

Dec. 16, 1969

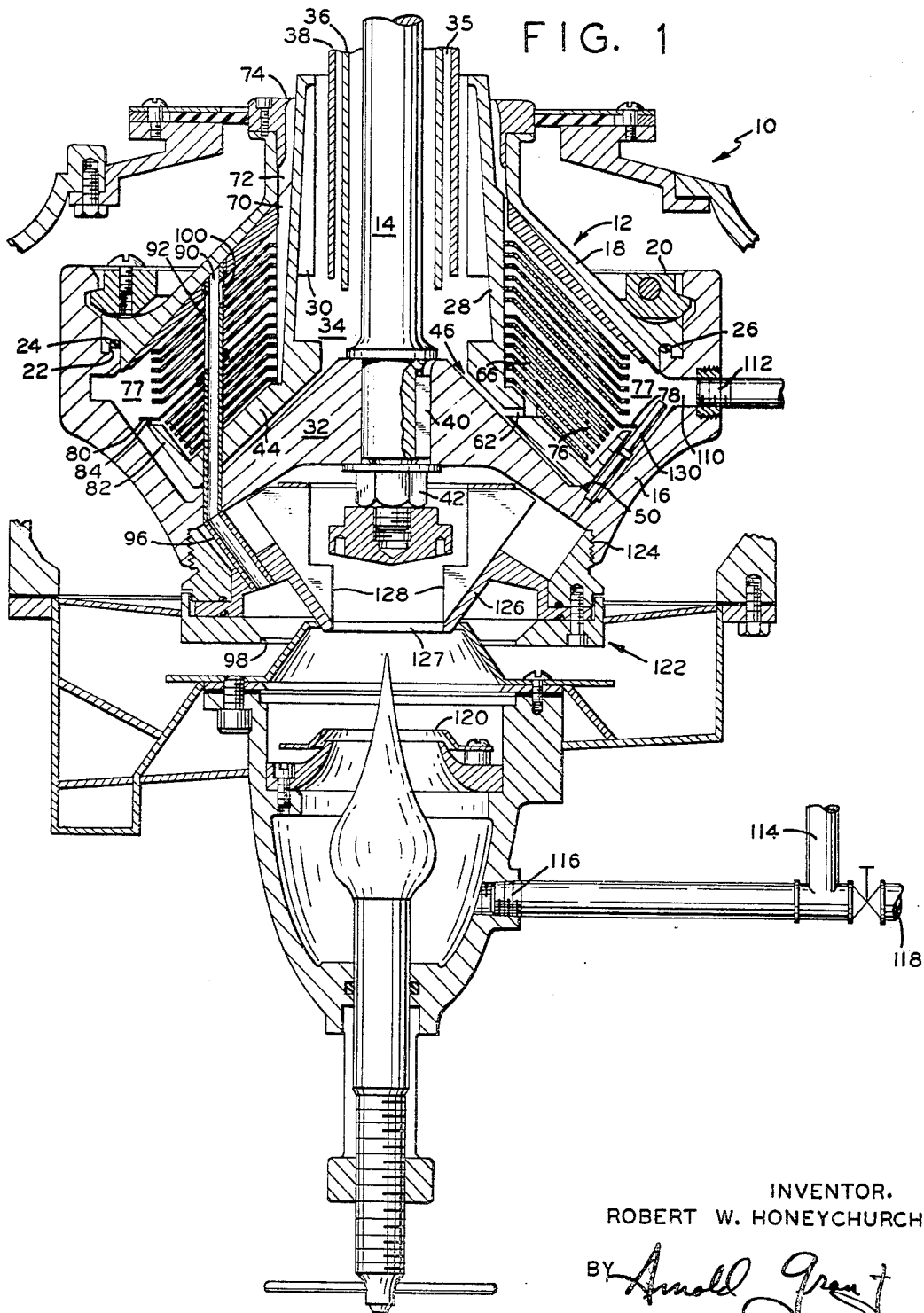
R. W. HONEYCHURCH

3,484,040

MULTIPLE CHAMBER CENTRIFUGE

Original Filed Dec. 21, 1966

2 Sheets-Sheet 1



Dec. 16, 1969

R. W. HONEYCHURCH

3,484,040

