Dec. 23, 1952 J. BAXTER, JR 2,622,795

CENTRIFUGAL SEPARATOR

Filed Oct. 30, 1948 4 Sheets-Sheet 1

Fig-1

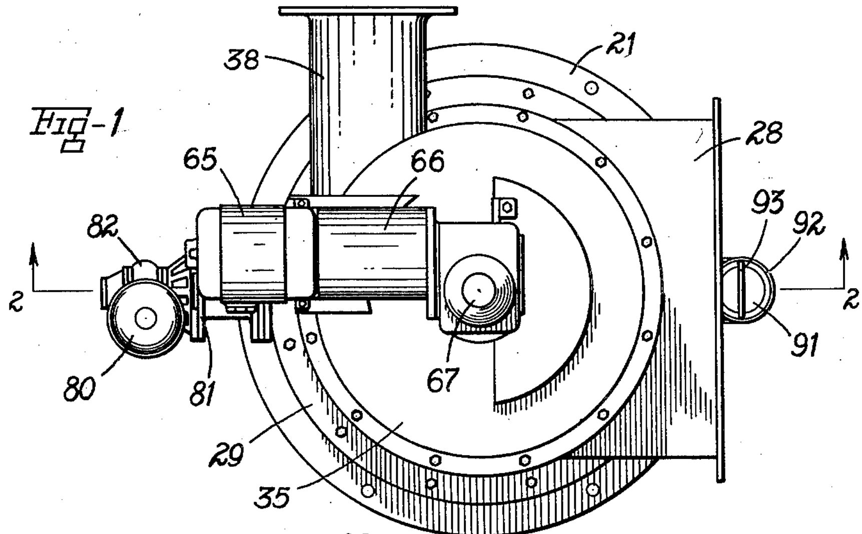
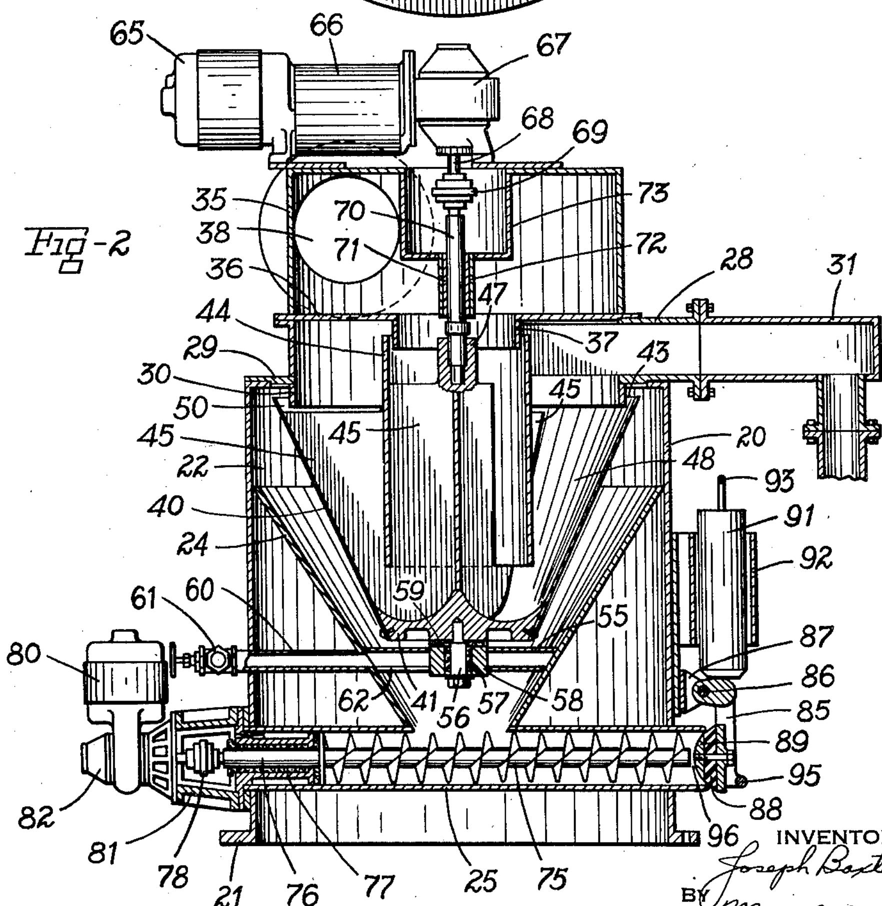


