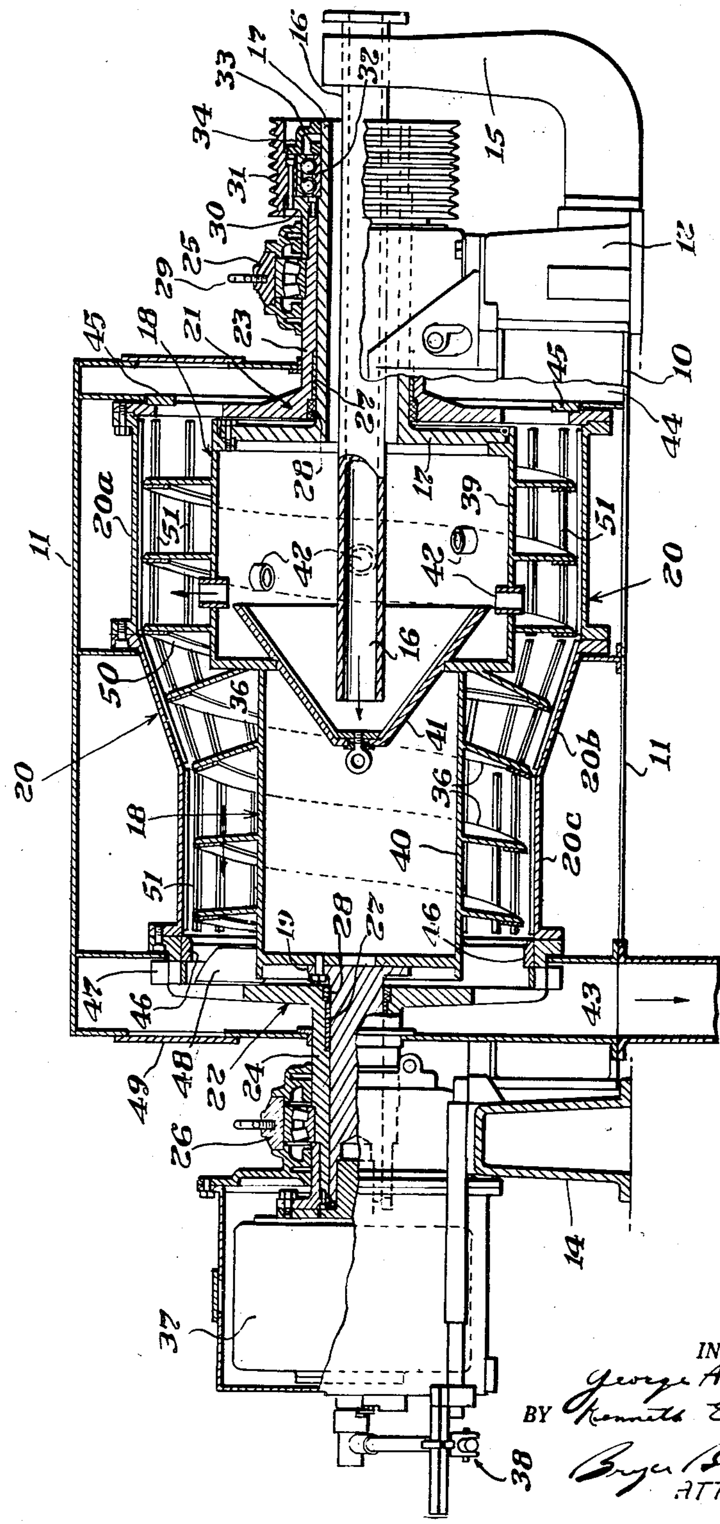
June 10, 1952 | G. A. MILLIKEN ET AL | 2,600,372