MULTIPLE CHAMBER CENTRIFUGE

Original Filed Dec. 21, 1966

2 Sheets-Sheet 2

FIG. 2

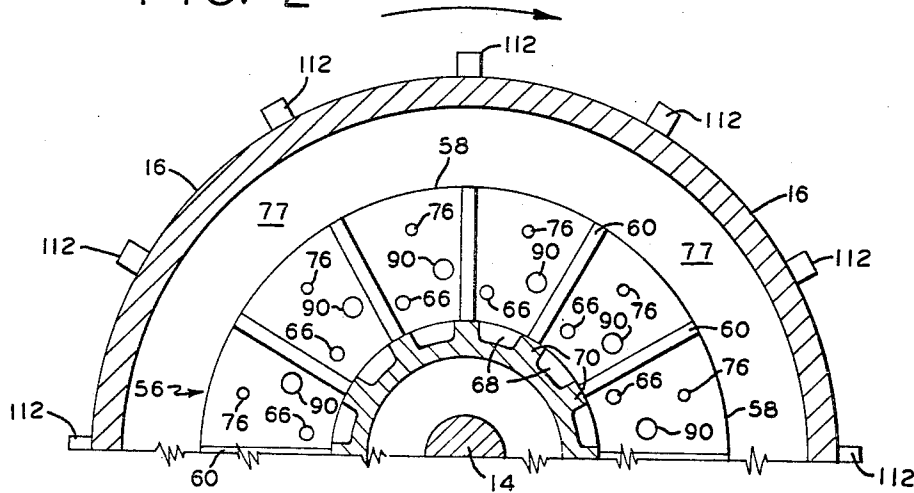
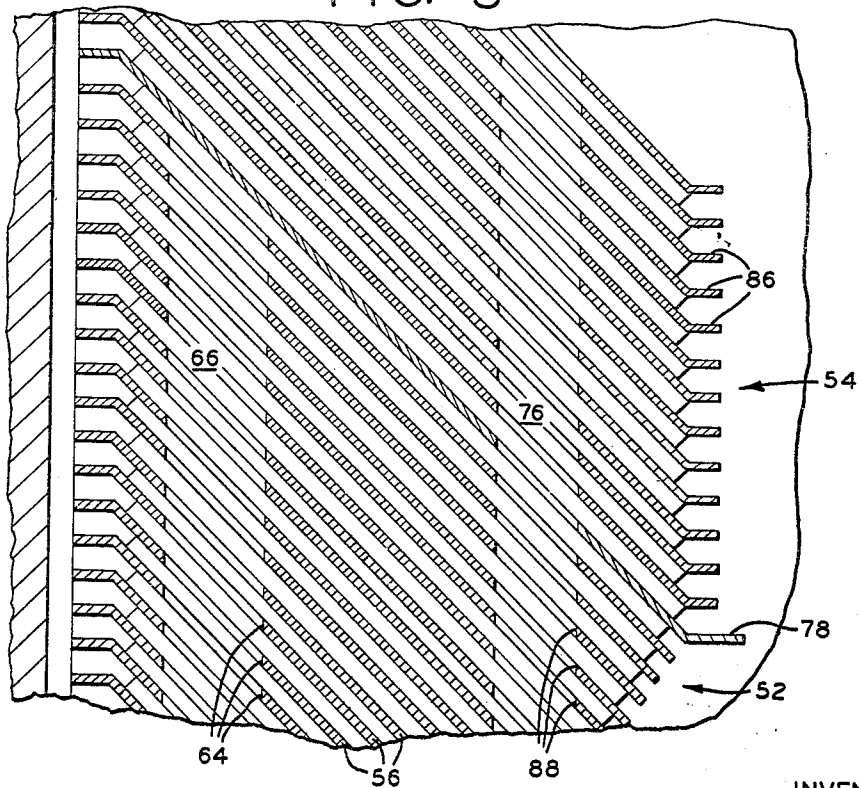


FIG. 3



INVENTOR
ROBERT W. HONEYCHURCH
BY *Arnold Grant*
AGENT.