Fig-2



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CENTRIFUGAL SEPARATOR

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Fig-4

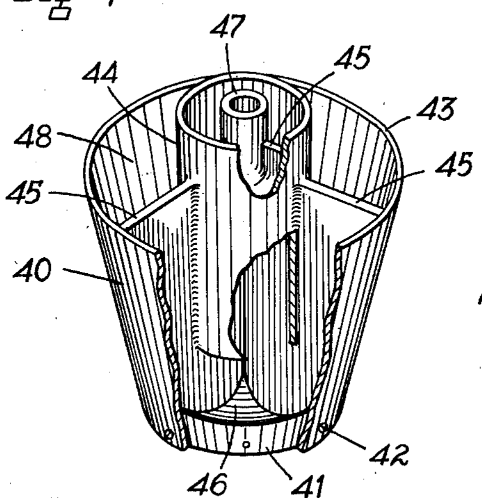

Fig-3

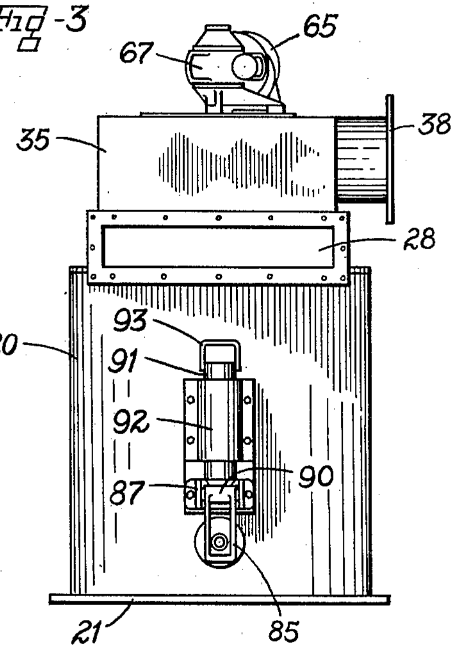

Fig-5

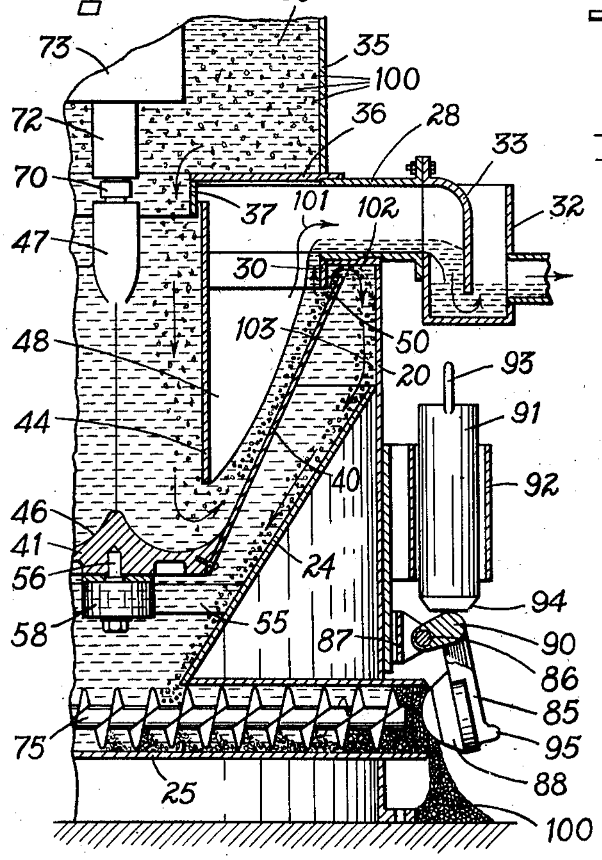

Fig-6

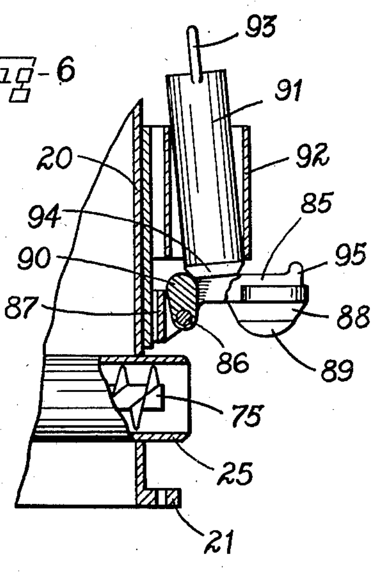

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Fig-7

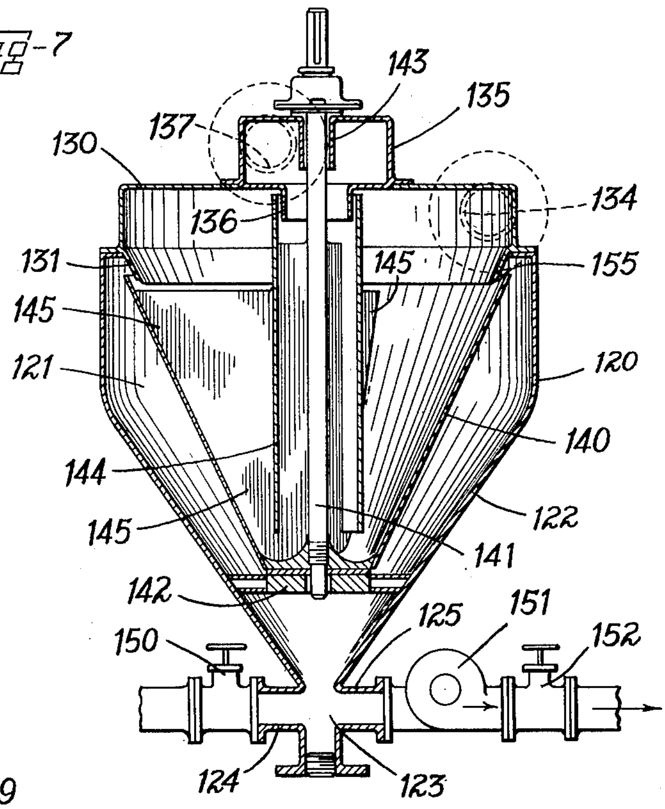

Fig-9

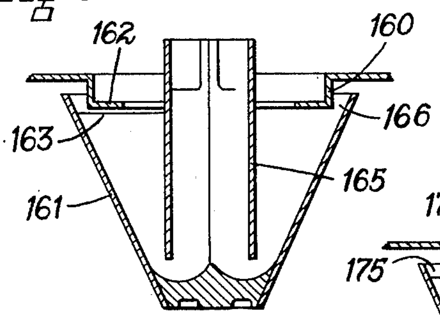

Fig-8

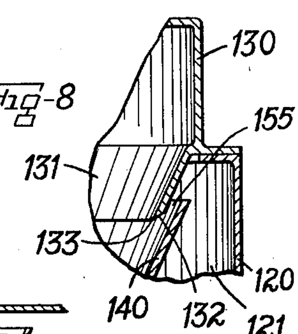

Fig-10

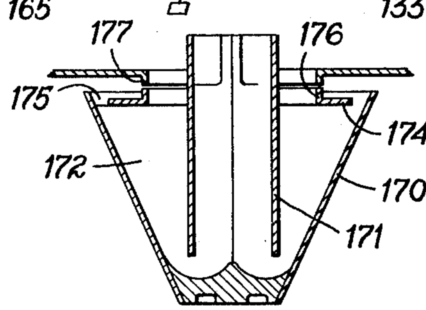

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Fig-11

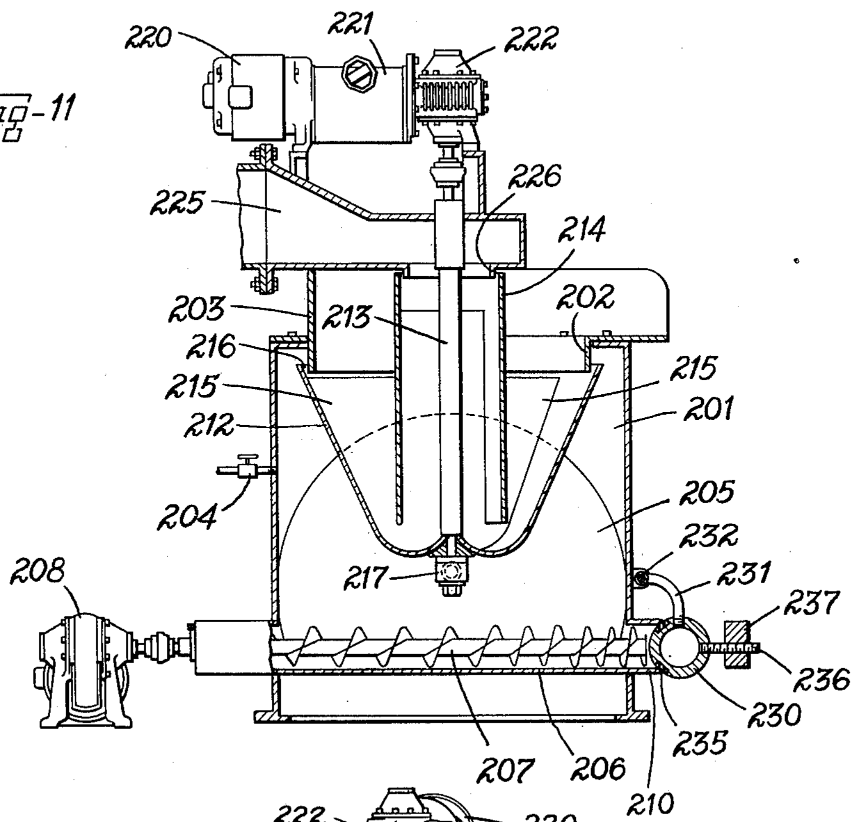
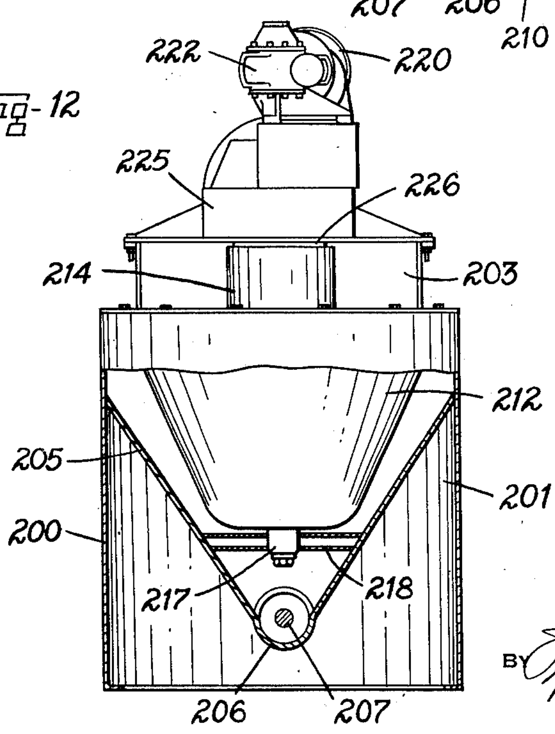


Fig-12



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CENTRIFUGAL SEPARATOR

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Application October 30, 1948, Serial No. 57,559

8 Claims. (Cl. 233—15)

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This invention relates to centrifugal separating apparatus.

