

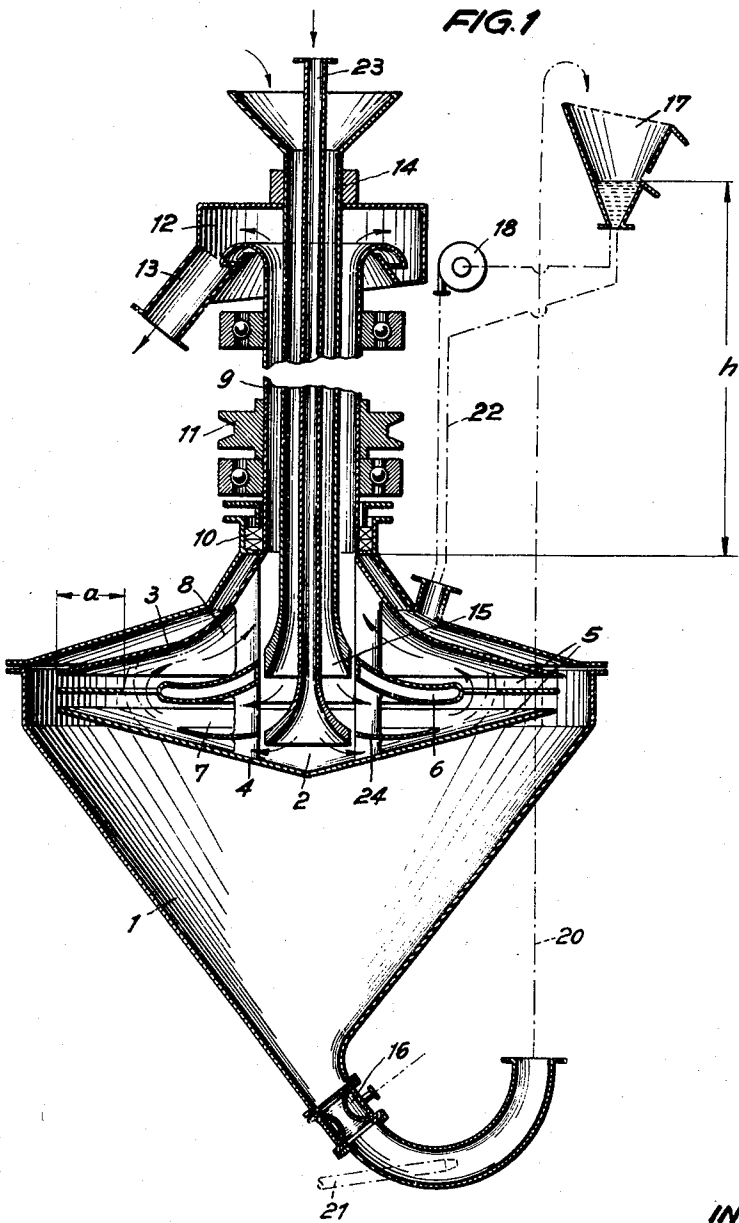
Dec. 16, 1958

R. TEUTEBERG  
HEAVY MEDIA CENTRIFUGAL SEPARATING  
APPARATUS AND METHOD

2,864,499

Filed Sept. 9, 1952

5 Sheets-Sheet 1



INVENTOR  
Rudolf Teuteberg  
BY  
Burgess & Dillidge  
attorneys

Dec. 16, 1958

R. TEUTEBERG  
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2,864,499

Filed Sept. 9, 1952

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FIG. 2

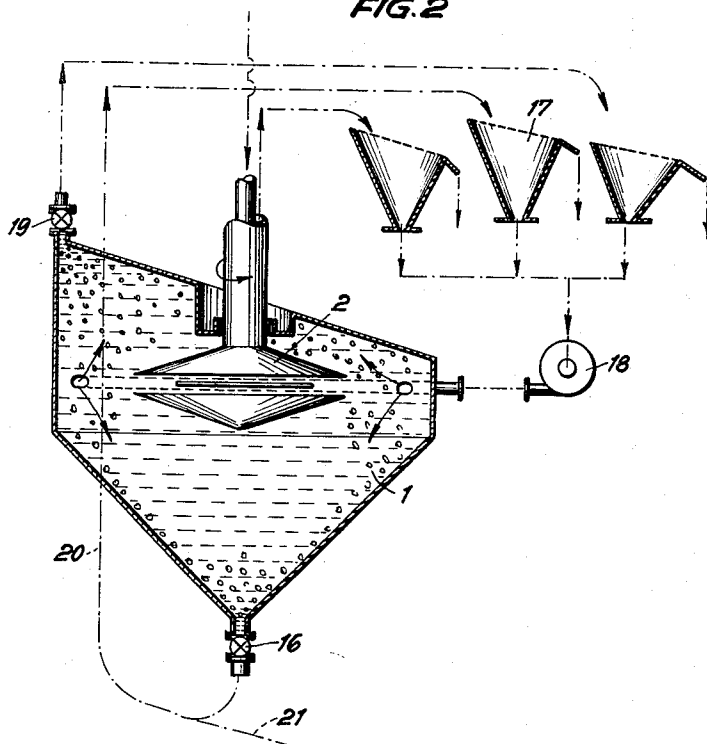
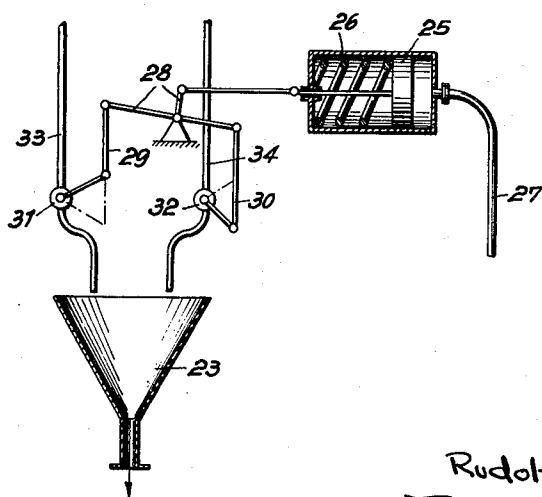