CENTRIFUGAL SEPARATOR

Filed Dec. 16, 1949 | 4 Sheets-Sheet 1

FIG. 1



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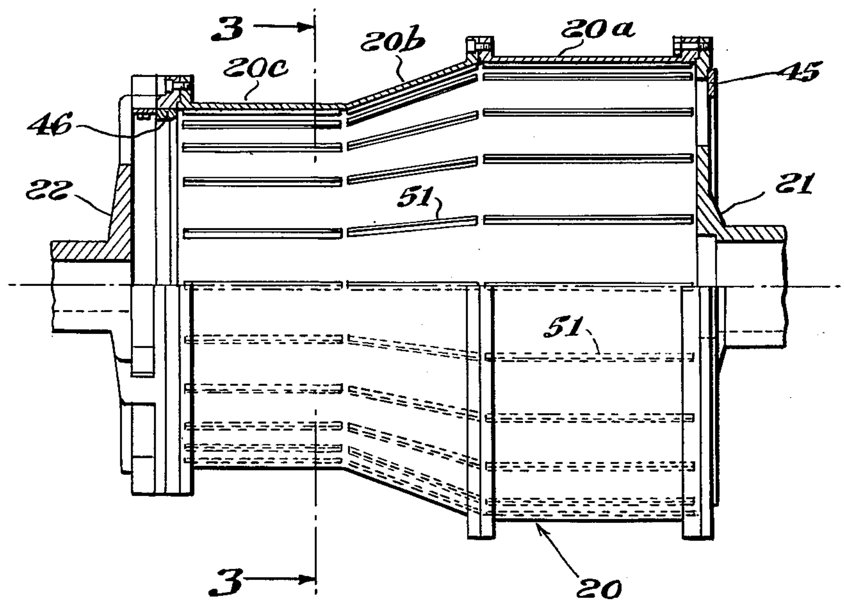