One of the principal objects of the invention is to provide centrifugal separating apparatus which will operate effectively at relatively low rotational speeds and low rates of linear flow of the liquid under treatment to minimize turbulence in the liquid and thus to give efficient separation even when the material to be separated is in finely divided form and is of specific gravity only slightly different from that of the carrier liquid.

Another object is to provide a centrifugal separator wherein the material removed from a suspension is continuously unloaded from the apparatus under controlled conditions substantially preventing loss or waste of the suspending medium.

An additional object is to provide a centrifugal separator which is of simple and relatively lightweight and compact construction, which has high operating capacity and low power requirements, and which affords assurance against damage or injury in the event of power failure or other breakdown.

It is also an object of the invention to provide such a centrifugal separator which is well suited for use in the preparation of paper-making stock to remove gritty materials therefrom, which operates under such controlled conditions of low speed and freedom from turbulence that substantially complete separation of the reject particles is effected with minimum loss of usable fiber, and which also continuously unloads the reject material in semi-dry condition and is thus capable of continuous operation for extended periods of time without the necessity for shutdown and cleaning.

A further subject is to provide such a centrifugal separator wherein the separating action is so gentle and at the same time so effective that it will operate successfully to remove colloidal dirt and other finely divided materials such as are found in the waste water from mills of many types, and which is thus applicable where problems of stream pollution exist to clean such waste water before it is finally discharged from the mill.

Still another object is to provide a centrifugal separator having a chamber filled with liquid for receiving the solid particles separated from the suspension and also having a conveyor arranged in the bottom of the chamber for conveying the separated particles to a discharge outlet provided with a counterweighted closure which

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opens under the pressure of the reject material to permit controlled discharge thereof substantially without loss of liquid.

Other objects and advantages of the invention will be apparent from the following description, the accompanying drawings and the appended claims.

In the drawings —

Fig. 1 is a top view of a centrifugal separator constructed in accordance with the present invention;

Fig. 2 is a view in vertical section on the line 2—2 of Fig. 1;

Fig. 3 is a front elevational view of the apparatus of Figs. 1 and 2;

Fig. 4 is a perspective view, partly broken away, showing the rotor or bowl assembly of the apparatus;

Fig. 5 is an enlarged fragmentary view in vertical section illustrating the operation of the apparatus;

Fig. 6 is a fragmentary section further illustrating the operating of the apparatus;

Fig. 7 is a view in vertical section showing a different construction of centrifugal separator in accordance with the invention;

Fig. 8 is an enlarged sectional view of a fragment of the apparatus of Fig. 7;

Figs. 9 and 10 are somewhat diagrammatic sectional views showing modified forms of the invention;

Fig. 11 is a section on the line 11—11 of Fig. 12 showing a further construction of separator in accordance with the invention; and

Fig. 12 is a front view, partly broken away, of the separator of Fig. 11.

Referring to the drawings, which show preferred embodiments of the invention, Figs. 1 to 6 illustrate a centrifugal separator particularly suitable for use in the removal of suspended gritty particles from paper making stock. The device includes a main casing 20 provided with a base portion 21 and forming a chamber 22 adapted to be filled with liquid. An inverted frusto-conical shell 24 is fixed within casing 20 to from the bottom of chamber 22, and the lower end of shell 24 connects with a cylindrical conveyor tube 25 extending through the lower portion of casing 20.

A discharge trough 28 and cover plate 29 enclose the upper end of casing 20 to close the top of chamber 22, and the discharge trough includes a cylindrical collar 30 extending downwardly into chamber 22 to form a discharge tube therefrom. Discharge trough 28 is rectangular at its open end and may be provided with a pipe connection 31 (Fig. 2) for receiving the discharge from chamber 22, or with a head box 32 or similar connection provided with a splash hood 33 as shown in Fig. 5. An inlet trough 35 having a bottom plate 36 is mounted on top of discharge trough 28, and the plate 36 has a central aperture from which a tube or collar 37 extends downwardly into the discharge trough. Incoming stock is supplied to the inlet trough 35 through a suitable pipe 38, which is arranged tangentially of the inlet trough to deliver the stock thereto with an initially spiral motion, and it will be noted that pipe 38 is at a higher level than discharge trough 28 to provide a pressure head effective on the discharge trough.

The rotor or bowl assembly mounted within chamber 22 includes a frusto-conical bowl 40 having a bottom member 41 bolted or otherwise secured thereto as indicated at 42. The bowl 40 is mounted for rotation within chamber 22 with its upper rim 43 positioned below the top of the chamber, and its side wall tapers outwardly at an angle to the vertical which is sufficiently large to assure free upward travel of solid particles at comparatively low rotational speeds, satisfactory results have been obtained with this angle within a range of 20 to 35° to the vertical. An inlet tube 44 is mounted and secured within bowl 40 by means of three radially arranged webs, partitions or vanes 45, which are generally J-shaped in side elevation as shown in Fig. 2. The vanes 45 are secured as by welding to bowl 40 and tube 44, and also the innermost edges of these vanes are welded together along the axis of the bowl and inlet tube and to a hub 47 at their upper ends.

The inlet tube 44 extends at its upper end into the interior of the discharge trough 28 and internally receives the downwardly extending collar 37 from the inlet trough in telescoping relation to receive incoming stock directly therefrom. At its lower end, the tube 44 is spaced in such relation to the upper surface of the bottom 41 of the bowl and to the sloping inner wall of the bowl that the frusto-conical area defined by the lower rim of the tube and a circle through the outer end of a normal from the bowl wall to the rim of the tube is substantially equal to the cross-sectional area of the tube, and similarly that the cylindrical area defined by the projection of the lower end of tube 44 to the upper surface of the bottom 41 is approximately equal to the cross-sectional area of the tube. The upper surface of the bottom 41 is accordingy curved as indicated at 46 to provide for smooth flow of liquid from the interior of tube 44 around the lower end of the tube and up into the annular space 48 between the tube and the bowl.

The bowl assembly is so positioned in chamber 22 that the discharge tube 30 extends downwardly into the interior of the bowl to leave an annular space 50 between its lower end and the inner surface of the bowl which forms a discharge orifice from the interior of bowl 40 into chamber 22. The amount of overlap between the bowl and tube 30 is preferably relatively small in order to assure that liquid entering the bowl through inlet tube 44 will travel upwardly over the major portion of the vertical extent of the bowl before reaching the discharge tube, an overlap of the order of ¾ inch having been found satisfactory with a bowl approximately 24 inches in overall height and 40 inches in diameter at its upper end, with the discharge tube 30 having a diameter

of 36 inches and the lower end of inlet tube 44 positioned 18 inches below the rim 43 of the bowl.

It will be seen that the vanes 45 effectively partition the major portion of the interiors of the tube 44 and the annular space 48 into sector-shaped passages in the direction of flow therethrough. Thus when the bowl and tube are rotated about their common vertical axis, the vanes cause the contents of both the tube and the bowl to rotate with the entire assembly at substantially the same angular rate. The inner portions of vanes 45 terminate at a position spaced below the lower end of the inlet collar 37 to minimize splashing as the stock enters the tube, and the outer portions of the vanes terminate at a relatively short distance below the lower end of the discharge tube 30. Satisfactory results have been obtained with this distance just sufficient to give a running clearance, and if the vanes extend higher, they may be slotted to receive the discharge tube.