FIG. 3



INVENTOR  
Rudolf Teuteberg  
By Burgess & Dinwiddie  
attorneys

Dec. 16, 1958

R. TEUTEBERG  
HEAVY MEDIA CENTRIFUGAL SEPARATING  
APPARATUS AND METHOD

2,864,499

Filed Sept. 9, 1952

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FIG. 4

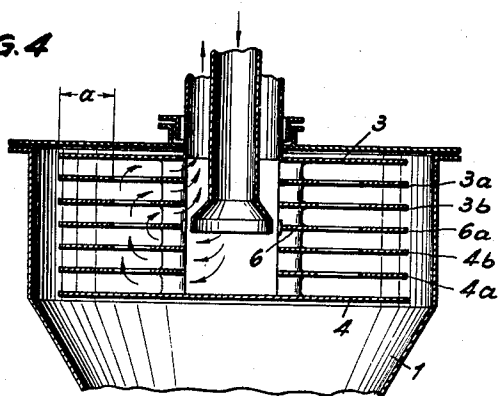


FIG. 5

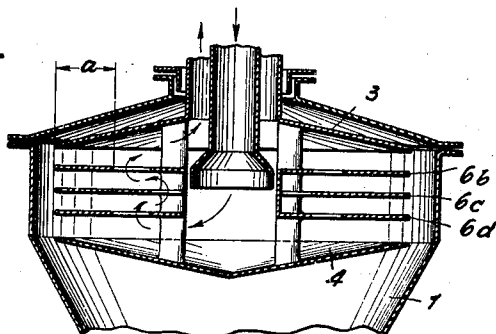
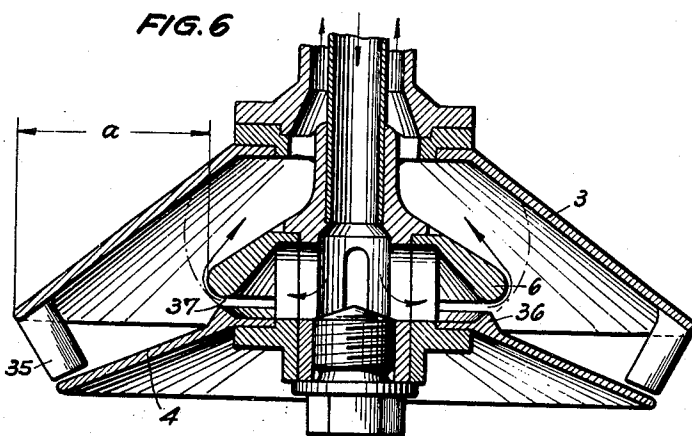


FIG. 6



INVENTOR

Rudolf Teuteberg  
By  
Burgess & Dunlap  
attorneys

Dec. 16, 1958

R. TEUTEBERG  
HEAVY MEDIA CENTRIFUGAL SEPARATING  
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2,864,499

Filed Sept. 9, 1952

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FIG. 7

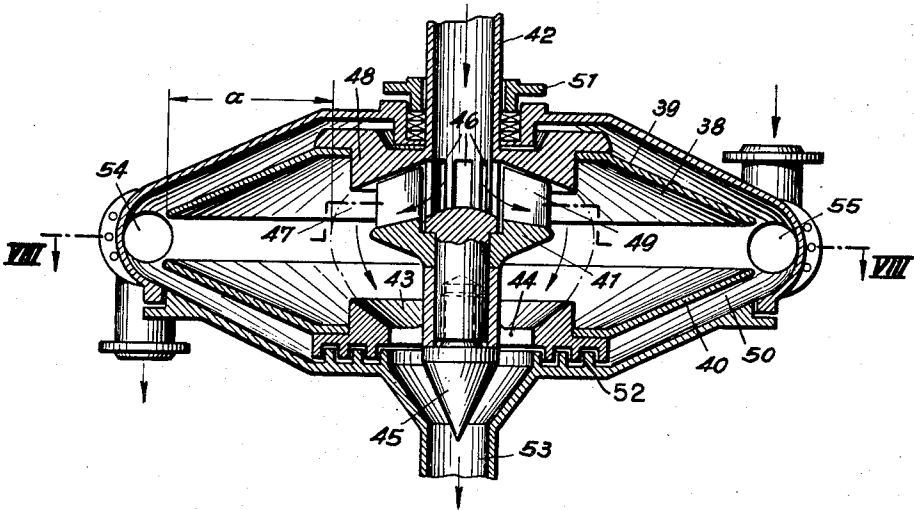
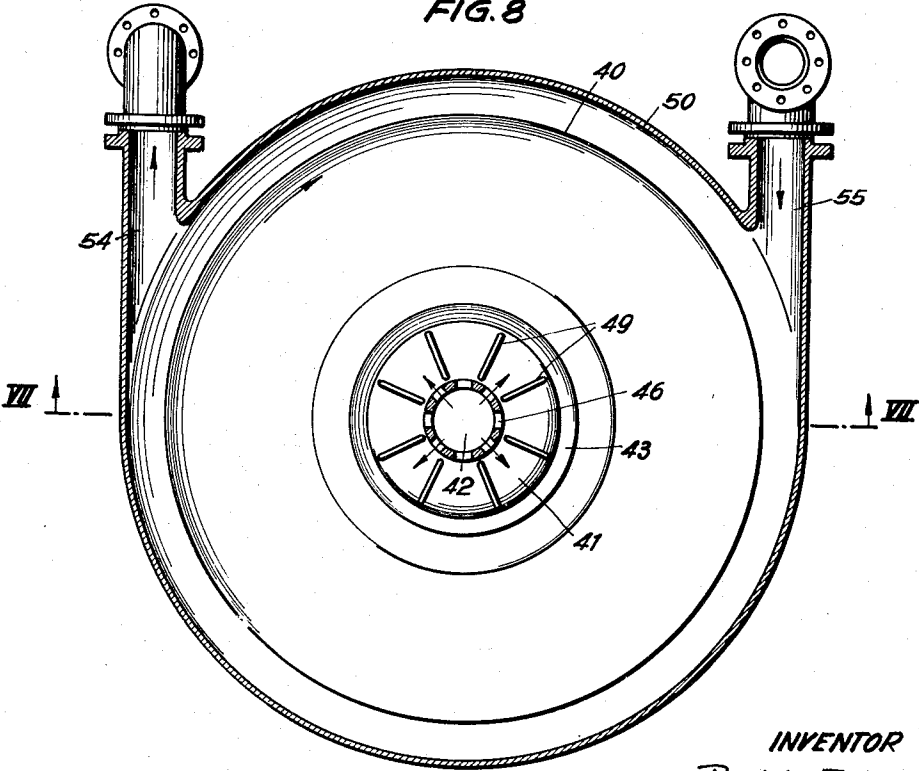


