.S. Patents 2,013,668 and 2,060,239 utilize a rotor which has provision for introducing fluid feed material into the separating chamber, an overflow lip for discharging the centrifugally separated overflow, and underflow discharge nozzles mounted upon the peripheral margin of the rotor. The rotor is also provided with an impeller which has an axially disposed opening and which is connected to discharge material into the outer part of the centrifuge chamber through an annular space of substantially uniform cross-sectional flow area which distributes the returned underflow into a so-called racing chamber forming the outer part of the separating chamber. The housing which surrounds the rotor is provided with a volute or like means for collecting the centrifugally separated underflow. The flow connection from this volute serves to deliver a large portion of the underflow back into the centrifuge chamber through the axial impeller opening. Provision is made for introducing wash liquid into the return circuit to displace substantially all of the liquid in the feed into the overflow with the solubles contained therein. This is a highly important operation termed "soluble blocking" in the art and to improve the efficiency thereof is a primary object of my present invention.

Under certain operating conditions and more noticeably in prior machines of smaller sizes, there has been a tendency towards dispositing of solids between the underflow discharge nozzles. After periods of operation, deposits of underflow solids have been found in the outer part of the separating chamber in regions intermediate the discharge nozzles. These deposits frequently attain the proportions of tetrahedrons with one of the triangular corners parallel with the center of rotation which may extend inwardly to the separator discs. These difficulties are also present more noticeably in a recently introduced return type commercial centrifuge machine using a series of tubes for continuously returning underflow material. In this latter machine the return circuit tubes extend outwardly into the lower part of the separating chamber and discharge into pockets formed at the inlet ends of the underflow discharge nozzles in an effort to prevent clogging of the nozzles. During operation, underflow solids also accumulate in the outer part of the separating chamber of this machine in regions intermediate the inlet ends of the underflow nozzles, tending to form substantial tetrahedrons extending for a substantial distance into the separating chamber. In both types of machines such accumulations tend to limit separating capacity, and frequent clogging of the underflow nozzles occurs which is attributed to sloughing off of fragments of such deposits. In addition to these difficulties the latter tube type machine is subject to clogging of the tubes which deliver the underflow material into the separating chamber.

The range of commercial uses for continuous return centrifuges is in part dependent upon their capacity. The separating capacity of such prior art machines for a given fluid feed material and desired efficiency of separation, as well as the amount of wash liquid which can be employed with a given size rotor capable of operation at a given speed of rotation, is limited. Efforts to crowd the prior machines beyond these limits by increasing the feed rate and amount of wash water result in definite impairment of the separating efficiency of particular machines. According to my observations, the amount of fresh wash liquid which can be used during operation of the machine is a measure for the capacity which can be obtained without sacrifice in separating efficiency. Limitations as to capacity and the amount of wash water which can be employed serve to limit the range of usefulness of such return type centrifuge machines, and in many instances their application is made impractical for economic reasons.

Accordingly, a further primary object of the present invention resides in the provision of new centrifuges of the continuous return type which overcome the foregoing limitations and disadvantages of prior return machines.

It is another object of my invention to provide a new centrifuge of the continuous return type which for a given diameter of rotor and speed of rotation will afford a relatively high capacity in comparison with capacities heretofore obtained with prior machines.

A further object resides in providing an improved centrifuge of the continuous type which permits use of relatively greater amounts of wash liquid in the underflow return circuit with high separatory efficiency and improved regulation of the amounts of feed and wash liquids passing either way through the machine with improved soluble blocking.

A still further object of my invention is provision of new return type centrifuges and methods of utilizing and controlling the return of underflow material, whereby much higher capacities can be obtained in machines of given size without sacrifice in separating efficiency and whereby plugging or clogging of the underflow nozzles is alleviated.

Another object of the invention is to provide a centrifuge of the continuous type having a return circuit for underflow material which does not require the use of an excessive number of underflow discharge nozzles, and which is consequently relatively efficient with respect to power consumption.

Still another object of the invention is to provide a novel centrifuge method characterized by the novel manner in which optimum separating conditions are maintained in the separating chamber, and by the manner in which the returned underflow material is utilized to minimize or prevent the build up of tetrahedrons of solid material between the underflow nozzles.

Additional objects and features of the invention will appear from the following description in which the preferred embodiments have been set forth in detail in conjunction with the accompanying drawings, and within the scope of the present invention as defined by the appended claims.

The foregoing objects I accomplish in general by the use of properly proportioned and arranged underflow return tubes which distribute the returned underflow and wash liquid between the bowl nozzles adjacent the bowl periphery in a manner and at velocities that prevent accumulations of solids between the nozzles, minimize or eliminate clogging of the nozzles, and, for soluble recovery, displace original feed liquid with wash liquid causing the original feed liquid to pass out in the overflow, all with a substantially greater degree of control and efficiency than has heretofore been available in return type machines.