Fig. 2

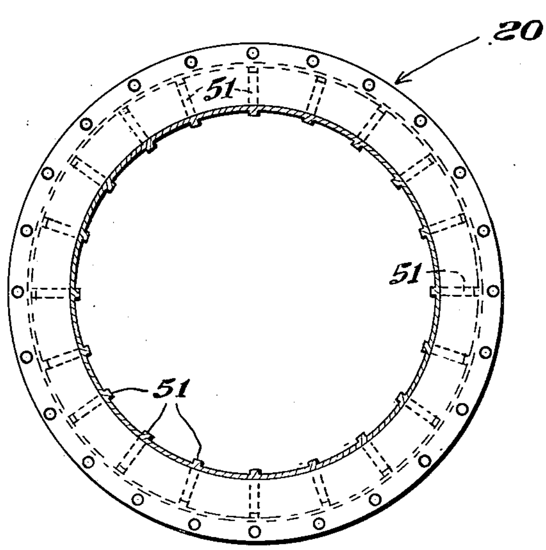

Fig. 3

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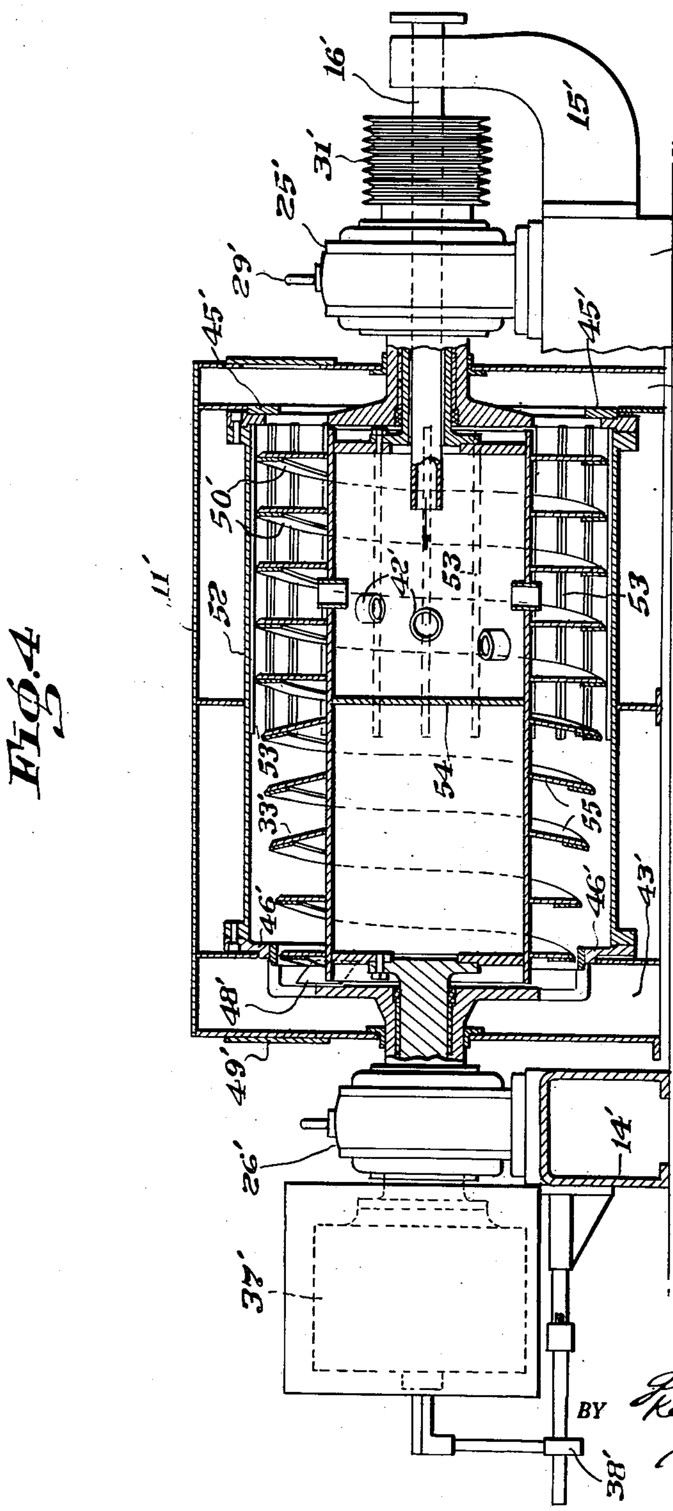

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CENTRIFUGAL SEPARATOR

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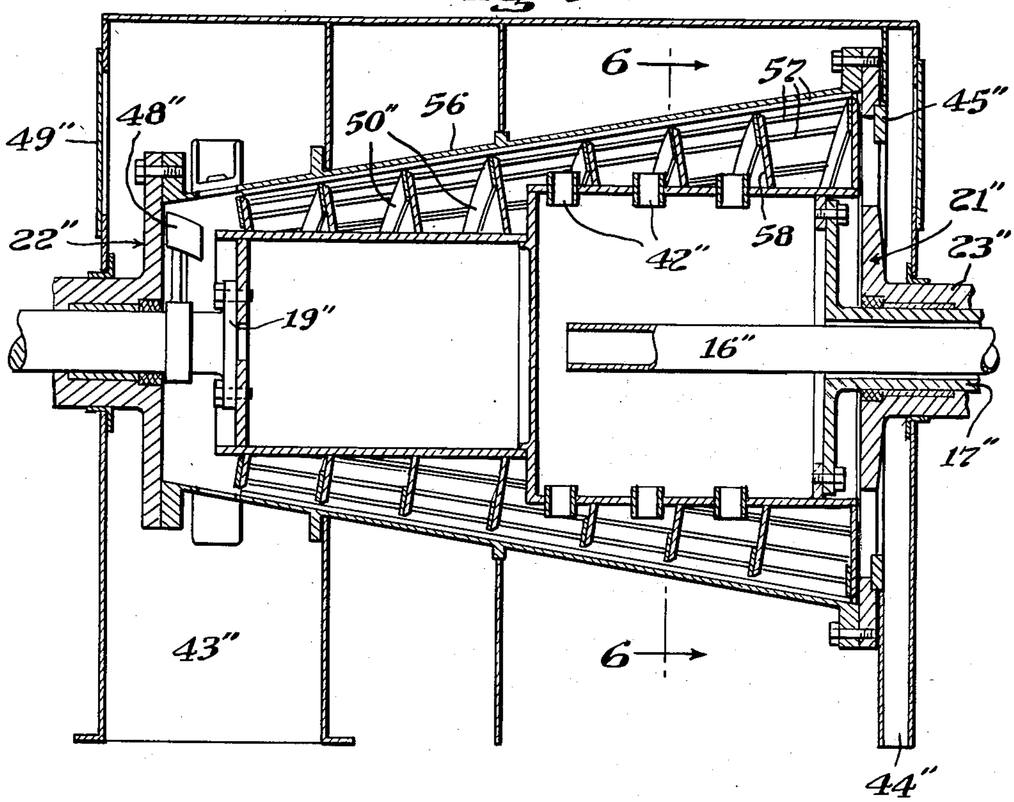