FIG. 8



INVENTOR  
Rudolf Teuteberg  
By  
Bungess + Dinkelager  
attorneys

Filed Sept. 9, 1952

# HEAVY MEDIA CENTRIFUGAL SEPARATING APPARATUS AND METHOD

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**FIG. 9**

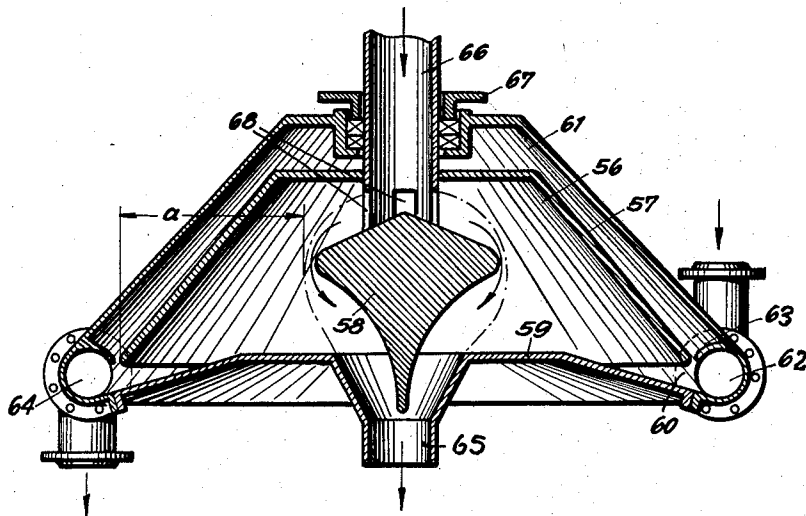
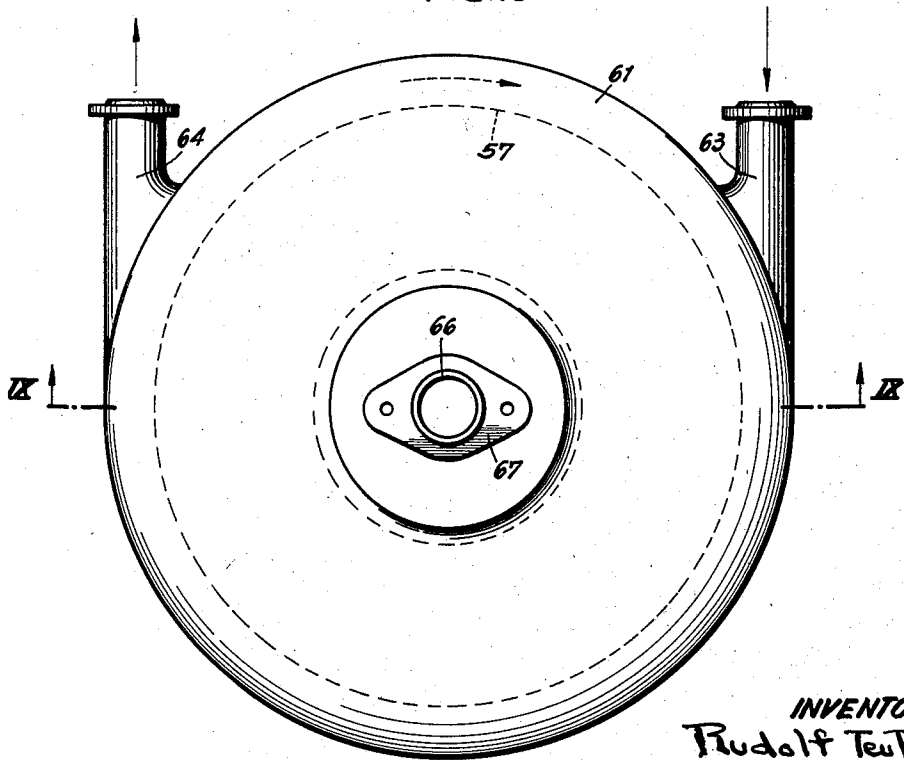


**FIG. 10**



INVENTOR  
Rudolf Teuteberg  
By  
Bungess & Dunlop  
attorneys

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2,864,499

## HEAVY MEDIA CENTRIFUGAL SEPARATING APPARATUS AND METHOD

Rudolf Teuteberg, Dortmund, Germany, assignor to SKB Schuechtermann & Kremer-Baum, Aktiengesellschaft Fuer Aufbereitung, Dortmund, Germany, a German corporation

Application September 9, 1952, Serial No. 308,630

Claims priority, application Germany September 21, 1951

19 Claims. (Cl. 209—172)

This invention relates to improvements in the working up of minerals in heavy liquids. It more particularly relates to a method and apparatus for working up minerals, such as the cleaning of coal in heavy liquids with the use of centrifugal force.

The working up of minerals such as coal with heavy liquids is known. The heavy liquids used in addition to true solutions such as zinc chloride include preferably suspensions of water and very finely ground weighting substances such as, for example, pyrites, magnetite and sand. The specific gravity of the heavy liquids used for the working up should lie between the specific gravity of the mineral and that of the material to be separated. Thus, in the case of coal, the specific gravity of the heavy liquids should lie between the specific gravity of the coal and that of the rock, so that the former floats in the heavy liquid, while the rock will sink. Gravity was generally used as the force for effecting the separation in this working up with the use of heavy liquids.

The use of centrifugal force instead of gravity in the working up and cleaning has also been proposed. Thus, for example, it was proposed to tangentially introduce a suspension of the material to be cleaned in a heavy fluid mass into a cyclone, so as to utilize the centrifugal forces produced by the rapid eddying of the liquid in the cyclone to effect the separation of the components in accordance with their specific gravities. In this case a portion of the heavy fluid will flow downward with a strong eddying action together with the heavy constituents centrifuged outwardly against the wall of the cyclone. These portions will be discharged out of the discharge opening at the tip of the cyclone, while the rest of the liquid flows upwardly with violent eddying in the vicinity of the axis of the cyclone and discharges the light components forced toward the center of the cyclone through a central discharge opening in the upper, broad end of the cyclone. Thus, with the use of a cyclone in addition to the centrifugal forces produced by the rotational motion of the liquid, strong eddy currents also exist which interfere with each other, particularly between the outer, downward eddy and the inner upward eddy, and prevent the full action of the centrifugal forces on the solid components. These eddy flows, which are unavoidable in cyclones, thus interfere in the operation and cause a substantially faulty discharge of the material, particularly in the case of material having large differences in particle size.