In accomplishing these new improved and highly desirable results I have discovered that the following factors are interrelated and of varying importance: (*a*) the number and position of discharge of the return tubes with respect to the bowl nozzles, (*b*) tube size, (*c*) the differential head created by relative bowl entry diameters and overflow discharge diameter, (*d*) the speed, size and shape of rotor bowl, (*e*) the nature of the separation desired, (*f*) the viscosity and other characteristics of the process liquids, (*g*) the percentage and physical characteristics of the process solids, and (*h*) the number and size of underflow nozzles vs. tube size and number.

The correct position for tube discharge is important, and should be substantially midway between adjacent bowl nozzles for optimum results. Tubes slightly leading mid-position are not too harmful. In a series of tests made with a liquid containing refined starch solids slurried in salt water which gives generally typical results, and with the return tube discharges leading and lagging the exact mid-nozzle location, the overflow invariably contained considerably less solids with the tubes discharging at mid-position between nozzles than when shifted from mid-position. Lagging mid-location was very detrimental and slightly leading mid-location was somewhat worse than mid-location, but not too detrimental for use. As mid-location is approached the separator results improve. Tubes discharging parallel to the periphery of the bowl are not especially beneficial over tubes discharging radially.

These tests show that the inside pipe size or cross sectional area of the tubes is important in relation to the number of tubes used, volume of fluid passing through the tubes, the differential head pumping the fluid through the tubes and the nature of the fluid itself. The velocity of the return tube jet discharge must be great enough to keep the bowl, nozzles and the tubes themselves cleared. Tubes too large in area relative to area of underflow nozzles plugged up with solids. The tube length may be varied without adversely affecting clarification of the overflow to any substantial extent so long as the clearance between the end of the tube and bowl is sufficient to avoid clogging of the tube, and so long as velocity of the jet discharge is sufficient. The minimum clearance of the tube ends should be about equivalent to one-fourth of the tube outlet diameter.

Now referring to the drawings:

Figure 1 is a side elevational view in section illustrating one specific embodiment of my invention.

Figure 2 is a diagrammatic plan view on a reduced scale, illustrating particularly a portion of a return circuit for returning underflow material.

Figure 3 is an enlarged cross-sectional detail of a portion of the rotor and particularly illustrating a part of the underflow return circuit.

Figure 4 is a quarter plan section of the rotor, illustrating the underflow discharge nozzles and the positioning of the underflow return tubes.

Figure 5 is an enlarged cross-sectional development taken along the line **5—5** of Figure 3.

Figure 6 is a cross-sectional detail like Figure 3 but illustrating another embodiment of the invention.

Figure 7 is a cross-sectional detail like Figure 3 but illustrating another embodiment of the invention.

Figure 8 is a cross-sectional detail taken along the line **8—8** of Figure 7.

Figure 9 is a cross-sectional detail like Figure 3 but illustrating a further embodiment of the invention.

Figure 10 is a cross-sectional detail taken along the line **10—10** of Figure 9.

That embodiment of the invention illustrated in Figures 1 to 5 inclusive consists of a rotor **10** which is disposed in the housing **11.** The rotor is carried by the vertical shaft **12** which in turn is connected by coupling **13** to the vertical drive shaft **14.**

For convenience the rotor **10** is made of a number of separable annular parts. Thus, the upper and lower frustro-conical bowl parts **16** and **17** are fitted together and held in assembled relationship by the threaded lock ring **18.** Parts **16** and **17** are formed to provide the inner separating chamber **19** having upper and lower conical outer wall sections converging outwardly from the axis of rotation to the bowl discharge nozzles hereinafter described. The fit between these parts is sealed by suitable means such as the resilient O-ring **20.** The lower part **17** is provided with an inner frustro-conical hub **21** which is fitted upon the lower end of the shaft **12** and forms one wall of the feed passages for the separating chamber. The lower extremity of the shaft **12** is threaded to receive the nut **22** and the threaded sleeve **23**. Nut **22** serves to hold the bowl assembly and an impeller assembly hereinafter described to shaft **12**. Sleeve **23** is flanged to provide a disc like lower face **24**, for a purpose to be presently explained.

To provide means for the discharge of centrifugally separated overflow, the upper section **16** is provided with a cylindrical extension **26**, which terminates with the annular over flow lip **27**. A conical sleeve-like member **28** is positioned within rotor section **16** and is provided with a lower flared portion **29** overlying the inner portion **21** of the bowl section **17**. Member **28** is provided with inwardly extending circumferentially spaced ribs **31**, and the spaces between these ribs form outwardly discharging passages **32** for introduction of feed material. Feed material introduced through passages **32** enters the separating chamber **19** at relatively high velocity through the annular orifice **33** adjacent the lower end of the upwardly inclined frustro-conical lower outer wall of chamber **19**.