1

3,484,040

MULTIPLE CHAMBER CENTRIFUGE

Robert W. Honeychurch, Stamford, Conn., assignor to
Dorr-Oliver Incorporated, Stamford, Conn., a corpora-
tion of Delaware

Continuation of application Ser. No. 603,539, Dec. 21,
1966. This application Feb. 6, 1969, Ser. No. 800,342

Int. Cl. B04b 15/00

U.S. Cl. 233—14

19 Claims

ABSTRACT OF THE DISCLOSURE

The present invention relates to a three-phase, liquid-liquid-solid, centrifugal separator. A series of separating chambers are provided to fractionate the feed material and a series of conduits are provided in and between the separating chambers to introduce feed material, transfer partially fractionated feed material and discharge separated fractions of the feed material.

This application is a continuation of application Ser. No. 603,539, filed Dec. 21, 1966, and now abandoned.

More particularly, the present invention relates to a double overflow centrifugal separator which will effect a simultaneous clarification of the heavy liquid fraction of a three fraction mixture together with the clarification of the light liquid fraction and concentration of the solids fraction.

In the majority of industrial situations the light liquid fraction is the dominant and most valuable component of the three fraction mixture. As a result most double overflow centrifuges for three fraction mixtures are designed specifically to maximize the separation between the light liquid fraction and the remaining heavy liquid-solids fraction, with minimum interest in the disentrainment of the solids from the heavy liquid. In those instances where it is also desired to maintain the integrity of the heavy liquid acceptable results have been obtained through the use of fan shaped secondary overflow tubes as the discharge outlet for the heavy liquid from the separating zone of the centrifuge. Flat, elliptical shaped secondary overflow tubes will decrease the exit velocity of the heavy liquid and this in turn enhances the disentrainment of solids from the heavy liquid. These results remain acceptable as long as the light liquid continues to be the dominant component of the three fraction mixture. Once the heavy liquid loses its subordinate position in the mixture vis-à-vis the light liquid, the increased flow in the zone contiguous to the fan shaped secondary tubes will tend to retain and re-entrain solids rather than disgorge them.

When the heavy liquid begins to dominate the mixture and becomes the principal component for recovery, two basic centrifugal systems are applicable. The first involves a second centrifugal operation to separate the solids from the heavy liquid. Although such a process involves increased capitalization and service costs, it has been the usual mode of operation, especially for those three fraction mixtures where the relative difference in specific gravities between the heavy liquid and solids is minimal and the solids are not readily separated from the heavy liquid. The second alternative has been to use a single centrifugal separator having primary and secondary separating chambers. Devices such as those shown by Lindgren, Patent No. 2,179,941 and Strezynski, Patent No.

2

2,500,100 have given acceptable results as long as there is a sharp distinction and a clear differentiation in the relative specific gravities of the components of the three fraction mixture. As soon as any two of the fractions become difficult to separate from each other the re-mixing of the fractions inherent in these particular devices and devices of similar character prohibits their use.

In both Lindgren and Strezynski, the partially fractionated mixture is pumped out of the primary separating chamber, around a blind disc through the solids settling portion of the bowl, into the secondary separating chamber. As a result of this round-about route, many of the solid particles previously deposited in the solids settling portion of the bowl are re-entrained by the mixture as it flows from the primary to the secondary separating chambers. This increases the load on the separating discs in the secondary chamber. In addition, solids which are stripped in the separating discs of the secondary chamber must move against the countercurrent flow of the incoming mixture which increases the possibility that these solids particles will also be re-entrained by the mixture, thereby further decreasing the clarifying efficiency of these separators. These deficiencies are magnified when, as explained above, there is no clear distinction between the specific gravities of the heavy liquid and solids, and the solids component is readily re-entrained by the heavy liquid. This accounts for the prevalence in the art of the former of the two systems, i.e., separate centrifugation of the heavy liquid-solids mixture.