It has furthermore been proposed to feed a suspension of material to be cleaned or worked up in heavy liquid to a jet centrifuge. In this jet centrifuge the chamber is provided with discharge nozzles at the periphery for the heavy components which are centrifuged out. Nozzles are also provided in the vicinity of the axis of rotation for the discharge of the light components which are forced toward the center of rotation. With the use of the jet centrifuge, however, substantial quantities of the heavy liquid are centrifuged out through the nozzles so that there is a very strong flow of a heavy liquid in the

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centrifuge chamber which prevents a dependable separation. It is only possible to hold this disturbing flow within permissible limits by strongly throttling the cross-section of the nozzles. Narrow nozzle cross-sections, however, permit only a small output, continuously cause disturbances in operation due to clogging, and will only permit the centrifuge to be charged with very fine material, so that its field of use is greatly restricted.

One object of this invention is the working up and cleaning of minerals in heavy liquids with the use of centrifugal force without the above-mentioned difficulties. This, and still further objects will become apparent from the following description, read in conjunction with the drawings, in which:

Fig. 1 shows a longitudinal section of a centrifugal heavy liquid separator in accordance with the invention;

Fig. 2 shows a longitudinal section of an embodiment of a three-material heavy liquid separator;

Fig. 3 diagrammatically shows a control device for controlling the specific gravity of the heavy liquid in the rotary field of a centrifugal heavy liquid separator in accordance with the invention;

Fig. 4 shows a longitudinal section of an embodiment of an impeller for a centrifugal heavy liquid separator;

Fig. 5 shows a longitudinal section of still another embodiment of an impeller;

Fig. 6 shows a longitudinal section of still another embodiment of an impeller;

Fig. 7 shows a longitudinal section of still another embodiment of an impeller;

Fig. 8 shows a cross-section through the plane II—II of the impeller shown in Fig. 7;

Fig. 9 shows a longitudinal section of another embodiment of a centrifugal heavy liquid separator in accordance with the invention; and

Fig. 10 shows a top elevation of the separator shown in Fig. 9.

In accordance with the present invention, the charged material is conducted by a stream of conveying liquid, which need not consist of heavy liquid, into the vicinity of an annular, heavy-liquid field of rotation which is maintained within a vessel which is closed or held under the pressure head produced by the rotating field and filled with heavy liquid. The field is in communication with the inside of the vessel only at the periphery. Such a rotating field can be maintained completely free of flow or with a relatively low flow rate other than rotational, i. e., substantially static. It impresses its rotary motion on the charged material and separates it, under the influence of the centrifugal force, exclusively in accordance with the specific gravity, in that it forces the components of lower specific gravity towards its center of rotation and the constituents of heavier specific gravity towards its periphery. If the stream of conveying liquid feeds the charged material to the center of rotation of the rotating field, the light components remain in the stream of conveying liquid and are carried off with the latter while the heavy components are centrifuged towards the outside through the field of rotation. If, on the other hand, the stream of conveying liquid is fed at the periphery to the field of rotation, the heavy constituents remain in the stream while the light constituents are forced towards the field of rotation to the center of the field.

The field of rotation can be produced in any desired manner. In accordance with the present invention, it is produced between at least two driving discs rotating in a closed heavy liquid container and having their opposed surfaces spaced from each other. The space between said discs, which forms the rotating field, is in open connection with the space of the vessel only at the periphery and has centrally, with respect to the axis of rotation on one side an admission and on the other side a discharge

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for the stream of conveying liquid. Instead of the rotating discs there can also be provided stationary discs between which there rotates a rim of radial blades, which places the heavy liquid contained in the space between the discs in rotation. Between the admission and discharge for the stream of conveying liquid, there may be provided a reversing disc extending into the space between the driving discs. This reversing disc forces the stream of conveying liquid to move radially outward into a region of higher centrifugal action of the rotary field before it is conducted to the discharge opening. This new apparatus brings about a disc-shaped or annular rotary field in which the centrally-admitted components are loosened up along their path radially outwards through considerable increase in space and due to the greater distances apart thus brought about, can follow without impediment the centrifugal forces of the rotary field acting on them. In this way there is obtained a sharpness of separation of the cleaning process, with large output, such as neverbefore could be achieved.

The specific gravities in the rotary field can, in accordance with the invention, be maintained by heavy liquid introduced together with the charged material or by a special heavy liquid flow which is introduced into the space between the driving discs in such a manner that it surrounds the flow of material in the rotary field on the outside. In the latter case, the flow of conveying liquid for the charged material can consist of water.

In the drawing there are shown several embodiments of the subject matter of the invention.

The closed container 1 is filled with heavy liquid and contains a rotatable impeller 2. The impeller consists essentially of two driving discs 3, 4, the opposed surfaces of which are spaced from each other so as to form an intermediate space 5 which is in open connection with the inside of the container only at the periphery. Between the driving discs there is provided a reversing disc 6 of small diameter, which subdivides the intermediate space 5 in the vicinity of the axis of rotation into an inlet space 7 and an outlet space 8. The impeller 2 has a hollow drive shaft 9 which extends through a stuffing box 10 in a pressure-tight manner out of the container 1. The driving pulley 11 is positioned on this shaft 9 for rotating the impeller. The hollow shaft 9 is connected with the outlet space 8 of the impeller 2 and discharges on top into a stationary collector chamber 12 having an outlet connection 13. Centrally in the hollow shaft 9 there is arranged a preferably stationary inlet pipe 14 which discharges into the inlet space 7 of the impeller and engages by means of a slender flaring 15 with slight play in a water-tight manner into the bore of the reversing disc 6.

The container 1 tapers conically downward and has at the apex of the cone an outlet opening, the cross-section of which can be adjusted by means of an adjustable throttle valve 16.