The exterior ribs **34** of member **28** serve to maintain spaced relationship with the upper rotor section **16**, thus permitting flow of overflow material to the lip **27**. A stack of spaced conical-shaped separating discs **36** located by ribs **34** have outer horizontal discharge lips having a diameter approximately equal to that of the feed annular orifice **33**. This provides a settling or separating region or zone surrounding the feed orifice and the outer edges of the discs for effective separation of the solids from the feed and for separation of the feed from the return in a manner that will more fully hereinafter appear. During operations of the rotating chamber **19** the feed material entering through inlet **33** will resolve itself into an annular zone whose inner boundary is located approximately at the outer edges of the discs **36** and surrounds the discharge or the inlet orifice **33** thus assuring that the feed inlet is wholly within the settling or separating zone. As separation of the solids from the feed material commences, the outer boundary of the separating zone resolves to a position radially inward of the peripheral margin of the separating chamber and outer zone of separated solids occupies the annular space which surrounds the outer boundary of the separating zone. This separation of the feed material into three concentric zones with the lighter materials or solubles occupying the inner zone, the feed material occupying a mid zone and the heavier materials or solids occupying the outer zone is well known to those familiar with continuous rotor centrifuges.

The centrifugally separated underflow material is discharged from the rotor through the nozzles **41**, which are mounted at circumferentially spaced points (Figure 4) on the outer peripheral margin **42** of the rotor. The details of construction of these nozzles may vary, but to reduce power loss it is desirable that they discharge material backwardly with respect to the direction of rotation. In the nozzle construction illustrated in Figure 4 the rotor is provided with the radially extending openings **43**, which are threaded to receive the collars **44**. A bushing **46** is fitted within and seated upon a collar **44**, and forms a mounting for the body of a nozzle **41**. The flow passage through this nozzle includes the portion **48** which extends in a radial direction, and the orifice portion **49** which is directed backwardly with respect to the direction of rotation.

In that form of the invention illustrated in Figures 1 to 5 inclusive, the inlet ends of the nozzles **41** all communicate with an annular recess **51**, a so-called racing chamber, which in turn communicates on its inner side with the main separating chamber **19**. While this racing chamber is not necessary in the practice of this invention, it has been found helpful to soluble blocking although it is not particularly helpful to overflow clarification or separation of solids. As shown particularly in Figure 3 the annular recess **51** is defined by the spaced upper and lower horizontal surfaces **52** and **53**, and the peripheral surface margin **54**.

The outer stationary housing **11** is preferably made from a number of separable annular sections including particularly the parts **56**, **57** and **58** (Figure 1). The upper section **56** forms an annular volute or chamber **59** for receiving overflow material discharging over the lip **27**, and carries the concentric conduits **61** and **62**, which provide a passage **63** for introducing feed material into the feed well formed by the member **28**. Housing sections **57** and **58** are formed to provide annular chamber or volute **64**, which receives underflow material discharged from the nozzles **41**. Filler rings **66** and **67**, carried by the housing sections **57** and **58**, may be provided to form between them a relatively restricted annular throat passage **68** through which jetting material enters volute **64**. By maintaining a liquid level in the restricted throat passage **68** kinetic energy of the discharging underflow material is substantially converted to static pressure head in the volute chamber **64**.

In the embodiment of Figures 1 to 5 inclusive the underflow return circuit comprises lower housing **77** (Figure 1) forming inlet passage **78** to nozzle **79**. Inlet **78** is in communication with the discharge end of conduit **81** (Figure 2), the inlet end of which connects tangentially with the underflow volute chamber **64**. Valve controlled pipe **82** is provided for controlled introduction of wash liquid into conduit **81** and final drawoff of underflow material is effected through valve controlled pipe **83**.

A needle valve member **84** (Figure 1) carried by the threaded operating stem **86**, which extends to the exterior of the housing and is provided with the operating hand wheel **87**, is preferably provided to control the velocity of the jet of return underflow and wash liquids. By turning the hand wheel **87** the effective flow area in the orifice **88** of nozzle **79** may be varied as may be desirable to keep the velocity of the jet at the proper point.

The centrifuge rotor provided with an impeller assembly receives the material discharged upwardly through nozzle **79**. This assembly comprises a conical-shaped impeller part **89** attached to the rotor part **17**, provided with a downwardly faced axial opening **91** aligned with and directly above the nozzle **79**. Circumferentially spaced radial vanes **92** impart rotary velocity to returned fluid material which is impelled upwardly along the conical inner surface of bowl section **89**.