The present invention effectively eliminates any re-mixing of the components of the mixture once they are separated from each other so that a three fraction mixture having a dominance of heavy liquid can be fractionated in a single centrifugal separating operation. Re-mixing of the fractions is prevented by, first, retaining the partially fractionated component of the feed material within the disc stack throughout the separating process. That is, after the preliminary separation of the three fraction feed mixture into the light liquid fraction and a heavy liquid-solids mixture, the light liquid is discharged from the disc stack in one direction and the partially fractionated, heavy liquid-solids mixture flows in the opposite direction toward passageways provided in the disc stack between the primary and secondary separating chambers. The continued introduction of feed material into the primary separating chamber provides the motivating force to move the heavy liquid-solids mixture through the passageways to the secondary separating chamber. The partially fractionated heavy liquid-solids mixture is prevented from flowing out of the disc stack and into the solids compacting zone by the relative difference in energy levels between material outside the disc stack, and within the disc stack; the greater the radial distance from the axis of rotation the greater the velocity and thus the greater the energy. The heavy liquid-solids mixture within the disc stack does not possess sufficient energy to push aside the mixture immediately adjacent the periphery of the disc stack and the settled, conglomerated solids outside the disc stack. The heavy liquid-solids mixture in effect, being pushed from one side and hemmed in on the other, must then take the path of least resistance and that is the passageway between the primary and secondary separating chambers. By thus effectively preventing the heavy liquid-solids mixture from flowing through the settled solids, there is no danger of any re-entrainment of the settled solids by the mixture.

Re-mixing is further prevented by having each of the separated fractions move to its respective discharge orifice unhampered by the flow of the feed mixture or partially fractionated mixture and without re-contacting any other separated fraction. As stated above, the light liquid separated from the feed in the primary separating chamber moves out of the disc stack in a direction opposite to the flow of the heavy liquid-solids mixture. As the solids are stripped from the heavy liquid in the secondary separating chamber, the solids move in one direction and the heavy liquid flows in the opposite direction. Each of the phases, as they are separated, are, thus, moved away from the other fractions and away from the feed and partially fractionated mixtures so that even the most difficult to separate liquid-liquid-solids relationships are effectively prevented from re-mixing.

To insure complete clarification of the heavy liquid the secondary separating chamber and the heavy liquid discharge passage both have outlets which permit discharge into the light liquid collection passage. Thus, any light liquid which may have become entrained with the heavy liquid into the secondary separating chamber can still be stripped from the heavy liquid by the discs in the secondary separating chamber and be discharged into the light liquid collection passage, or if any light liquid should continue to flow with the heavy liquid into the heavy liquid discharge passage there is still another opportunity for separation and thus complete clarification of the liquids.

It is, therefore, an object of the present invention to separate and clarify the heavy liquid of a heavy liquid dominated three fraction mixture in a single centrifugal operation.

It is another object of the present invention to prevent any re-mixing of the separated fractions of a three fraction mixture once they are separated from the mixture.

It is a further object of the present invention to prevent the partially fractionated feed mixture from leaving the separating disc throughout the entire separating process.

It is yet another object of the present invention to provide passageways within the separating discs for introduction of the feed material, transfer of the heavy liquid-solids mixture, and discharge of a separated fraction.

The subject matter which applicant regards as his invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. The invention, however, as to its organization and method of operation together with further objects and advantages thereof will best be understood by reference to the following description taken in conjunction with the following drawings, in which:

FIGURE 1 is a vertical section through a three phase centrifugal separator incorporating the present invention;

FIGURE 2 is a fragmentary horizontal section through the rotor illustrating the underflow discharge nozzles and the positioning of the feed and discharged conduits within the disc stack; and

FIGURE 3 is an enlarged vertical section of a portion of the improved disc stack of the centrifugal separator of FIGURE 1.

Referring to the drawings, a centrifuge 10 is shown to illustrate an exemplary application of the present invention. However, it should be understood that the present invention is not limited in its application to the particular centrifugal apparatus disclosed.

Referring to FIGURE 1, the centrifuge 10 includes a rotor 12 carried by a vertical rotatable shaft 14. The rotor 12 has a frusto-conical bowl 16 and a matching cover 18 which are held in position by a clamp ring 20. The bowl 16 and cover 18 have matching inter-engaging rim portions 22, 24 suitably sealed by O-ring seal 26.