At its lower end, the rotor assembly is mounted on a pipe 55 extending across the shell 24 above the conveyor tube 25 to form a support for the rotor. A stud 56 is fixed to the bottom 41 of bowl 40 and is journaled in a guide bearing 57 mounted in a boss portion 58 of pipe 55, and a thrust bearing 59 is positioned between boss 58 and the bottom 41 of the bowl. Satisfactory results have been obtained employing water-lubricated fiber bearings at 57 and 59, since in operation these parts are continually submerged in water. In order to provide for convenient introduction of additional liquid to chamber 22, a pipe 60 extends from one end of pipe 55 to the outside of casing 20 and is equipped with a suitable valve 61 adapted for connection to an outside source of water, and the pipe 55 is slotted at 62 to admit liquid from pipe 60 to chamber 22.

The main drive motor 65 for the rotor is mounted on the top of inlet trough 35 and is shown as provided with a variable ratio transmission 66 and a worm and pinion drive 67 to a vertical shaft 68. A flexible coupling 69 connects shaft 68 with the rotor shaft 70 which is secured to hub 47. Shaft 70 is provided with a guide bearing 71 in a supporting tube 72 which extends downwardly from the upper portion 73 of the inlet trough. Bearing 71 may conveniently be of the water-lubricated type, in which case clear water may be readily supplied thereto through the trough portion 73 to maintain a small lubricating stream through the bearing into the incoming stock.

A conveyor screw 75 is mounted within the conveyor tube 25, and it includes a shaft portion 76 which extends through suitable bearings and glands in the housing 77 to a flexible coupling 78. A motor 80 is mounted on the outside of the casing by a suitable support 81 and is in driving connection with the flexible coupling 78 through a worm and pinion drive 82. The motor 80 accordingly operates the conveyor screw 75 to force solid materials settling to the bottom of chamber 22 to the outer end of the conveyor tube 25.

The conveyor tube 25 is provided at its outer end with a counterweighted closure which includes an arm 85 having the general configuration of a bell crank and having its upper end pivoted at 86 in a bracket 87 secured to casing 20 above the conveyor tube. The lower end of closure arm 85 carries a frusto-conical rubber plug 88 which is adapted to seat within the open end of the conveyor tube and is held in place by a rounded retaining plate 89. The middle portion 90 of the closure arm is rounded and is adapted to support the lower end of a counterweight 91 mounted for vertical sliding movement in a guide support 92 secured to the outer wall of casing 20, the counterweight 91 having a handle portion 93 at its upper end.

It will accordingly be seen that the counterweight 91 engages the rounded portion 90 of the closure arm 85 and thus causes the arm to swing about its pivot 86 and to carry the rubber plug 88 into position closing the outer end of conveyor tube 25. The counterweight and closure arm also have parts adapted to cooperate to hold the closure arm in open position. Thus referring particularly to Figs. 3 and 6, the lower end of counterweight 91 is tapered at 94 and is adapted to overlap the rounded portion 90 of the closure arm when the latter is raised through approximately 90° from its closing position, the closure arm being provided at its lower end with a handle 95 facilitating raising the arm against the counterweight. In this position, as shown in Fig 6, the lower end of the counterweight interlocks with the arm portion 90 to hold the arm horizontal with the conveyor tube fully opened, thus facilitating flushing the interior of the casing through the conveyor tube. It will also be noted that the conveyor screw 75 terminates short of the open end of tube 25 so that when the closure plug is fully seated in the conveyor tube as shown in Fig. 2, there is an open space 96 between the inner end of the plug and the adjacent end of the screw 75.

In operation, the motor 65 is operated to rotate the rotor assembly at a relatively low rate, satisfactory results having been obtained at a rate of 108 R. P. M., and before the flow of stock to be cleaned is commenced, water is admitted to chamber 22 through pipe 60 until the chamber is entirely full. The valve 61 is then adjusted to maintain a slow inward flow of water from chamber 22 through the orifice 50, at a volumetric rate slightly in excess of the volumetric rate at which reject material is discharged from the apparatus, a flow of the order of not more than about 25 G. P. M. having been found satisfactory.

The incoming stock 99 is shown in Fig. 5 as including suspended gritty particles 100 which are to be removed as the stock passes through the apparatus. The stock flows downwardly through the inlet collar 37 into the upper end of inlet tube 44 at a rate sufficient to maintain this tube substantially full at all times, for example at rate of 860 G. P. M. The stock enters the tube 44 with an initial spiral velocity imparted by the tangential arrangement of the inlet pipe 38, and as soon as the stock reaches the upper level of the vanes 45 within tube 44, it is accelerated to the same angular rate as the tube. The stock is thus subjected to relatively low centrifugal force as it flows downwardly through the compartments between vanes 45, and the particles 100 tend to move outwardly toward the inner wall of the tube as represented in Fig. 5.

As soon as the stock reaches and flows around the lower end of tube 44, it is thrown outwardly to the tapering inner wall of bowl 40 and is spread into a film the thickness of which decreases as it flows upwardly within the bowl under the effect of centrifugal force. The particles 100 are accordingly caused to concentrate along the surface of the bowl and to travel upwardly smoothly and continuously along this surface. During the travel of the stock from the lower end of tube 44 upwardly to the lower end of the discharge tube 30, the stock appears to separate into inner and outer strata having a zone of demarcation extending downwardly from the lower end of the discharge tube. The outer of these strata contains the gritty particles to be removed, whereas the inner of the strata consists of clean stock and flows upwardly into the discharge tube and thence out through the discharge trough as indicated by arrows 101 in Fig. 5. The effective pressure head between the inlet trough and the discharge trough is sufficient to maintain this desired through-flow of the clean stock, and the discharge connection such as shown at 31 in Fig 2 and 32 in Fig. 5 should be positioned to maintain this head to prevent back pressure on the discharge tube. It will be noted that since the upper end of inlet tube 44 extends above the level of stock in discharge trough 28, there is no tendency of back flow of clean stock between collar 37 and tube 44, or vice versa.

The outer of the liquid strata in the bowl is substantially prevented from discharge through the orifice 50 by reason of the pressure maintained in chamber 22 by the additional water continually admitted through the pipe 60. This provides an effective liquid seal at the upper end of the bowl preventing discharge of liquid from the bowl and in fact causing a slow inflow of water around the lower end of the discharge tube 30 as indicated by the broken arrow 102 in Fig. 5. However, this pressure and inflow are controlled to a low rate such that they will not offer material resistance to the continued passage of the grit particles 100 upwardly through the orifice 50 for discharge into chamber 22, as indicated by the arrows 103 in Fig. 5. These particles accordingly settle downwardly along the outer wall of the casing 22 and shell 24 into the conveyor tube 25.

With the conveyor screw 75 continually rotating during this operation, the particles 100 which settle into the tube 25 are conveyed toward the outlet end of the tube and initially collect as a slug in the space 96 between the outer end of the screw and the closure plug 88. This accumulation of reject in space 96 continues until, as more particles collect, the pressure from screw 75 acting through the accumulated slug of particles is sufficient to swing the closure arm 85 outwardly and upwardly against the counterweight 91 as shown in Fig. 5. When this occurs, the accumulated reject particles are forced outwardly and discharged past the plug 88. However, since this discharge does not occur until the space 96 is filled, the accumulated slug of reject particles between the plug and the end of the feed worm acts as a seal effectively preventing appreciable loss of liquid from the conveyor tube, and in practice the reject is found to be discharged from the conveyor tube in a consistency of the order of wet sand and with substantially no more water than that entrained with the individual particles. The unloading of the apparatus thus takes place continuously at a rate which is approximately proportional to the reject content of the stock, and it takes place substantially without the loss of usable stock or waste of water. In addition, the rounded surface of plate 89 presented to the accumulating reject acts in the manner of a deflector to prevent the reject from packing too closely before the plug opens.