A plurality of return tubes **93** (Figures 1 and 3 to 5) are located in the lower part of centrifuge chamber **19** overlying the inner conical surface of the bowl section **17**. The lower inner ends of the tubes **93** communicate with the impeller chamber and in the construction shown are secured to the sleeves **94**, which in turn are removably seated within the openings **96** formed in the bowl section **21**. Suitable sealing means such as a resilient O-ring **97** serve to prevent leakage past each sleeve. The outer ends **98** of the tubes **93** are substantially unobstructed, and discharge adjacent the outer periphery of separating chamber **19**. As illustrated in this embodiment the tubes are bent to discharge horizontally and at right angles to the surface **54** into racing chamber **51** midway between nozzle assemblies **41** as illustrated in Figure 4, and the number of tubes equals the number of nozzles. The diameter of tubes **93** and their location is an important feature of my present invention. As hereinbefore pointed out their diameter must be such as to maintain adequate velocity to prevent clogging within the tubes and also prevent accumulation of solids between rotor nozzles at the inside periphery of the rotor. Optimum results are secured when they discharge midway between nozzles.

It will be seen that from the structure so far described that complete separation between the fed material and the returned underflow is maintained with the feed entering the main separating chamber **19** radially well within the discharge ends of tubes **93**.

With twelve nozzles and tubes as illustrated in this embodiment, the distance between the discharge end of each tube **93** and the inlet ends of the adjacent nozzles is substantially less than the radial distance from the axis of rotation to the discharge end of each tube **93**. While a greater or lesser number of nozzles and tubes may be used for particular applications as hereinbefore set forth, it is generally desirable to maintain a relationship between the chord distance from the discharge end of tube to adjacent nozzle and the radial distance from axis of rotation to discharge end of tube of unity or less.

A shroud or barrier **101** preferably frustro-conical in shape, between the recess **51** and the main part of the separating chamber aids in soluble blocking. With this barrier or shroud, communication between recess **51** and the main part of separating chamber **19** is through the annular space **104**.

A drain pipe **106** (Figure 1) connected to the lower end of housing **11** serves to remove spilled material. Guide rods **107** urged downwardly by compression spring **108**, facilitate assembly of the machine.

Operation

In operation of the machine illustrated in Figures 1 to 5 inclusive a suitable feed material as for example mill starch liquor containing finely divided starch particles, gluten particles and solubles, is supplied to feed passage **63** while the machine is in operation. Within the separating chamber centrifugal forces act upon the material to separate the starch from the lighter gluten. The feed liquid containing solubles and gluten is carried off continuously in an overflow established over the lip **27**. An underflow of separated starch and carrying liquid is established through the discharge nozzles **41**, fills the volute chamber **64** and establishes a pressure head in the return circuit **81**, whereby a controlled large portion of the underflow material is continuously returned to the centrifuge rotor. The returned material jets upwardly from the nozzle orifice **88** into the impeller section **89** and is then discharged outwardly through the tubes **93**, to be finally delivered into the confined annular recess or racing chamber **51**. In a typical starch and gluten separation 85% or more of the discharged underflow material is continuously returned into the centrifuge rotor in this fashion and underflow material redischarges through the nozzles **41**, together with freshly separated underflow solids.

The use of a wash water or wash liquid introduced by way of pipe **82** is generally desirable to promote efficiency of separation, particularly where the feed material contains solubles which it is desired to block or to keep out of the underflow. Wash liquid introduced through pipe **82** serves to displace feed liquid containing solubles from the underflow material at the inner periphery of the rotor bowl and forces it into the overflow to the extent of the displacement thus blocking the solubles from passing into the underflow. The wash liquid which displaces the feed liquid passes out into the underflow. When less wash liquid is employed than the liquid removed in the underflow, a condition of so-called downflow exists within the rotor; and when more wash liquid is used than the amount of liquid removed in the underflow an upflow condition exists. During downflow part of the feed liquid passes out with the underflow, and during upflow part of the wash liquid moves countercurrently through the separating chamber for discharge with the overflow.

The relative amount of wash liquid used in practice is dependent upon the type of operation. For maximum displacement of solubles into the overflow, it is the practice to employ wash liquid in sufficient amounts to maintain an upflow condition. Where the soluble separating requirements are not exacting, the amount of wash water employed may be reduced to provide a downflow condition. In instances where two or more centrifuges are used in cascade, the first centrifuge may operate with downflow and the second with upflow.

While it is impossible to make direct observations as to what takes place within the centrifuge chamber **19** according to my present observations and understanding, the feed fluid passes down and outward through section **28**, passages **32** and orifice **33** adjacent the bottom of chamber **19** and is forced upward by the inner conical surface of section **10** of the bowl into the zone of chamber **19** surrounding the discs **36** where heavier feed overflow components are separated and pass out through orifice **104** (Figure 3) into racing chamber **51**, and the overflow passes upward through the disc stack **36** over lip **27** into volute **59**. In the stack further separation of heavier components occurs from the liquids passing upward through the stack.