In operation, after the container 1 and the impeller 2, including its hollow shaft 9, have been filled through the inlet pipe 14 with heavy liquid, valve 16 being closed, the impeller is placed in rotation. The container being closed prevents the impeller from emptying itself by pump action. The driving discs 3 and 4, as well as the reversing disc 6, are rotated by the shaft 9 and place only the liquid contained in the impeller in rapid rotation so that within the impeller there is produced a static, heavy-liquid rotary field which is in open communication with the inside of the container at the periphery of the impeller and has little or no flow motion other than rotation. Thereupon the material to be charged, which is suspended in a stream of heavy liquid, is conducted into the feed pipe 14 by gravity or under pressure. It passes first of all into the inlet space 7 in which it assumes the rotary motion of the impeller 2 and flows radially outward. Due to the strong widening of the inlet space in a radial direction, the flow velocity of the stream of mate-

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rial is reduced, while at the same time a strong loosening up of the components of the material charged takes place in the stream of conveying liquid. The components of the material which are now floating unhindered in the liquid flow are subjected on their path to centrifugal forces which increase strongly towards the outside and which throw the heavier parts of the material radially outwards considerably more rapidly than the lighter parts. At the end of the reversing disc 6, the liquid flow still has only a low flow velocity and reverses and flows back through the outlet space 8 radially inwards into the hollow shaft 9, inasmuch as the flow is not able to pass through the annular static rotary field *a* outside of the reversing disc 6. It carries along with it all components of the material, the specific gravity of which is less than the specific gravity of the liquid forming the rotary field *a*, while the components of heavier specific gravity are centrifuged through the rotary field *a* into the container 1, where they settle out. The liquid stream, laden with the light constituents, rises upward in hollow shaft 9 and discharges on top into the collector chamber 12 from where it is discharged through the outlet 13.

The impeller 2 produces in container 1 a positive pressure which depends essentially on the speed of rotation of the impeller; its volume and the specific gravity of the liquid contained in it. This pressure can be used for the continuous discharge of the heavy components which have settled out in the container 1. When the throttle valve 16 is open, the refuse is discharged out of the container 1 by the strong discharging liquid stream and possibly conveyed upwards to a drain screen 17 of known construction. This discharge of the refuse causes a radial flow of liquid through the rotary field *a* from the inside to the outside. Inasmuch, however, as the discharge cross-section at the periphery of the impeller can be made as large as desired, the flow in the rotary field remains so slight that it does not impair the separation.

The radial flow produced in the impeller 2 by the discharge of the heavy components can be completely controlled by the admission of liquid under pressure into container 1, and possibly entirely suppressed. For this purpose pump 18 is provided, this pump, for example, forcing the heavy liquid collected in the drain screen 17, with the addition of fresh heavy liquid, into the container 1. By adjusting the throttle cross-section 16, the pressure head produced by the pump 18 in the container 1 can be set at any desired value. If the adjustment is such that the pressure head produced by pump 18 in container 1 is equal to that produced by the impeller 2, equilibrium prevails at the outlet of the impeller 2. A radial flow in the impeller can then not occur. By further opening the throttle 16, an outward-directed radial flow in the impeller 2 is produced in the rotary field *a*, while further closing of the throttle results in an inward-directed radial flow. The pump 18 in this connection maintains a circulation throughout the container 1, it being possible to dimension the quantity circulating as desired by proper selection of the power of pump 18 and of the cross-section of the throttle opening 16. In practice, the throttle opening 16 will be made so large that clogging due to the discharged refuse will be dependably avoided. Corresponding to this throttle opening, the power of pump 18 will be so adjusted that the desired pressure head is maintained in container 1.

The circulatory flow in container 1 which has been described makes it possible to maintain there a different specific gravity than in the impeller, and preferably a higher one, so that the middlings, discharging with the heavy components from the impeller 2, float and become concentrated. This may be done, as shown in Fig. 2, provided the container 1 is properly shaped, in the upper part from where the suspended material and middlings are separately discharged by an adjustable throttle valve 19, similar to valve 16, by a flow of liquid

with the pressure prevailing in the container. In this connection the delivery line of pump 18 preferably discharges into the container 1, opposite the discharge opening on the periphery of the impeller, tangentially in the direction of rotation of the impeller 2. The thus introduced pressure liquid flow divides, as indicated in Fig. 2 by arrows, in front of the impeller into a rising and a descending partial current, the first of which carries the suspended material upward and the second the tailings downward. The discharge of the tailings can be facilitated possibly by the admission of compressed air into riser 20 by means of a nozzle 21. Instead of pump 18, a down pipe 22 of the pressure height  $h$  required in the container 1, can be provided (Fig. 1). The valves 16 and 19 can be developed, as shown in Fig. 1, as so-called rubber nozzles, in connection with which the middle opening of an annular, hollow rubber member is compressed or expanded by pressure media.

It is of essential importance for sharpness of separation that the specific gravity in the rotary field  $a$  remains constant. When using unstable heavy liquids such as so-called suspensions, it must be borne in mind that a part of the suspended weighting material will continuously be centrifuged out of the rotary field. This loss of weighting material must be replaced constantly.

As already stated, the heavy liquid required to maintain the specific gravity of the heavy liquid in the rotary field  $a$  can be introduced into the impeller 2 together with the charged material. A more advantageous possibility for the admission of the heavy liquid is shown in Fig. 1. Through the admission pipe 14 for the charged material, there passes centrally an admission pipe 23 for heavy liquid, said pipe discharging at the bottom in the impeller 2 below a guide disc 24. The guide disc 24 permits the heavy liquid to discharge into the rotary field  $a$  approximately opposite the reversing edge of the reversing disc 6, so that the heavy liquid, as shown in Fig. 1 by dotted lines, surrounds from the outside the stream of material coming from the inlet space 7 and flowing around the reversing disc 6, and thus feeds the rotary field  $a$  with fresh heavy liquid. The material to be charged can then be admitted with water as conveying liquid, which, due to its lower specific gravity, does not mix with the surrounding heavy liquid stream. In this manner only small quantities of weighting material are discharged with the stream of conveying water, i. e., only the quantities which adhere to the light components of the material upon their immersion into the surrounding stream of heavy liquid. Furthermore, a large part of this small quantity of weighting substances is centrifuged back into the rotary field on its path through the outlet space 8. The separate feed of the heavy liquid thus results in a very considerable saving of weighting substance when one bears in mind that in the case of run-of-the-mine coal, the ratio between pure coal and refuse is on the average of 5:1. The substantially smaller quantity of heavy liquid requires for its cleaning and regeneration substantially smaller apparatus than the apparatus heretofore necessary for heavy liquid separators. In addition to this, there is the fact that the cleaning apparatus is also considerably simpler, inasmuch as the increase in viscosity of the heavy liquid caused by contaminations, impedes the separating process far less in the rotary field  $a$  with its centrifugal force action which by far exceeds the force of gravity, than is the case in the known separators.