A tapered generally cylindrical shell 28 having a plurality of equally spaced axially extending vanes 30 surrounds shaft 14 to form a feedwell 34. Multi-fraction feed material is introduced into feedwell 34 through passage

35 between inner and outer concentric tubes 36, 38. The rotor hub 32 which is generally conical in shape is formed integrally with bowl 16 and is suitably secured to the shaft 14 by means of a key 40 and a hub nut 42.

An annular feed impeller 44 which is integral with feedwell shell 28 seats upon rotor hub 32 and has a plurality of radially extending vanes (not shown) which define outwardly extending channels 45 for the feed material. The peripheral portion 48 of the impeller is suitably secured with respect to the bowl by means of a resilient ring seal 50. The impeller vanes serve to impart rotary motion to the feed material to deliver the feed material downward and outward to channels 46.

A plurality of separating chambers 52, 54 (FIG. 3) occupy the space in the rotor overlying the feed impeller 44 to separate the feed material into its component fractions. In this particular exemplary application only two separating chambers are shown, but it should be understood that if a feed material having more than three fractions is to be separated additional chambers using the methods and apparatus herein disclosed are intended to be within the purview of this invention. The primary separating chamber 52 comprises a series of nested annular separating discs 56 which are divided into wedge shaped sections 58 by radially extending disc spacers 60 (FIGURE 2). The feed material from channels 46 (FIGURE 1) is pumped into the primary separating chamber 52 through a plurality of circumferentially spaced passages 62 in the impeller 44. A series of openings 64 in the discs overlies each passage 62 to form vertical feed distribution conduits 66.

The feed material rises through conduits 66 and discharges onto the discs 56 where the action of the centrifugal forces causes the primary separation of the mixture into the light liquid and the partially fractionated heavy liquid-solids mixture. The light liquid moves inwardly toward the axis of rotation due to the pressure created by the incoming feed material rising in conduit 66 and discharging onto the discs 56. The separated light fraction continues along the discs in the primary separating chamber until it is discharged into collection channels 68 between axially extending vanes 70 (FIGURE 2). The vanes 70 prevent the light liquid from developing cross-currents while the liquid rises in channels 68 to discharge over weir 74 as the primary overflow.

The partially fractionated heavy liquid-solids mixture moves in the opposite direction from the separated light liquid, outwardly along the discs, until it intercepts transfer conduits 76. The partially fractionated heavy liquid-solids mixture is prevented from continuing along the discs and discharging out of the primary separating chamber into the solids compacting zone 77 of the rotor by the relative difference in energy levels between the mixture within the separating discs and the solids slurry outside the separating discs. It is axiomatic that the greater the radial distance from the axis of rotation, the greater the velocity of the particles and correspondingly the greater the energy level of those particles. Although the radial component of the velocity and correspondingly the radial component of the energy of the particles in the centrifugal separator is relatively slight, the heavy liquid-solids mixture in the separator discs does not possess sufficient energy relative to the energy of the solids slurry outside the separating discs to further compact the solids slurry against the walls of the rotor and clear a path for the heavy liquid-solids mixture. The heavy liquid-solids mixture with no other path open will thus be forced to remain within the separating discs and move through transfer conduit 76, thereby effectively preventing any re-entrainment of settled solids by the mixture. To further insure that no heavy liquid-solids mixture discharges from the primary separating chamber 52 and enters the solids compacting zone 77 a phase divider or divider disc 78 is provided between the primary and secondary separating chambers. The phase divider 78 is an enlarged diameter annular

disc which extends outwardly beyond the separating discs 56 to a point just above the foot portion 82 of the impeller 44 to form an orifice 84. The orifice 84 will not allow any appreciable amounts of heavy liquid-solids mixture to pass through and into solids compacting zone 77 but will allow any especially heavy particles which may have been stripped from the heavy liquid-solids mixture by the separating action of the primary chamber to pass through. These heavy particles will bleed through orifice 84 into the solids compacting zone 77 of the rotor.