From chamber **51** the underflow discharges through nozzles **41** into volute **64**. Underflow in the proportion desired is divided and part is drawn off through pipe **83** (Figure 2) while the remainder is returned through conduit **81**, orifice **79** (Figure 1) and the impeller assembly through tubes **93** with the desired amount of wash liquid added through pipe **82** (Figure 2).

The mixture of underflow and wash liquid discharges through the tubes **93** with relatively high radial velocity and with a jet action from the outer ends of these tubes. Since the material is confined within the tubes until the instant of its discharge from the outer end thereof, rotary velocity is imparted to it equal to about the peripheral velocity of the outer ends of the tubes. Since discs **36** terminate short of the outer ends of the pipes **93**, returned material as it enters recess or chamber **51** has a relatively high apparent specific gravity compared to the material in the main separating zone of chamber **19** surrounding discs **36** and this contributes to the jet action from tubes **93**. The underflow material discharging through tubes **93** apparently largely fills the peripheral bowl space or recess **51** between the nozzles and flows circumferentially in a peripheral layer of live slurry discharging through underflow nozzles **41**. While flowing through recess **51** or along the outer bowl periphery when recess **51** is not used, a continual exchange of solids and liquid occurs between the returned live slurry layer and the material in the adjacent separating zone. Thus, centrifugally separated solids from the feed move outwardly from the main separating chamber through the space **104** into the recess **51**. Assuming that the amount of wash water or liquid is sufficient to provide upflow conditions, wash liquid flows from the recess **51** through space **104** in Figure 3 into the main separating chamber, to thereby effectively displace feed liquid and solubles from the centrifugally separated underflow solids. It will be noted that this continuous exchange between material in the outer live slurry layer and material in the main part of the separating chamber or adjacent separating zone is relatively evenly distributed completely about the rotor, whereas the returned material discharging from the outer ends of the tubes **93** is sharply localized in regions located midway between the discharge nozzles **41**. Therefore, the exchange takes place while the bulk of the material in recess **51** or the live slurry layer is flowing circumferentially toward nozzles **41**.

The returned peripheral live slurry layer is apparently maintained in a continual state of agitation due to eddy currents imparted to the material within the tubes **93**, and to further turbulence and eddy currents caused by material jetting from the outer ends of these tubes against the bowl periphery between the nozzles. Such turbulence or eddy currents are largely confined to the live slurry layer and do not spread into the main separating chamber to interfere with efficient separating action. However, the formation of tetrahedrons present in the prior art machines due to collection of centrifugally separated solids between the nozzles is either prevented in entirety or maintained within such size limits as to avoid interference with the operation of the machine. I attribute this highly important effect to the sweep action coupled with the high apparent specific gravity of the returned live slurry layer flowing circumferentially through the recess **51**.

An important characteristic of my invention is attainment of higher separating efficiencies with considerably higher capacities and/or use of considerably larger amounts of wash water than are possible in prior machines. With my invention, the rate of feed can accordingly be greatly increased over the prior art machines, and the amount of wash liquid can be greatly increased to secure efficient separation with respect to both solids and solubles. I attribute this to the manner in which liquid from the returned material is transferred to the main separating chamber, and also to the substantial or complete elimination of tetrahedrons of accumulated solids between nozzles which interfere with capacity and separating efficiency. As previously stated the relative amount of wash liquid or water employed can vary according to the separating requirements and the capacity desired. When operating with upflow conditions a relatively high capacity may be maintained while at the same time the rotor may be supplied with sufficient wash water to provide an upflow with a substantially more efficient displacement of solubles into the overflow as hereinbefore pointed out.

By way of specific example, the rotor in one instance had an external diameter of 11.25 inches and operated at a speed 7000 r.p.m. The outer and inner diameters of recess **51** were 10.25 and 9.25 inches respectively. Surfaces **52** and **53** had a radial width of 0.5 inch, and the vertical distance between these surfaces was 0.5 inch. Twelve underflow discharge nozzles were employed, with each nozzle having effective nominal orifice diameter of 0.064 inch. Twelve tubes **93** were employed, each having an internal diameter of 0.31 inch. The outer ends of these tubes were located midway between adjacent nozzles. The return inlet opening **91** had a diameter of 1.5 inches and the internal diameter of the overflow lip was 3.8 inches. The machine was operated on 14.5 Baumé starch feed containing 25.8% solids. This liquor was supplied to the machine at a feed rate of 34,000 cc. per minute with discharge of the overflow at the rate of 28,000 cc. per minute, and the underflow drawoff at 26,700 cc. per minute. The underflow was maintained at 18.2 Baumé and contained 32% dry solids. Fresh wash water was added at the rate of 20,700 cc. per minute. The material discharged from the underflow nozzles at the rate of approximately 226,700 cc. per minute, and underflow was continuously returned to the rotor at the rate of about 200,000 cc. per minute. The separating capacity in terms of dry starch per twenty-four hours was 31,000 pounds, and this was attained with highly efficient separation (minimum starch solids in overflow and minimum solubles in underflow drawoff). This contrasted with a maximum capacity of about 10,000 pounds per twenty-four hours for a machine of comparable size constructed substantially as illustrated in Patent 1,945,786, and operated with comparable separating efficiency. During operation of the machine there was complete freedom from clogging of the underflow nozzles and tubes **93**, and there was no substantial evidence of accumulated tetrahedrons when the machine was inspected after test runs such as are present in the prior machines.