Instead of the above-described method for maintaining the required specific gravity of the heavy liquid in the rotary field  $a$ , a light inward flow can, as already mentioned above, be produced in the rotary field  $a$  by the pump 18 or the down pipe 22, said flow continuously conducting heavy liquid from container 1 into the rotary field  $a$  and in this way maintaining the specific gravity of the heavy liquid constant in the rotary field  $a$ . The

heavy liquid introduced in this manner into the rotary field  $a$  is continuously discharged with the stream of conveying liquid which leads away the pure coal, said stream possibly also consisting of water in this case.

The described methods for maintaining the specific gravity of the heavy liquid can be applied individually or combined.

The impeller 2 produces in container 1 a pressure head which depends on the specific gravity of the heavy liquid in the rotary field  $a$ , for a given speed of rotation. The pressure head increases with increasing specific gravity. In accordance with the invention, this pressure dependency is utilized to supervise or regulate the specific gravity of the heavy liquid in the rotary field  $a$  required for the separation. According to Fig. 3, there is provided a working piston 25 which is acted on by the pressure in container 1 against the force of a spring 26 via pipe line 27. The piston moves towards the left upon an increase in pressure in container 1 and vice versa, and in this connection, by means of the rod system 28, 29, 30, controls two regulating valves 31, 32, one of which, 31, is arranged in a water line 33, while the other, 32, is arranged in a heavy liquid line 34. Lines 33, 34 discharge into a mixing vessel which conducts the heavy liquid of adjusted specific gravity via the line 23 (see also Fig. 1) to the heavy liquid separator. The rod system 28, 29, 30 is so developed that in the right-hand end position (in the drawing) of the piston 25 which corresponds to the lowest pressure in container 1 which is still permissible and thus to a minimum specific gravity of the heavy liquid in the rotary field  $a$  which is still just permissible, the heavy liquid valve 32 is entirely open, and the water valve 31 is entirely closed. In the left end position of the piston 25, which corresponds to the maximum pressure still just permissible in container 1 and thus to a maximum specific gravity of the heavy liquid in the rotary field  $a$  which is still permissible, the heavy liquid valve 32 is entirely closed, and the water valve 31 is entirely open. The spring 26 is so dimensioned in this connection that it is in equilibrium in the right-hand end position of the piston 25 with the minimum pressure still permissible in container 1, and also in the left-hand end position of the piston 25 with the maximum pressure still permissible in the container 1. Upon change of the specific gravity in the rotary field  $a$  and corresponding changes of pressure in the container 1, piston 25 moves valves 31, 32 in the manner that the desired specific gravity in the rotary field  $a$  is continuously maintained. In the above-described method for maintaining the specific gravity of the heavy liquid in the rotary field  $a$  by maintaining a flow of heavy liquid directed from the container 1 into the impeller 2, the piston 25 controls the throttle valve 16 (Fig. 1) in the manner that the latter is increasingly closed upon decrease of pressure in the container 1, and vice versa, of course, for the control of the regulating valves 31, 32 and the throttle valve 16 in the above-described manner, there may also be provided a servomotor of known design which is controlled by means of the working piston 25, by the pressure in the container 1, and therefore merely increases the force of the regulating impulses exerted by the pressure in container 1.

It has already been pointed out that the discharge cross-section at the periphery of the impeller 2 can be made as large as desired without impairing the separating action. Instead of the disc forming of the impeller 2 shown in Figs. 1 and 2, the impeller, as shown in Fig. 4, may also have the shape of a roller. The impeller shown in Fig. 4 again has two lateral driving discs 3, 4 and a reversing disc 6 located between them. In order to assure the carrying along of the heavy liquid enclosed in the high space between the lateral driving discs, there are provided additional driving discs 3a, 3b, 4a, 4b which are provided at the height of the periphery of the reversing disc 6 with perforations for the conveying liquid

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stream indicated by arrows. The reversing disc 6 can be continued on the other side of these perforations at 6a and act as driving discs in the region of the rotary field *a*. The impeller shown in Fig. 4 permits a substantially greater weight rate of output than the impeller shown in Figs. 1 and 2.

In Fig. 5 there is shown an impeller which repeatedly moves the stream of material indicated by an arrow into the field of action of the rotary field *a* and back again into the vicinity of the axis. In order to achieve this, there are provided between the two lateral driving discs 3, 4, reversing discs 6b, 6c, 6d, which are alternately provided in the region of the rotary field and in the vicinity of the axis with perforations for the passage of the flow of material. This arrangement permits any desired number of repetitions of the separating process in one impeller, which may be advantageous, particularly in the case of fine material which it is difficult to separate.

Fig. 6 shows another impeller for the heavy liquid separator of Figs. 1 and 2, the impeller in this case again consisting of two driving discs 3 and 4 and an intermediate reversing disc 6. The upper driving disc has the shape of a cone or bell; its opening is located at the bottom and it encloses laterally practically the entire inner space of the impeller. The lower driving disc is also of conical shape with its opening at the bottom, and encloses the inner space of the impeller at the bottom except for an annular gap 35. In the annular gap 35 there can be provided radial blades. The reversing disc 6 is rounded in accordance with principles of stream-lined flow, and together with a sharp-edged, annular bead 36 on the lower driving disc 4, forms an annular discharge opening 37 for the flow of the charged material. The discharge opening 37 permits the flow of material free passage into the rotary field *a*. The sharp edge of the bead 36 loosens the flow of material in a dependable manner from the lower driving disc and prevents fine, light components of the charged material from entering the boundary layer at the lower driving disc and from being centrifuged outward therein.

In Figs. 7 and 8 there is shown a further embodiment of the new heavy liquid separator which differs from those described above thereby that the stream of conveying liquid laden with the material to be cleaned, flows in one direction through the impeller, i. e., is not reversed therein. The impeller 38 consists of two conical driving discs 39, 40 having their hollow spaces facing each other, and of the reversing disc 41 arranged between the said driving discs. The upper driving disc 39 is provided with the hollow drive shaft 42 and the lower driving disc 40 with a central discharge ring 43. The discharge ring 43 is connected by means of the ribs 44 with the drive shaft continued below the reversing disc 41. The drive shaft terminates below ribs 44 in a stream-lined tip 45. The ribs 44 can be arranged obliquely as in the case of a propeller, so that they exercise a conveying action on the stream of conveying liquid. The hollow drive shaft 42 is provided above the reversing disc 41 with discharge port 46, which discharges into an annular space 47 between the reversing disc 41 and a sharp-edged bead 48 on the upper driving disc 39. The sharp-edged bead 48 loosens the stream of material to be cleaned, entering the impellers from the upper drive disc. In the annular chamber 47 there may be provided blades 49 which act like a pump and compel the incoming stream of material to participate without slip in the rotary motion of the impeller. The container 50, in the same manner as impeller 38, is disc-shaped like a convex lens and surrounds the impeller with some clearance. The drive shaft is inserted in a pressure-tight manner in the container by means of a stuffing box 51. The discharge ring 43 of the impeller 38 forms, together with the wall of the container, a labyrinth seal 52 and its outlet open-