Analysis of the operation of the apparatus indicates that the liquid passing through the apparatus is permitted to form its proper contour in complete accordance with physical laws and with minimum turbulence. Thus it will be apparent that if the supply of incoming stock and water is shut off and the bowl continues to rotate, the liquid will discharge through the discharge tube 30 until it reaches an equilibrium condition in which it forms a parabola extending downwardly from the upper end of tube 30. No further radiation of upward flow will occur so long as the speed of rotation of the bowl remains constant and no liquid is added, since with chamber 22 filled, there is an effective liquid seal at the discharge orifice 50.

If the inflow of stock and water is then resumed, it appears to form a second parabolic layer superimposed on the relatively more slowly moving or practically static outer layer. Any heavy particles in this inner layer promptly migrate to the outer layer, and once received within this outer layer, they are effectively trapped, the outer layer thus forming in effect a liquid mat for receiving such particles and moving with them only slowly toward the discharge orifice 50, rapid separation of the particles being thus facilitated. Furthermore, rapid separation is also aided by the fact that the radial thickness of the combined layers is quite low, for example of the order of less than one inch at its thinnest point, and the radial path of the particles from the inner layer of stock to the wall of the bowl is thus correspondingly short.

It should be noted that although the rate of movement of the outer parabolic layer of liquid is thus restricted by the liquid seal at orifice 50, the particles which are received in this layer remain relatively free to travel through the layer and upwardly along the inclined surface of the bowl under the effective centrifugal force. It is desirable that this upward travel of the particles be not too rapid, in order to minimize turbulence in the outer liquid layer. A suitably low rate of upward travel of the particles is obtained with the wall of the bowl inclined at an angle of 25° to the vertical, and this angular configuration of the bowl also has the advantage of holding the pumping action of the rotating bowl within economical limits from the standpoint of the load on drive motor 65.

The inflow of water through orifice 50 is maintained sufficiently low to permit free travel therethrough of the reject particles into chamber 22, while at the same time substantially preventing discharge of liquid, and particularly of clean stock, through orifice 50. The incoming water appears to form an interface with the inner layer of clean stock adjacent the lower end of discharge tube 30; thus in effect providing a pool adjacent the rim of bowl 40 into which the particles travel. In addition, the inflow of water through orifice 50 tends to wash off usable fiber which may be clinging to the reject particles and to return such good fiber to the clean stock.

Return of the grit particles into the flow of clean stock through the discharge tube 30 is thus prevented, both by the inflow of water, which acts as a separating medium between the particles and the clean stock, and also by the portion of tube 30 extending into the bowl, which effects physical separation within th bowl between the respective strata of clean stock and of grit-bearing liquid. Thus as soon as the particles pass beyond the lower end of the discharge tube 30 into the space between the outer wall of tube 30 and the inner surface of the bowl, centrifugal force prevents them from returning, and they must continue outwardly and into chamber 22. Furthermore, since there is relative rotational movement between the bowl and the liquid above the level of vanes 45, with the bowl rim traveling at a peripheral speed of the order of 1100 feet per second in the above example, the reject particles will be further accelerated as they pass beyond tube 30 and will be literally thrown from the bowl into chamber 22, the discharge being free and unobstructed over the entire rim of the bowl at its portion of greatest circumference. The discharge of clean stock into tube 30 is similarly unobstructed and takes place in generally straight line flow free of sharp turns, tortuous passages and the like.

This construction and operation of the apparatus offer material advantages from the standpoint of economical and efficient operation. Since the vanes 45 cause the stock traveling through the bowl assembly to rotate at substantially the same angular rate as the bowl, there is substantially no laminar flow or scouring circumferentially of the bowl, thus minimizing turbulence and the resulting carrying tendency of the stock with respect to gritty particles. The forced vortex imposed on the stock within the bowl assembly accordingly provides an adequate separating force on the stock even at low rotational speeds, the effective separating force being of the order of six times gravity at 108 R. P. M. for a bowl of the dimensions given above. In addition, the free vortex created in chamber 22 by the rotating bowl assembly tends to carry the discharged particles to the periphery of the chamber, whence they settle to the conveyor tube 25.

It is accordingly possible to operate the apparatus with the stock flowing at relatively low speeds such that its carrying capacity for gritty particles is correspondingly low. Thus satisfactory results have been obtained in the above example with the stock at 1% consistency flowing at a rate of 860 gallons per minute, giving an upward velocity within bowl 40 of the order of only 1.75 to 2.50 feet per second. At this gallonage and under the above operating conditions, the film of stock along the wall of bowl 40 ranges in radial thickness from approximately 2½ inches between the lower end of tube 44 and the bowl to less than 1 inch as the stock approaches the discharge tube 30 before turning upwardly into tube 30, thus providing coresepondingly short paths for the reject particles to the inner surface of the bowl.

This apparatus is also economical and efficient from the standpoint of power consumption. The arrangement of the inlet trough and discharge trough as described provides for gravity feeding of stock through the apparatus. The low operating speed for the rotor assembly correspondingly minimizes the power consumption of drive motor 65, a 3 H. P. motor having been found adequate, and conveyor screw 75 operates satisfactorily with a ½ H. P. motor 80. In addition, the space requirements of the apparatus are relatively low, satisfactory results having been obtained for cleaning paper stock in the above example with a unit approximately 85 inches in height overall and occupying a floor space only approximately 52½ inches by 82 inches.

It will also be apparent that the apparatus is effectively self-cleaning. Thus when the stock flow is stopped, complete cleaning of the unit may be effected by simply running clear water into the bowl assembly while the latter rotates until all particles within the bowl are discharged, followed by flushing with the closure plug 88 held open in the manner shown in Fig. 6. It should also be noted that there is minimum danger of damage to the apparatus and injury to the operating personnel in the event of failure of any part during operation. Thus in case of a power failure for drive motor 65, the only result would be that the stock would continue to flow through the unit without being cleaned. If the motor 80 for the conveyor screw should stop, the reject particles might accumulate in the bottom of chamber 22 sufficiently to overload the drive motor by their friction against the bowl, but such failure of the screw would ordinarily be noted before undesirable accumulation could occur, the average grit content of the stock being only of the order of 15 pounds per hundred tons of stock at 1% consistency. Furthermore, since the apparatus normally runs in balance without operating cycles or periods, there is a corresponding small tendency for unequal stresses or loads to develop which might contribute to breakdown.

Under certain conditions such, for example, as clarifying with or like fitting purposes, the inflow of liquid from chamber 22 is not necessary and the valve 61 may remain closed. When operation of the apparatus first begins, the incoming liquid suspension will fill chamber 22 before any discharge takes place through the discharge tube 30. Thereafter, the liquid filling chamber 22 will provide its own liquid seal at the discharge orifice 50 to hold the outer layer of liquid in bowl 40 in the desired relatively static condition. Discharge of particles from the incoming liquid will take place into this outer layer as already described, and the inner layer of clean liquid will flow upwardly into discharge tube 30 and out through the discharge trough. The particles received within the outer layer of liquid in the bowl will travel upwardly in the same manner as already described for discharge through orifice 50 into chamber 22, whence they will settle into the conveyor tube for discharge by way of screw 75.