The secondary separating chamber 54 extends from the phase divider 78 to the rotor cover 18 and like the primary separating chamber 52 is also comprised of a series of nested annular discs 86 divided into wedge-shaped sections by radially extending disc separators 87. Transfer conduits 76 are defined by a series of vertically aligned openings 88 through the full length of primary separating chamber 52, phase divider 78, and the full length of secondary separating chamber 54 to transfer the partially fractionated heavy liquid-solids mixture from the primary separating chamber to the secondary separating chamber. Alternatively, as is well known in the art, transfer conduit 76 could be a conduit, within the series of aligned openings, with at least one opening in the conduit for each series disc to receive or discharge the partially fractionated mixture. The mixture is evenly distributed along the secondary separating discs 86 due to the equalized opposing pressures and acted upon by centrifugal forces to strip the solids from the heavy liquid by means of the well known separating disc principle.

The heavy liquid moves inwardly, toward the axis of rotation, until it intercepts heavy liquid discharge tubes 90. Discharge tubes 90 are positioned in the disc stack with one tube per wedge-shaped disc section. The tubes have slots 92 on their outer wall for the full length of their exposure in the secondary separating chamber 54 and are imperforate through that portion located in primary separating chamber 52. A seal 94 is positioned around each tube 90 where it intersects divider disc 78 to prevent leakage between the primary and secondary separating chambers. The tubes 90 discharge the heavy liquid into conduits 96 and from there it is discharged over weir 98 as the secondary overflow.

Any light liquid that may have been entrained by the heavy liquid-solids mixture and transferred through passages 76 into the secondary separating chamber will travel inwardly, toward the axis of rotation, to channels 68 to join the rest of the separated light liquid. Should any light liquid be entrained with the heavy liquid entering tubes 90, a weep hole 100 is provided at the inner surface at the upper end of each tube to allow the light liquid to discharge. This light liquid will also move inwardly along discs 86 to channels 68.

The solids stripped from the heavy liquid in the secondary separating chamber move outwardly from the discs and settle in the solids compacting zone 77 for subsequent discharge from the rotor.

Thus it can be seen that re-mixing between the separated fractions is prevented by causing the separated fractions to move away from each other and from the feed material and from the partially fractionated heavy liquid-solids mixture.

By way of review, the light liquid is stripped from the heavy liquid-solids mixture in the primary separating chamber; the light liquid moves inwardly, toward the axis of rotation to discharge into channels 68, the heavy liquid-solids mixture moves outwardly, away from the axis of rotation, to transfer conduit 76. In the secondary separating chamber the solids are stripped from the heavy liquid and move outwardly toward solids compacting zone 77 and the heavy liquid moves inwardly to discharge into tubes 90. As can be seen from FIGURE 2, the feed conduit 66 and the transfer conduit 76 in the primary separating chamber 52 are so situated that as the feed material fans out from passageway 66 toward the separation

interface, between the two sets of conduits, the greater portion of the light liquid on being stripped from the heavy liquid-solids mixture moves towards discharge channels 68 unhampered by the countercurrent flow of the feed material. In a like manner, the heavy liquid-solids mixture discharged from conduit 76 into the secondary separating chamber 54 fans out toward the separation interface between conduit 76 and tube 90. The solids stripped from the heavy liquid by the action of the separating discs move out of the discs unhindered by any countercurrent flow of heavy liquid-solids mixture. The heavy liquid, once free of the interface, also has nothing to hamper its movement between it and discharge tube 90. Thus, with any possibility of re-mixing removed, even the most difficult to separate mixture can be effectively and permanently fractionated.

The solids in compacting zone 77 are moved by centrifugal force into a raceway 110 on the periphery of rotor 12 for subsequent discharge out of the rotor through a series of equally spaced discharge nozzles 112 into the volute chamber of the surrounding stationary housing, here not shown. A return conduit 114 which receives the solids from the volute chamber recycles a portion of the discharged underflow to the rotor through inlet 116. Underflow is returned to the system to maintain the desired overflow-underflow equilibrium and the desired concentration of the discharge underflow. A wash liquid, to scrub the concentrated solids, can be introduced into the system through conduit 118 which feeds into return conduit 114 before it enters the rotor. The returned underflow, either with or without a wash liquid, passes through nozzle 120 into return impeller 122. Impeller 122 which is attached to bowl 16 by threaded attachment 124 mounts impeller ring 126 which forms an opening 127 into return impeller 122. The return impeller brings the recycled underflow up to speed by means of radially extending vanes 128 and pumps it into return tubes 130 for subsequent discharge into the solids compacting zone 77.