The machine referred to above by way of example was not provided with a barrier or shroud member **101**. With such a barrier in place, the capacity of the machine was substantially the same, but the efficiency of separation with respect to the solubles contained in the feed was substantially bettered. In other words, more efficient displacement action occurred to displace such solubles into the overflow.

After extended periods of operation dismantling of the

machine (made according to the foregoing sample) revealed that no accumulation of solid material, such as formed in prior machines, occurred in the centifuge chamber or in the annular recess **51**. According to my observations and present understanding, the absence of such accumulated solids is largely responsible for the absence of plugging or clogging of the underflow discharge nozzles, and also contributes to attaining the remarkably high separating capacity. In addition it is well known that accumulations of starch or like solid material in the centrifuge machines used for processing food products is objectionable because such deposits offer a possible source of contamination by bacteria or other micro-organisms, or may require expensive periods of shutdown for cleaning the machine.

Previous reference has been made to the relatively high velocity flow through the tubes **93**. High velocity flow through the tubes is desirable not only because it causes the desired circumferential peripheral live slurry flow between the nozzles, but in addition it prevents clogging of the passages through the tubes. Relatively high flow velocity through the tubes **93** is due in part to the relatively high differential head applied to the returned material. This can be better understood by reference to Figure 1. Thus as in the case of the dimensions specified by way of example, the inlet **91** of impeller section **89** is comparatively small relative to the diameter of the overflow lip **27**. At rotative speeds such as used to obtain good separation, the relatively large difference in diameter at these points results in a substantial difference in hydraulic head between the underflow material being returned into the recess **51** at the outer ends of the tubes **93**, and the head on the material moving outwardly through the separating chamber at the outer ends of tubes **93**. For the particular machine specified in the foregoing example, the differential head at the outer ends **98** of the tubes **93** calculates theoretically to be of the order of about 180 feet of water for a rotational speed of 7,000 r.p.m. In practice I prefer that the differential head be of the order of from 50 to 100 feet of water or more.

My invention can be modified in various ways within the scope of the appended claims. Thus castings or other structures can be used in place of the tubes **93**, and which provide comparable passages for discharging the returned underflow material into localized regions intermediate the underflow discharge nozzles, in substantially the same manner as the tubes.

The return circuit need not be a direct closed return passage, as illustrated in Figure 2. Thus it is possible to include in the return circuit a vent box or flotation cell as disclosed in Patent 2,039,605.

In the embodiment of the invention illustrated in Figure 6, the recess **111**, corresponding to recess or racing chamber **51** of Figures 1 to 5 inclusive, is defined by an outer curved wall **112**, and the upper and lower surfaces **113** and **114**. The tubes **116**, corresponding to tubes **93**, have their outer ends **117** terminating within the recess **111**. The tubes are provided with pads **118** for seating upon the adjacent surface of the bowl. It will be noted that in this embodiment the shroud or barrier member **101** has been omitted.

In the embodiment illustrated in Figures 7 and 8 the construction of the bowl is further simplified. Tubes **121** deliver the returned material into the outer portion of the separation chamber and intermediate the discharge nozzles. A shroud **122** overlies the tubes **121** and another shroud or barrier **123** extends between the tubes **121**, and downwardly from the outer periphery of the shroud **122**. This construction forms in effect an annular space **124** which serves in place of the annular bowl recess **51** of Figure 1.

A further simplified embodiment of the invention is illustrated in Figures 9 and 10. In this instance the bowl is constructed the same as in Figure 7, and the tubes

126 discharge underflow material into the outer peripheral portion 127 of the separating chamber. The outer ends of the tubes 126 are located midway between the underflow discharge nozzles. This embodiment makes possible higher capacity than conventional centrifuges, although it is not as effective as the embodiments previously described in making possible high capacity together with efficient displacement of solubles by wash.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims, are therefore intended to be embraced therein.