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ing is located above the stationary outlet connection 53 of the container 50. On the periphery of the container there is provided in the direction of rotation of the impeller 38 a tangential outlet connection 54 through which the heavy components of the material to be treated, centrifuged out of the impeller, are discharged, and the discharge cross-section of which can be adjusted by means of a throttle valve which is similar to valve 16 of Fig. 1. An inlet connection 55, discharging tangentially in the direction of rotation of the impeller into the container 50, feeds a stream of heavy liquid to container 50, said stream scavenging the heavy components out through the connection 54, and, if the discharge cross-section 54 is properly adjusted, maintains a pressure in container 50 which corresponds approximately to the pressure head produced by impeller 38 in container 50.

After the heavy liquid separator is entirely full with heavy liquid, the impeller 38 is started in operation. At the same time, a stream of heavy liquid is introduced via connection 55 into container 50, the stream discharging from the container out through the discharge connection 54. The admission pressure of this heavy liquid stream is so high that the impeller 38 cannot empty itself. The liquid contained in the impeller then rotates solely with the impeller and forms a static, heavy liquid rotary field *a*. The stream of conveying liquid laden with the material to be cleaned is fed through the hollow drive shaft 42 and flows—as indicated in dotted lines in Fig. 7—in the direction indicated by the arrow through the impeller 38. As already described with reference to Fig. 1, the heavy components of the material to be cleaned are in this connection centrifuged through the heavy liquid rotary field *a* into the container 50, while the light components remain in the stream of conveying liquid, and are discharged with the latter through the discharge connection 53. The heavy components circulating in the container 50 are scavenged by the scavenging current introduced tangentially at 55 into the discharge connection 54.

In Figs. 9 and 10 there is shown an embodiment of the heavy liquid separator which differs from the one shown in Figs. 7 and 8 by a different development of the impeller. As can be noted from Fig. 9, the impeller 56 has only a single bell-shaped driving disc 57 and the reversing disc 58 in the hollow space of said drive disc. The lower opening of the impeller is closed by the stationary container wall 59, except for an annular gap 60. The container 61 in the vicinity of the annular slot 60 forms a bead-shaped annular space 62 to which there is connected—exactly in the same manner as in the case of the separator of Figs. 7 and 8—tangentially in the direction of rotation of the impeller—an inlet connection 63 for a stream of heavy liquid and a discharge connection 64 for the heavy components centrifuged out of the impeller. The discharge cross-section of the discharge connection 64 is adjustable by means of a throttle valve, similar to valve 16 of Fig. 1. The container wall 59 has a central stationary outlet connection 65. The hollow drive shaft 66 is introduced in a pressure-tight manner into container 61 by means of the stuffing box 67. Its cavity is in communication above the reversing disc 58 via inlet ports 68 with the inside of the impeller 56. Below the reversing disc the drive shaft is tapered in accordance with the principles of stream-lined flow and extends into the discharge connection 65, where it can possibly be supported in a bearing.

The manner of operation of the heavy liquid separator of Figs. 9 and 10 corresponds exactly to that of the separator of Figs. 7 and 8. The stationary lower limiting wall 59 of the inner space of the impeller 56 does not disturb the rotary field *a* which is formed in the im-

PELLER 56. However, it makes possible a very simple construction of the heavy liquid separator.

The heavy liquid separators of Figs. 7-10 can also be built very easily with horizontal drive shaft, i. e., with vertical container. In this case, the arrangement is preferably such that the tangential discharge connection 54, 64 for the heavy components of the material is located at the lowest part of the container. The circulatory flow taking place in containers 50 and 61 via the tangential connections 55, 54 and 63, 64, respectively, and the regulation of the specific gravity of the heavy liquid in the rotary field *a* is carried out in the manner shown in Figs. 1 and 3.

It has already been stated that in the heavy liquid rotary field *a*, there act on the material to be cleaned centrifugal forces which exceed many times the force of gravity acting as separating force in normal, heavy liquid separators, and that this fact makes it possible to use heavy liquids of high viscosity. This property of the rotary field *a* makes it possible to operate the heavy liquid separator with a mixture of refuse sludge, i. e., fine refuse sludges obtained from flotation or in clarification peaks of the cleaning plants and high grade weighting substances, for instance, pyrites or magnetite of coarser grain size than the refuse sludge. In this connection, the coarser weighting material which is admixed to the material to be charged or introduced separately from same into the rotary field *a* through the pipe 23 (Fig. 1) is continuously centrifuged through the rotary field *a* and discharged exclusively with the refuse, so that no weighting material is present any longer in the coal discharging from the separator. The high viscosity of the refuse sludge strongly retards the centrifuging of the weighting material out of the rotary field *a*, and therefore makes it possible to maintain the necessary specific gravity in the rotary field by the continual addition of relatively small quantities of expensive weighting substances. By maintaining a slight inward flow in the rotary field *a* by means of the pump 18 or the down pipe 22, refuse sludge is continually conveyed from container 1 into the rotary field, so that the material to be cleaned can be fed to the impeller with clean water. The refuse sludge forced in this manner from the outside into the impeller is continuously discharged from the impeller with the stream of conveying liquid discharging the pure coal, and can be readily separated from the coal by drenching.

Of course, weighting material discharged continually with the refuse from container 1 is first of all separated from the coarse refuse by screening and recovered practically without loss from the fine screenings by a simple method, such as, for example, by screening, centrifuging, magnetic separation, or by one of the known settling processes.

In connection with the settling separators described, the arrangement heretofore was such that the stream of conveying liquid laden with the material to be cleaned, was passed centrally through the heavy liquid rotary field. The stream of material to be cleaned can be admitted to the rotary field also tangentially at its periphery, so that it surrounds the rotary field on the outside. This possibility is discussed below on basis of Figs. 9 and 10.