As this invention may be embodied in several forms without departing from the spirit or essential character thereof, the present embodiment is illustrative and not restrictive. The scope of the invention is defined by the appended claims rather than by the description preceding them, and all embodiments which fall within the meaning and range of equivalency of the claims are, therefore, intended to be embraced by those claims.

I claim:

1. A rotor for a centrifugal separator comprising a rotor bowl, means defining a plurality of separating chambers within said bowl to sequentially separate a multi-fraction feed material into fractions, each of the separating chambers having a plurality of nested separating discs therein, means for supplying the multi-fraction feed material to a first separating chamber, conduit means for transferring at least one separated fraction from the first separating chamber to a second separating chamber, said conduit means being open to the spaces between the discs in the first separating chamber for receiving the material to be transferred and being open to the spaces between the discs in the second separating chamber for discharging the transferred material thereto, and means to discharge each of the separated fractions from said rotor.

2. A rotor for a centrifugal separator as defined in claim 1 wherein said conduit means between separating chambers is a series of aligned openings in said separating discs.

3. A rotor for a centrifugal separator as defined in claim 1 wherein said first separating chamber has at least one conduit means therein with at least one opening for each of the first chamber separating discs to distribute the multi-fraction feed material from said supply means to said separating discs.

4. A rotor for a centrifugal separator as defined in claim 1 wherein a fraction separated in said first separat-

ing chamber is discharged from one end of the rotor and one of the fractions separated in said second separating chamber is discharged from the other end of the rotor.

5. A rotor for a centrifugal separator comprising a rotor bowl, means defining a primary and a secondary separating chamber each having a series of longitudinally spaced separating discs, means to supply a feed material to said primary separating chamber, means in the separating discs of said primary separating chamber to distribute the feed material to said discs, said primary separating chamber separating at least one of the fractions from the feed material, conduit means extending longitudinally within the separating discs of said primary and secondary separating chambers to transfer the remaining feed material from said primary to said secondary separating chamber, and means to individually discharge each of the separated fractions from said rotor.

6. A rotor for a centrifugal separator as defined in claim 5 wherein the fraction separated in said primary separating chamber is an overflow fraction which discharges from the inner periphery of the primary chamber discs into at least one overflow channel, said channel extending longitudinally through the secondary separating chamber to discharge adjacent the secondary-separating-chamber end of the rotor, said overflow channel being open to the inner periphery of the secondary chamber discs.

7. A rotor for a centrifugal separator as defined in claim 6 wherein the means to discharge a secondary overflow fraction separated in said secondary separating chamber comprises at least one longitudinal conduit, said conduit extending through the separating discs in said secondary and primary separating chambers to discharge adjacent the primary-separating-chamber end of the rotor, said conduit being open to the spaces between the discs in the secondary chamber and closed to the spaces between the discs in the primary chamber.

8. A rotor for a centrifugal separator as defined in claim 7, said secondary overflow conduit being open to the spaces between the secondary discs only on its radially outward side, said conduit having a weep aperture on its radially inward side to release any primary overflow fraction which should have been separated in said primary separating chamber but which is entrained with the remaining feed material transferred to said secondary separating chamber and then entrained with the secondary overflow discharged into said conduit.

9. A rotor for a centrifugal separator as defined in claim 5 wherein said means defining said primary and secondary separating chambers includes a divider disc having an outer periphery extending radially outwardly of the discs in the separating chambers to prevent the discharge of remaining feed material from said primary separating chamber other than through the longitudinally extending transfer conduit means.

10. A rotor for a centrifugal separator as defined in claim 9 wherein underflow fractions separated in said primary and said secondary separating chambers are discharged from the separating discs radially outwardly past the outer periphery of said divider disc to an underflow compaction zone of said rotor bowl.