I claim:

1. In a centrifuge, a rotor having an annular separating chamber provided with a passage for introducing a fluid feed material into the chamber, and also having provision for discharge of a centrifugally separated overflow; underflow discharge nozzles mounted at spaced points on the peripheral margin of the rotor; and means for continuously returning underflow material back into the centrifuge rotor separately from the feed material including substantially unobstructed tubes arranged to discharge streams of returned underflow material into the periphery of said chamber at localized regions substantially midway between adjacent ones of said nozzles.

2. In a centrifuge, a rotor having an annular separating chamber with an inlet for fluid feed material and constructed to discharge centrifugally separated overflow radially inward of said inlet and centrifugally separated underflow radially outward of said inlet; underflow discharge nozzles mounted at spaced points on the peripheral margin of the rotor; and means for continuously returning underflow material separately from said feed material back into said rotor to maintain a circumferentially flowing zone of material of underflow discharge consistency surrounding the zone of separation including substantially unobstructed tubes having their inlet ends radially inward of said feed inlet and discharging streams of underflow material under a comparatively high differential hydraulic head into localized regions adjacent the periphery of said chamber and substantially midway between adjacent ones of said nozzles.

3. In a centrifuge, a rotor having an annular separating chamber convergent in a direction outwardly from the axis of rotation with an unobstructed separating zone, and a passage for introducing a fluid feed material into said chamber adjacent the inner periphery of said zone; a discharge for the centrifugally separated overflow radially inward of said zone; an annular confined recess formed in said rotor having an inner open side communicating with the outer periphery of said separating zone; spaced underflow discharge nozzles having their inlet ends communicating with said recess; and means for continuously returning underflow material through said separating zone into said recess including an impeller carried by said rotor and tubes having their inlet ends isolated from the feed material connecting with the impeller extending outwardly to discharge returned underflow material into said recess at circumferentially spaced localized regions located substantially midway between the inlet ends of adjacent ones of the nozzles at a sufficient velocity to maintain a live annular zone of material of discharge consistency in said recess.

4. In a centrifuge, a rotor having an annular separating chamber convergent in a direction outwardly from the axis of rotation; passages for introducing fluid feed material into said chamber and removing centrifugally separated overflow therefrom; a confined annular recess having its inner open side communicating with the outer portion of said separating chamber; underflow discharge

nozzles mounted at spaced points on the peripheral margin of said recess; and means for continuously returning underflow material back into said rotor comprising an impeller carried by the rotor, circumferentially spaced tubes extending outwardly from said impeller having their inner ends communicating with the impeller to receive fluid material therefrom, separated from said feed material, and having their outer open ends terminating within said confined recess at regions located substantially midway between the inlet ends of adjacent ones of said nozzles; whereby the underflow material continuously returned into said rotor by way of said impeller and said tubes maintains a circumferentially flowing zone of material of discharge consistency throughout the length of said recess.

5. In a centrifuge, a rotor having an annular separating chamber and provided with a passage for introducing fluid feed material into the chamber and provision for the discharge of a centrifugally separated overflow, the cross-sectional contour of the separating chamber being convergent in a direction outwardly from the axis of rotation, the peripheral margin of the bowl being formed to provide a confined annular recess having its inner open side freely communicating with the outer portion of the separating chamber; a plurality of underflow discharge nozzles mounted at regularly spaced intervals on the peripheral margin of the bowl and having their inlet ends communicating with said recess at spaced points, and means for introducing a supplemental fluid material into said rotor comprising an impeller carried by the rotor, tubes connected to the impeller and extending outwardly from the same having their outer ends discharging into said recess at circumferentially spaced regions located substantially midway between the inlet ends of adjacent ones of said nozzles, the maximum distance from the discharge end of each tube and the inlet end of an adjacent nozzle being a minor fraction of the radial distance from the axis of the rotor to the discharge ends of the tubes.

6. In a centrifuge, a rotor having an annular separating chamber convergent outwardly from the axis of rotation; a feed passage for introducing a fluid feed material into said chamber; a passage for the discharge of a centrifugally separated overflow from said chamber; a stack of separating discs in said chamber surrounded by an unobstructed separating zone; an annular recess surrounding said zone; spaced underflow discharge nozzles having their inlet ends communicating with said confined recess; and means for continuously returning heavier underflow material back into said recess comprising tubes having their inlet ends isolated from said feed passage, and extending outwardly through said separating zone into said recess outward of said separating discs and substantially midway between the inlet ends of adjacent ones of said nozzles, providing for continuous return of heavier underflow material into said recess for redischarge through said nozzles, whereby a circumferentially flowing zone of material of substantially discharge consistency is maintained in said recess.