The heavy liquid separator shown in Figs. 9 and 10 is filled with heavy liquid and its impeller placed in operation. Through the connection 63 there is fed to the container a stream of heavy liquid which is possibly under the pressure produced by the impeller in container 61 and again discharges through the discharge connection 64 from container 61. The heavy liquid rotary field *a* is then formed in the impeller 56, as in the above-described separators. Thereupon, the material to be cleaned is admixed with the stream of heavy liquid entering through connection 63. The stream of

material then flows in the direction of rotation of the impeller 56 through the bead-shaped annular space 62 to the discharge connection 64, and in this connection surrounds the rotary field *a* in the vicinity of the annular plot 60, i. e., in a zone of maximum centrifugal force. In this connection the components of light specific gravity are forced inwards into the rotary field *a* and pass through same to the axis of rotation, while the heavier components remain outside in the annular space 62 and are carried by the heavy liquid flow to the discharge connection 64. The discharge of the light constituents from the impeller 56 is effected by means of a stream of conveyor water which is fed centrally to the impeller through the hollow drive shaft 66 and discharges from the impeller through the central connection 65 at the opposite side. Of course, the light constituents may also be removed from the impeller by a heavy liquid flow which is either, in the same manner as the above-described flow of conveying water, conducted axially through the impeller, or which is produced by increasing the pressure of the heavy liquid flow entering connection 63 and flows inward through the rotary field *a* to the discharge connection 65. The regulating of the specific gravity of the heavy liquid in the rotary field is effected in the same manner as in the above-described settling separators.

I claim:

1. Method for working up mineral-containing materials in heavy liquid with centrifugal force, which comprises, establishing a substantially volume-confined, pressure-restricted zone of heavy liquid, rotating and maintaining an annular field of heavy liquid within said zone only in peripheral communication with the rest of the heavy liquid in said volume-confined zone, said annular field being substantially free of internal flow current other than rotational, conveying mineral-containing material in a conveying liquid stream to said field, whereby said material is centrifugally separated into at least two specifically differing fractions by the centrifugal action of said field and the passage of one of said fractions through said field.

2. Method according to claim 1, in which said mineral-containing material is conveyed in said conveying liquid stream to the central portion of the said field, a specifically heavier fraction of said material separated and passed through said field by the centrifugal action thereof, a specifically lighter portion of said material removed from the central portion of said field by said conveying liquid stream, and said separated, specifically heavier fraction recovered from said zone.

3. Method according to claim 2, in which said specifically heavier fraction is recovered by removal from said zone with a portion of the heavy liquid and the separation from said removed portion of said heavy liquid.

4. Method according to claim 1, in which said mineral-containing material is conveyed in said conveying liquid stream to the periphery of said field, and in which a specifically lighter fraction is separated and passed through said field by the centrifugal action thereof.

5. Method according to claim 4, in which said stream of conveying liquid is passed tangentially to the periphery of said field.

6. A centrifugal heavy liquid separator for the working up of mineral-containing material, which comprises, a stationary substantially enclosed heavy liquid container, an impeller rotatably positioned in said container, said impeller having at least two spaced-apart opposed surfaces defining a space therebetween in free peripheral communication with said container, means defining a fluid outlet from said container, means for retaining fluid in said container at a predetermined pressure, means defining a path of fluid flow from the central portion of said space out of said container, conduit means posi-

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tioned for passing fluid to said space, and means for rotating at least one of said opposed surfaces of said impeller.

7. Separator according to claim 6, in which said impeller consists of at least two spaced-apart opposed rotatable drive discs defining said space therebetween.

8. Separator according to claim 6, which includes a reversing disc of smaller diameter than said space positioned in the central portion of said space.

9. Separator according to claim 8, in which said reversing disc is mounted for rotation with said impeller.

10. Separator according to claim 6, including at least one rotatable driving disc positioned in said space and defining therethrough at least one opening for the passage of conveying liquid axially through said space.

11. Separator according to claim 6, which includes a driving disc package consisting of a multiple number of parallel driving discs defining staggered openings there-through positioned in said space.

12. Separator according to claim 6, in which said impeller consists of two spaced-apart inclined driving discs, an edged annular bead defined on one of said driving discs, a rotatable streamlined reversing disc positioned in said space in spaced relation to said sharp-edged annular bead and defining therebetween a discharge opening, and in which said conduit means are positioned for passing fluid to the central portion of said space for passage through said discharge opening.

13. Separator according to claim 6, in which said impeller consists of two opposed spaced-apart conical driving discs with a rotatable reversing disc of smaller diameter positioned therebetween, the upper disc having a sharp annular bead defined thereon opposed to the edge of said reversing disc, said fluid conduit means being positioned for passing fluid to the space between said reversing disc and said annular bead, said means defining a path of fluid flow from the central portion of said space defining a path of flow through the central portion of said lower disc, said means defining a fluid outlet from said container being positioned tangentially to the space between said driving discs, and including a fluid inlet positioned tangentially to the space between said driving disc.

14. Separator according to claim 13, in which said reversing disc has fluid driving blades connected thereto.

15. Separator according to claim 6, in which said container is a conical container at and in which said means defining a fluid outlet from said container is positioned at the apex thereof and in which said means for retaining fluid in said container at a predetermined pressure comprises an adjustable throttle valve positioned in said fluid outlet from said container.

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16. Separator according to claim 6, in which the lower portion of said container is conically shaped containing said means defining a fluid outlet at the apex thereof, and in which the upper portion of said container increases in height across the diameter thereof and has a discharge throttle valve for the discharge of middlings positioned substantially at the highest point of said container.

17. Separator according to claim 6, which includes means for passing heavy liquid into said container at a predetermined pressure.

18. Separator according to claim 6, which includes means for passing liquid from two separate valve-controlled conduits to said container and pressure-responsive means connected to said container for co-operatively controlling the valves on said two separate conduits.

19. A centrifugal, heavy liquid separator for the working up of mineral-containing material, which comprises a stationary, substantially enclosed, heavy liquid container, an impeller rotatably positioned in said container, in which said impeller consists of a substantially bell-shaped rotatable driving disc positioned with the inner surface thereof defining a space in free peripheral communication with an opposed portion of the wall of said container, the lip of said bell-shaped driving disc being positioned in spaced relation to said opposed container wall to define an annular gap therebetween means for retaining fluid in said container at a predetermined pressure, and conduit means defining a path of flow are positioned for passing fluid to one side of the central portion of said space and conduit means defining a path of fluid flow from the central portion of said space are positioned on the other side of the central portion of said space, the fluid outlet from said container being positioned tangentially to said annular gap and including a conveying liquid conduit positioned tangentially to said annular gap, and means for rotating said impeller.

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