11. A rotor for a centrifugal separator comprising a rotor bowl, means defining within said bowl a plurality of functionally sequential separating chambers, said means including at least one divider disc having an inner periphery and an outer periphery, means supplying a multi-fraction feed material into a first separating chamber of the bowl at a first location having a radius intermediate the radius of the inner and outer periphery of said divider disc whereby the feed material is separated into at least two fractions, means for discharging one of said fractions from the rotor, means for collecting another of the fractions from the first separating chamber at a second location having a radius intermediate the radius of the inner and outer periphery of the divider disc, means for

delivering the fraction so collected to a second separating chamber at a third location having a radius intermediate the radius of the inner and outer periphery of the divider disc so as to separate such fraction into at least two further fractions, and means for discharging the latter two fractions from the rotor.

12. A rotor as defined in claim 11, the collecting means at said second location being radially outward of the feed supply means at said first location whereby the lighter fraction separated in the first separating chamber moves radially inwardly from said feed means and the heavier fraction moves radially outwardly to said collecting means for delivery to the second separating chamber.

13. A rotor as defined in claim 11, said means for discharging the two further fractions separated in the second separating chamber including overflow conduit means open to the second chamber at a fourth location, said fourth location being radially inward of the delivery means at said third location whereby the lighter of said two further fractions moves inwardly from said delivery means to said overflow conduit means and the heavier of said two further fractions moves outwardly from said delivery means past the outer periphery of said divider disc to the periphery of the rotor bowl.

14. A rotor for a centrifuge comprising a rotor bowl, an annular disc dividing the bowl into a first and a second separating chamber, the disc having an inner periphery and an outer periphery, a primary overflow means positioned in the rotor so as to create a liquid level in the bowl radially inward of the inner periphery of the divider disc whereby primary overflow from both the first and the second separating chambers are discharged together by the primary overflow means, means positioned in the outer periphery of the rotor bowl to discharge underflow from the first and the second separating chambers, the rotor being characterized by: means for supplying a multi-fraction feed material into the first separating chamber at a first location having a radius intermediate the radii of the inner and outer peripheries of the divider disc, means for transferring material out of the first separating chamber at a radius intermediate the radii of the feed supply means and the outer periphery of the divider disc and for introducing such material into the second separating chamber at a radius intermediate the radii of the inner and outer peripheries of the divider disc, and means for discharging a secondary overflow from the second separating chamber at a radius intermediate the radii of the outlet of the transfer means in the second chamber and the inner periphery of the divider disc.

15. A rotor as defined in claim 14 including a plurality of separating discs in the separating chambers, the rotor being further characterized in that the secondary overflow discharge means includes at least one longitudinal conduit extending through the separating discs in the second separating chamber, the conduit being open to each of the spaces between the separating discs in the second chamber.

16. A rotor as defined in claim 15 further characterized in that the primary overflow means is located at one end of the rotor bowl and the secondary overflow means discharges at the opposite end of the bowl.

17. A rotor as defined in claim 16, said primary overflow means being located at the end of the rotor bowl adjacent the secondary separating chamber, said secondary overflow discharge conduit also extending through the separating discs in the primary chamber but being closed to the spaces therebetween, the secondary overflow means discharging at the end of the rotor bowl adjacent to the primary separating chamber.

18. A rotor as defined in claim 15 further characterized in that the secondary overflow conduit is open to the spaces between the separating discs in the secondary chamber only on its radially outward side so as to inhibit the entry of stray underflow material which moves outwardly along the separating discs,

9

19. A rotor as defined in claim 18 further characterized in that the portion of the secondary overflow conduit within the second separating chamber has a weep aperture on its radially inward side to release any primary overflow material which is entrained with the secondary overflow material entering the conduit. 5

10

2,331,352	10/1943	Sharples	233—17
2,500,100	3/1950	Strezynski	233—28
2,715,994	8/1955	Steinacker	233—18
3,080,108	3/1963	Jacobson	233—14

ROBERT W. JENKINS, Primary Examiner

References Cited

UNITED STATES PATENTS

2,179,941	11/1939	Lindgren	233—27	10
-----------	---------	----------	--------	----