Figs. 7 and 8 show a modified construction of separating apparatus which is equipped for use in the removal of exceedingly fine suspended solids from a liquid, for example, in clarifying the discharge water of a mill by removing finely divided chemical or like sludge therefrom. In Fig. 7, the stationary casing 120 encloses a chamber 121 and has a cylindrical upper portion and a frusto-conical lower portion 122 leading into a base portion 123 provided with two open pipe connections 124 and 125. A discharge trough 130 is mounted at the upper end of casing 120 and is formed with a downwardly extending collar portion 131 which forms the discharge tube from chamber 121. The tube 131 is frusto-conical with its smaller end lowermost, and the outer edge of its lower rim is beveled at 132 to provide a sharpened edge 133. The discharge pipe from discharge trough 130 is indicated at 134 as tangentially arranged. The inlet trough 135 is mounted on top of discharge trough 130 and includes a downwardly extending collar portion 136 projecting into the interior of the discharge trough. The inlet pipe for inlet trough 135 is indicated at 137 as arranged tangentially with respect to collar 136.

The rotor assembly comprises a frusto-conical bowl 140 rotatably mounted on a shaft 141 supported on a bracket 142 extending across the frusto-conical casing portion 122, the upper portion of this shaft being journaled in a supporting collar portion 143 of the inlet trough. The bowl 140 is provided with an inlet tube 144 and webs or vanes 145 similar to the parts 44 and 45 in the apparatus of Figs 1 to 6. It will also be noted that the degree of inclination of the bowl of wall 140 is substantially the same as that of the frusto-conical discharge tube 131.

The pipe connection 124 at the lower end of the casing is shown as provided with a throttling valve 150, and the pipe connection 125 connects with a variable discharge pump, shown as a centrifugal pump 151 provided with a throttling valve 152. In operation, this apparatus is adjusted to provide a controlled outflow from the lower end of casing 120 at a volumetric rate sufficiently in excess of the volumetric sludge content of the incoming liquid to be cleaned to assure that all sludge discharged into chamber 121 will be removed through the lower end of the casing. Such controlled withdrawal of liquid may be readily obtained either by suitably throttling the output of pump 151 through valve 152, in which case valve 150 will remain closed, or if the pump is not used, the valve 152 may be closed and valve 150 adjusted to provide the desired volumetric outflow.

The action of the apparatus in initially separating sludge from the incoming liquid is substantially the same as already described in connection with Figs. 1 to 6. Rotation of the bowl results in the formation of inner and outer strata extending downwardly from the lower end of discharge tube 131, with the reject material becoming concentrated in the outer layer against the inner wall of the bowl. However, instead of having this layer remain relatively static as in the examples already described, the outflow through the lower end of casing 120 will result in a corresponding volumetric outflow of the sludge-bearing layer of liquid through the discharge orifice 155 between tube 131 and the bowl. The clean liquid will be discharged upwardly through tube 131, and it will be noted that the tapered construction of tube 131 and its sharp edge 133 minimizes turbulence around the lower end of the discharge tube and provides a clean cleavage between the strata being discharged into tube 131 and through orifice 155, respectively. A similar arrangement may be embodied in the discharge tube 30 of Figs. 1 to 5, if desired.

This construction and arrangement of apparatus is particularly well suited for clarifying waste liquids and to remove finely divided suspended matter, because at the low operating speeds of rotation and flow, as already described in connection with Figs. 1 to 6, there is such low turbulence that effective separation is obtained even when there is a relatively slight difference in specific gravity between the suspended matter and the carrier liquid. With such materials, the use of a conveyor screw as shown in Figs. 1 to 6 might result in stirring up the reject sufficiently to prevent complete separation, but such undesired results are avoided by drawing the sludge off in concentrated liquid suspension at the lower end of the apparatus as described.

In clarifying operations of this type, it may be found desirable to operate a plurality of separators in succession. For example, if the sludge content of the liquid is less than 1%, as is usually the case with respect to sludge too fine to permit efficient filtration, the separator first receiving the liquid might be adjusted to provide an outflow at the lower end of the casing equal to approximately 10% of the inflow, giving a 90% discharge of clear water through the discharge trough. The 10% of liquid drawn off from the first separator could then be passed through a second, similar separator which could be similarly set to give an outflow again of 10% and a discharge of 90% clear water. Since the 10% drawn off from the second separator amounts to only 1% of the original input and contains all of the sludge, it can be readily filtered or dried to give a substantialy dry sludge deposit for convenient disposal.

An operation somewhat the converse of that just described may be performed where it is desired to remove a relatively small amount of liquid from a liquid carrier of higher specific gravity, for example, to recover the relatively small amounts of suspended grease from the waste water of some types of mills. If, for example, the grease content of the water is initially of the order of 2 or 3%, the discharge from the lower end of the casing would be set to equal the water content of the incoming liquid, i. e., 97 or 98%. Under such conditions, substantially pure water would be drawn off from the lower end of the casing while the recovered greasy residue would be discharged through the discharge tube 131 to the discharge trough.

It will accordingly be seen that the invention provides apparatus applicable to a wide variety of different materials and capable of giving a wide range of desired results. In all such uses of the invention, the volume and content of the discharge from the discharge trough, constituting the lighter component of the incoming suspension, is readily predetermined and controlled in accordance with the pressure maintained within the outer chamber in which the rotor assembly revolves. Thus when the apparatus is operated as described to remove gritty particles from paper stock with minimum loss of fiber, a back pressure is maintained in the outer chamber to provide an inflow of liquid substantially preventing discharge of usable fiber, the inflow counterbalancing the volumetric loss represented by the reject particles. When the desired discharge product is clear liquid free of heavier suspended matter, the back pressure is unnecessary because at most the liquid lost by replacing reject in the outer chamber will amount only to a volume approximately equal to that of the chamber.

When the apparatus is operated to remove finely divided solid particles, as in treating waste water for the removal of sludge of such fineness that any appreciable resistance or turbulence in the discharge orifice might tend to cause remixing, the pressure is decreased in the outer chamber sufficiently to cause a controlled outflow of the sludge-bearing outer layer in the rotating bowl, thus assuring free discharge of the sludge. Similarly when the apparatus functions in the nature of a skimmer, as in removing suspended small amounts of grease from water as described, the outflow is increased to such extent as to provide for discharge only of the skimmed light material through the discharge trough, and intermediate degrees of control may be employed for separating suspensions of other types and percentages.

It should also be noted that as the result of the extremely gentle and at the same time effective separating action of the apparatus, as well as the flexibility of control as discussed, it is highly useful in connection with the removal of chemical residue in waste mill water of the stream-polluting type. Such chemical residue can be readily precipitated or caused to flocculate

to a solid form which the apparatus of the invention will effectively remove even when the resulting sludge is so fine and so easily broken up that it cannot be satisfactorily removed by filtration or like methods.

Fig. 9 shows a modified construction of the apparatus wherein the discharge tube 160 which projects within the upper end of bowl 161 includes an annular flange portion 162 extending inwardly above the vanes 163, these vanes and the inlet tube 165 being of substantially the same construction as already described in connection with Figs. 1 to 6. With this construction, there is a discharge orifice 166 which corresponds with the orifice 50 as already described, but it will be seen that the discharge of the clean liquid takes place upwardly through the flange 162, the points of discharge of the clean liquid and the reject material being thus spaced by a substantial radial distance. The operation with this construction is similar to that already described except that the zone of demarcation between the inner and outer strata of liquid will extend downwardly from the inner rim of the flange portion 162, thus providing a relatively static layer of substantially greater depth or thickness at its upper end than with the constructions previously described.