7. In a centrifuge, a rotor having an annular separating chamber provided with passages for introducing a fluid feed material and for the discharge of a centrifugally separated overflow, the cross-sectional contour of the separating chamber being convergent outwardly from the vertical axis of rotation; an annular recess surrounding and communicating with said chamber; a stack of separating discs centrally disposed in said chamber surrounded by an unobstructed separating zone communicating with said recess; spaced underflow discharge nozzles having their inlet ends communicating with said recess; and means for continuously returning heavier underflow material back into the centrifuge chamber, said means comprising an impeller carried by said rotor, tubes having their inner ends connecting with said impeller and extending outwardly through said separating zone and

discharging into said recess, the outer ends of the tubes being located intermediate the end planes of said stack and substantially midway between the inlet ends of adjacent ones of said nozzles, said tubes serving to continuously return heavier underflow material into said recess for redischarge through said nozzles; whereby a zone of material of substantially discharge consistency is maintained in portions of said recess extending between the outer ends of the tubes and the inlet ends of the nozzles.

8. The centrifuge as set forth in claim 7 in which the maximum distance from the discharge end of each tube and the inlet end of an adjacent nozzle is a minor fraction of the radial distance from the axis of the rotor to the discharge ends of the tubes.

9. In a centrifuge, a rotatable chamber provided with a radially unobstructed substantially annular separating zone merged into an annular collecting region having a continual peripheral margin defined by the inner surface of the rotatable chamber; a feed inlet for said separating zone adjacent its radially inner boundary; an inner annular zone adjacent the inner boundary of said separating zone; an overflow outlet for said inner zone radially inward of said inner boundary; spaced underflow discharge nozzles in the chamber wall having inlets in said peripheral margin; and spaced tubes extending into said chamber and beyond said separating zone with their inlet ends isolated from said feed inlet and closer to the chamber axis than said inner boundary of the separating zone and their outlet ends freely spaced from said peripheral margin a distance at least equal to one-fourth the effective tube diameter and located to discharge fluid fed therethrough into said collection region at localized areas substantially midway between adjacent ones of said spaced nozzles.

10. In a centrifuge, a rotatable chamber provided with a radially unobstructed annular separating zone merged into an annular collecting region having a continual peripheral margin defined by the inner surface of the rotatable chamber; a feed inlet for said separating zone; an overflow outlet for said separating zone radially inward of the inner boundary of said separating zone; spaced underflow discharge nozzles in the chamber wall and having inlets in said peripheral margin; spaced tubes extending into said chamber and beyond said separating zone with their inlet ends isolated from said feed inlet and closer to the chamber axis than the inner boundary of the separating zone and their outlet ends located to discharge fluid fed therethrough into said collecting region substantially midway between adjacent ones of said spaced nozzles.

11. In a centrifuge, a rotatable chamber provided with a radially unobstructed annular separating zone merged into an annular collecting region having a continual peripheral margin defined by the inner surface of the rotatable chamber; a feed inlet to said separating zone for a primary fluid; an overflow outlet for said separating zone radially inward of the inner boundary of said separating zone; spaced underflow discharge nozzles in the chamber wall and having inlets in said peripheral margin; spaced tubes extending into said chamber and beyond said separating zone with their inlet ends isolated from said feed inlet and closer to the chamber axis than the inner boundary of the separating zone and their outlet ends located to discharge fluid fed therethrough into said collecting region substantially midway between adjacent ones of said spaced nozzles; and means for feeding a supplementary fluid through said tubes into said separating zone.

12. In a centrifuge, a rotatable chamber provided with a radially unobstructed annular separating zone merged with an annular collecting region having a continual peripheral margin defined by the interior peripheral surface of the rotatable chamber; a feed inlet for said separating zone adjacent its radially inner boundary; an overflow outlet for said zone radially inward of said inner boundary; spaced underflow discharge nozzles in the chamber wall having inlets in said peripheral margin; and spaced tubes extending into said chamber and beyond said separating zone with their inlet ends isolated from said feed inlet and closer to the chamber axis than the inner boundary of the separating zone and the cross-sectional area of each of said tubes being of a size and their outlet ends being located to discharge fluid fed therethrough into said collecting region at concentrated portions of said continual peripheral margin substantially midway between adjacent ones of said spaced nozzles.

13. In a centrifuge, a rotatable chamber provided with a separating zone; a feed inlet for said chamber adjacent the bottom of said separating zone, an overflow outlet for said separating zone disposed radially closer to the rotating axis than said inlet and axially separated from said inlet; underflow discharge nozzles for said chamber radially outward of said separating zone; and substantially unobstructed tubes extending into said chamber and beyond said separating zone with inlet ends radially inward of said feed inlet and overflow outlet disposed to freely discharge material passing therethrough into localized regions substantially midway between adjacent ones of said underflow nozzles.

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