Fig. 10 shows a modified construction of rotor assembly which includes a bowl 170, inlet tube 171 and vanes 172 similar to those already described. A ring 174 is mounted in the bowl on the upper edges of vanes 172 at a position spaced between the inlet tube 171 and the wall of the bowl to leave an annular discharge orifice 175, and this ring includes a collar 176 extending upwardly from its inner rim and into end to end relation with the downwardly extending discharge tube 177. The operation of this form of the invention is substantially the same as that of the form shown in Fig. 9, with the additional feature that since the collar portion 176 extends upwardly to the discharge tube 177 and rotates with the bowl assembly, there is no relative rotational movement between the clean liquid and the discharge tube until after the clean liquid is beyond the upper limits of the bowl. In addition, when this form of the invention is operated as described in connection with Figs. 1 to 5 with an inflow of liquid from the casing chamber, this inflow will take place both through the discharge orifice 175 and also through the space provided by the running clearance between the collar 176 and discharge tube 177.

Figs. 11 and 12 show a separator generally similar in construction to the apparatus described in connection with Figs. 1 to 5 and including a cylindrical outer casing 200 enclosing a chamber 201 and provided at its upper end with a discharge tube or collar 202 extending downwardly from the discharge trough 203. A valved connection 204 provides for a controlled flow of water to chamber 201 and corresponds to the valve 61 in Fig. 2. Within chamber 201 is a trough member formed with diverging side walls 205 extending upwardly from a semi-cylindrical portion 206 which receives a screw conveyor 207 having a drive motor 208. The casing 200 is also provided with a cylindrical discharge outlet 210 into which the conveyor 207 extends.

The rotor assembly in Figs. 11 and 12 includes a frusto-conical bowl 212 mounted on a shaft 213 and provides with an inlet tube 214 and vanes or webs 215 similar to the parts 44 and 45 in Figs. 1 to 5, and the lower end of discharge tube 202 extends into the upper end of bowl 212 to form therewith an annular discharge orifice 216 to chamber 201. The lower end of shaft 213 is mounted in a bearing 217 supported by a bracket 218 welded or otherwise secured to the trough walls 205. The drive motor 220, transmission 221 and worm and pinion drive 222 are mounted on the top of the apparatus and are similar to the parts 65–67 in Figs. 1 to 3. Incoming stock enters the apparatus through an inlet trough 225 mounted on top of the discharge trough 203 and provided with a downwardly extending collar portion 226 which extends into the upper end of the inlet tube 214 of the rotor assembly.

Fig. 11 shows a modified construction of closure unit for the outer end of the discharge outlet 210. A ball 230 is supported by a curved arm 231 pivoted to the casing 200 at 232. A rubber ring 235 is inserted in the inner side of ball 230 in position to engage the outer rim of discharge outlet 210 when the ball swings to the left as viewed in Fig. 11. A threaded rod 236 extends outwardly from the outer side of the ball and has a counterweight 237 threaded thereon. With this construction, the counterweight can be readily adjusted on rod 236 to vary the force urging ball 230 into its closing position with respect to the conveyor tube, thus readily predetermining the pressure from the reject propelled by screw 207 which will effect opening movement of the closure for discharge of the reject.

The operation of the apparatus shown in Figs. 11 and 12 is similar to that described in connection with Figs. 1 to 6, with the clean liquid being discharged upwardly through discharge tube 202 and the reject material being discharged into chamber 201 through the annular discharge orifice 216. The whirling rotor assembly will create a free vortex in chamber 201 in the same manner as in the other forms of the apparatus described, but the V-shaped trough 205 is found to have a baffling effect on the current set up in this chamber. As a result, there will be less turbulence in the lower part of the chamber than with the frusto-conical constructions shown in Figs. 1 to 7, and under some conditions this arrangement may be found to be desirable as promoting more rapid settling of the reject particles into the bottom portion of the trough for removal by the conveyor screw.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. Centrifugal separating apparatus of the character described for separating solid particles from a liquid suspension, comprising a casing forming a chamber adapted to be filled with liquid, a generally conical bowl positioned in said chamber with the rim thereof spaced below the top of said chamber, a pipe extending across the lower portion of said chamber to form a support for said bowl, means for supplying a suspension to be separated to the lower end of said bowl, a discharge tube extending downwardly into said chamber and into the upper end of said bowl in spaced relation with the wall of said bowl to define therewith an annular discharge orifice between said bowl and said chamber, means for rotating said bowl to effect separation of said suspension therein into inner and outer strata with said particles in the outer of said strata and to effect discharge of the inner of said strata upwardly through said discharge tube, partition means secured within said bowl to divide the interior thereof into a plurality of upwardly extending passages separated from each other circumferentially of said bowl to prevent laminar flow of said strata circumferentially of said bowl, said pipe including an extension portion extending through the outer wall of said chamber, said pipe having an opening in the side wall thereof connecting the interior of said pipe with said chamber, and means for supplying additional liquid to said pipe extension and through said opening into said chamber at a controlled rate providing a relatively slow inflow from said chamber through said orifice into said bowl effective to prevent discharge of liquid through said orifice into said chamber while permitting said particles to discharge through said orifice.

2. Centrifugal apparatus for separating heavy particles from a liquid suspension comprising a stationary casing forming a chamber, a bowl supported for rotation within said chamber and including an upwardly diverging imperforate wall having the rim thereof located below the top of said chamber, a stationary discharge tube located in the upper end of said chamber, an inlet tube extending into the lower part of said bowl for introducing said suspension to said bowl for upward flow to said discharge tube, partition means securing said inlet tube and said bowl together and arranged to form the interiors thereof into a plurality of separate passages in the direction of flow therethrough causing said suspension to rotate at the same angular rate with said bowl and tube while flowing therethrough, said discharge tube having the lower end thereof extending below the level of said bowl rim in radially inwardly spaced relation with said bowl wall to form therewith an annular discharge orifice and discharge space within said bowl, means for maintaining said chamber continuously filled with liquid to control outward flow of liquid through said orifice and to maintain a relatively static outer layer of liquid over the upper portion of said bowl wall below said orifice, means for rotating said bowl to subject said suspension to centrifugal force while flowing upwardly in said bowl causing said particles therein to be collected in said static layer of liquid while maintaining a continuous upward flow of liquid inwardly of said static layer into said discharge tube, said discharge tube being of a diameter materially greater than said inlet tube and closely approaching that of the adjacent wall of said bowl to provide an effective flow area therethrough greater than through said inlet tube and to maintain said upwardly flowing liquid and said static layer in a relatively shallow body along said bowl wall with the radially inner surface of said upwardly flowing liquid layer exposed substantially entirely to the atmosphere and lying radially outward of said inlet tube, said bowl wall diverging continuously up to said rim to cause said collected particles to travel upwardly within said static liquid layer and through said discharge orifice and discharge space for discharge over said rim into said chamber, means forming a discharge outlet from said chamber, and means for effecting controlled discharge of said particles through said outlet.

3. Centrifugal apparatus adapted for use in separating heavy particles from paper making stock, comprising a stationary casing forming a

chamber, a bowl supported for rotation within said chamber and having an upwardly diverging wall having the rim thereof located below the top of said chamber, an inlet tube secured within said bowl for rotation therewith and having the lower end thereof located in closely spaced relation above the lower part of said bowl, means for introducing said stock to said lower part of said bowl for upward flow along said bowl wall, means for rotating said bowl to subject said upwardly flowing stock to centrifugal force causing said particles therein to collect along said wall, generally radially arranged partitions within said bowl and said inlet tube for causing said stock to rotate at the same angular rate with said bowl and tube while flowing therethrough and substantially preventing laminar flow circumferentially thereof, a stationary discharge tube concentric with said inlet tube for receiving said upwardly flowing stock and having the lower end thereof extending below the level of said bowl rim in radially inwardly spaced relation with said bowl wall to form therewith an annular discharge orifice and discharge space within said bowl, said discharge tube being of a diameter materially greater than that of said inlet tube and closely approaching that of the adjacent wall of said bowl to provide an effective flow area therethrough substantially greater than through said inlet tube and to maintain said upward flow of stock relatively shallow substantially entirely radially outward of said inlet tube, said bowl wall diverging continuously up to said rim to cause said collected particles to travel upwardly thereon and through said discharge orifice and discharge space for discharge over said rim, and means for supplying additional liquid to said chamber at a controlled rate maintaining said chamber filled with liquid and providing a relatively slow inflow through said discharge orifice substantially preventing outward flow of stock through said orifice and washing back into said bowl fibrous material from said particles while permitting said particles to discharge through said orifice.

4. Centrifugal apparatus for separating heavy particles from a liquid suspension comprising a stationary casing forming a chamber, a bowl supported for rotation within said chamber and having an upwardly diverging wall having the rim thereof located below the top of said chamber a stationary discharge tube located in the upper end of said chamber, an inlet tube extending into the lower part of said bowl for introducing said suspension to said bowl for upward flow to said discharge tube, said discharge tube having the lower end thereof extending below the level of said bowl rim in radially inwardly spaced relation with said bowl wall to form therewith an annular discharge orifice and discharge space within said bowl, means for rotating said bowl to subject said suspension to centrifugal force while flowing over said upwardly diverging bowl wall causing said particles therein to collect along said wall, said discharge tube being of a diameter closely approaching that of the adjacent wall of said bowl to maintain said upward flow of liquid relatively shallow and to minimize inward travel within said bowl after discharge from said inlet tube, said bowl wall diverging continuously up to said rim to cause said collected particles to travel upwardly thereon and through said discharge orifice and discharge space for discharge over said rim into said chamber, means for maintaining said chamber continuously filled with liquid to control outward flow of liquid through said orifice while maintaining a continuous upward flow of liquid within said bowl and through said discharge tube, means forming a cylindrical passage having an outlet located exteriorly of said casing and connected at an inner portion thereof with said chamber for receiving said particles by gravity therefrom, a conveyor screw rotatably mounted within said passage and having the forward end thereof spaced axially within said passage from said outlet to provide a space therebetween, means for rotating said screw to convey said particles from said inlet to said outlet, a closure for said outlet pivoted exteriorly thereof for movement towards and away from said outlet, and means for counterweighting said closure into closing relation with said outlet to hold said closure in closed position causing accumulation and compaction of said particles in said space between said conveyor screw and said outlet and thereafter to open from the pressure of said compacted particles for discharge thereof while retaining sufficient compacted particles in said space to effect substantial sealing of said outlet against escape of liquid therethrough.

5. A discharge mechanism for use with apparatus for separating solid particles from a liquid suspension in a separating apparatus including a separating chamber and means for causing said suspension to flow through said chamber and for separating said particles from said suspension and collecting said separated particles within said chamber, comprising means forming a cylindrical discharge passage at the lower end of said chamber having an inlet for receiving said collected particles by gravity from said chamber and having an outlet located exteriorly of said chamber, a conveyor screw rotatably mounted within said passage and having the forward end thereof spaced axially within said passage from said outlet, means for rotating said screw to convey said particles from said inlet to said outlet, a closure for said outlet pivoted exteriorly thereof for movement towards and away from said outlet, and means for counterweighting said closure into closing relation with said outlet to hold said closure in closed position causing accumulation and compaction of said particles in said space between said conveyor screw and said outlet, said counterweighting means being yieldable in response to the pressure of said compacted particles on said closure to cause said closure to open for discharge of said particles while retaining sufficient compacted particles in said space to effect substantial sealing of said outlet against escape of liquid therethrough.

6. Centrifugal apparatus adapted for use in separating solid particles from suspension in a liquid of lower specific gravity, comprising a casing forming a separating chamber adapted to be filled with liquid, means in said casing for causing said suspension to flow through said chamber and for separating said particles from said suspension and causing said separated particles to be collected within said chamber, means forming a cylindrical discharge passage at the lower end of said chamber having an inlet for receiving said collected particles by gravity from said chamber and having an outlet located exteriorly of said chamber, a closure for said outlet pivoted exteriorly thereof for movement towards and away from said outlet, a conveyor screw rotatably mounted within said passage and having the forward end thereof terminating in-

wardly of said outlet to provide a space in said passage between said screw and said closure, yieldable means for counterweighting said closure into closing relation with said outlet, and means for rotating said screw to convey said particles from said inlet for accumulation and compaction of said particles in said space and thereafter to urge said compacted particles against said closure and to open said closure against said counterweighting means for discharge of said said particles through said outlet while retaining sufficient compacted particles in said space to effect substantial sealing of said outlet against escape of liquid therethrough.

7. Centrifugal apparatus for separating heavy particles from a liquid suspension comprising a stationary casing forming a chamber, a bowl supported for rotation within said chamber and including an upwardly diverging imperforate wall having the rim thereof located below the top of said chamber, an inlet tube secured within said bowl with the lower end thereof closely spaced above the bottom of said bowl and of materially smaller diameter than said bowl rim, means for introducing said suspension downwardly through said inlet tube to said bowl for upward flow along said wall, means for rotating said bowl and tube to subject said suspension to centrifugal force causing said particles therein to collect along said wall, generally radial partitions within said bowl and inlet tube causing said suspension to rotate at the same angular rate with said bowl and tube while flowing therethrough and substantially preventing laminar flow circumferentially thereof, a stationary discharge tube concentric with said inlet tube for receiving said upward flow and having the lower end thereof extending below the level of said bowl rim and spaced radially inwardly from said bowl wall to form therewith an annular discharge orifice and discharge space within said bowl, said discharge tube being of a diameter materially greater than said inlet tube and closely approaching that of the adjacent said bowl wall to provide an effective flow area therethrough greater than through said inlet tube and to maintain said upward flow of stock relatively shallow and substantially radially outward of said inlet tube, said bowl wall diverging continuously up to said rim to cause said collected particles to travel upwardly thereon and through said discharge orifice and discharge space over said rim into said chamber, and means for maintaining said chamber continuously filled with liquid to control outward flow of liquid through said orifice while maintaining a continuous upward flow of liquid within said bowl and through said discharge tube.

8. Centrifugal apparatus for separating heavy particles from a liquid suspension comprising a stationary casing forming a chamber, a bowl supported for rotation within said chamber and

including an upwardly divering imperforate wall having the rim thereof located below the top of said chamber, an inlet tube secured within said bowl with the lower end thereof closely spaced above the bottom of said bowl and of materially smaller diameter than said bowl rim, means for introducing said suspension downwardly through said inlet tube to said bowl for upward flow along said wall, means for rotating said bowl and tube to subject said suspension to centrifugal force causing said particles therein to collect along said wall, generally radial partitions within said bowl and inlet tube causing said suspension to rotate at the same angular rate with said bowl and tube while flowing therethrough, a stationary discharge tube for receiving said upward flow concentric with and of materially greater diameter than said inlet tube to provide an effective flow area therethrough greater than through said inlet tube, said discharge tube having the lower end thereof extending below the level of said bowl rim in closely radially spaced relation with said bowl wall to form therewith an annular discharge orifice and discharge space within said bowl and to maintain said upward flow of stock relatively shallow and radially outward of said inlet tube, said bowl wall diverging continuously up to said rim to cause said collected particles to travel upwardly thereon through said discharge orifice and discharge space over said rim into said chamber, and means for supplying additional liquid to said chamber at a controlled rate maintaining said chamber filled with liquid and providing a relatively slow inflow of liquid through said discharge space and orifice minimizing outward flow of liquid through said orifice while permitting said particles to discharge through said orifice.

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