Fig. 5

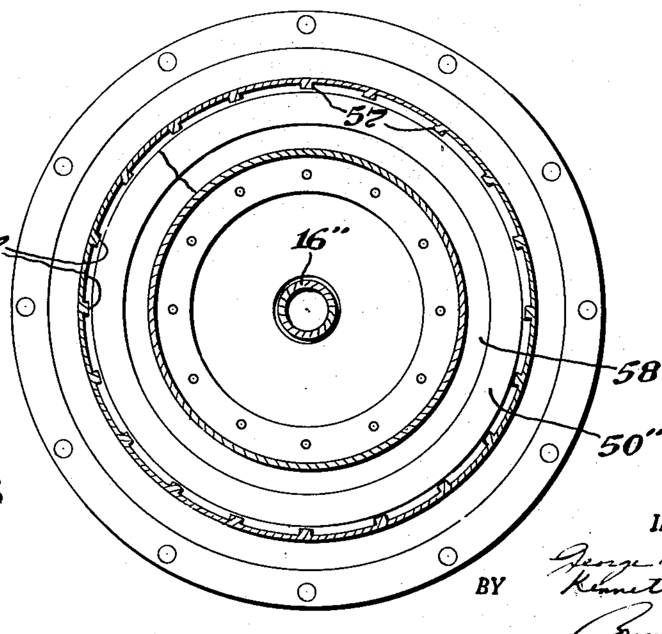

Fig. 6

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UNITED STATES PATENT OFFICE

2,600,372

CENTRIFUGAL SEPARATOR

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Application December 16, 1949, Serial No. 133,376

7 Claims. (Cl. 233—7)

Our invention concerns a solid bowl centrifugal separator for deliquefying fine solid particles. One particularly important application of the separator is in the coal industry for dewatering fine coal difficult or impossible to adequately dewater by draining procedures.

The trend in the coal industry is toward mechanized full seam mining. With this procedure, substantial quantities of refuse must be loaded with the coal, necessitating cleaning or preparation of the coal for marketing after it has been delivered to the surface. One condition which materially increases the difficulty of cleaning mechanically mined coal is the presence therein of a large proportion of fines of a particle size within the range minus ¼" to plus 0. It is generally considered by preparation engineers that the drying and recovery of this fine coal constitutes the most important problem facing them today.

The centrifugal separator provided by our invention effectively solves this problem. The separator is readily integrated in existing coal preparation schemes, is capable of processing large tonnages, and discharges the coal in immediately marketable form. The physical condition of the coal is such that it does not ball up under pressure and discharges freely from belt conveyors.

Our separator gives a filtrate sufficiently low in solids that it may be continuously returned to the process without excessive build-up of fines in the water circuit. Thus it is applicable to installations involving a closed water system. The operation of the separator is entirely automatic and maintenance costs are low.

Solid bowl centrifugal separators heretofore proposed for separating fine solid particles from liquids have been found unsuited for dewatering fine coal, tending to become choked. In the case of several of the separators tested, the choking was accompanied by costly gear failures. At best, the largest of the prior separators are capable of handling only about 20 tons of coal per hour and even then breakdowns are frequent. Our separator, on the other hand, is capable of handling upwards of 50 tons of coal per hour and without maintenance difficulties.

Generally described, our separator consists of an outer rotating member and an inner rotating member. The outer member, which represents the bowl portion of the separator, normally has the shape of a cylinder or truncated cone or comprises both a cylindrical section and frusto-conical section. The inner member is a helical conveyor which may or may not be generally shaped to follow the contour of the bowl, but is always

of lesser diameter at the solids discharge end of the bowl than at the opposite or feed end thereof. In operation, the conveyor is rotated at a slightly different speed than the bowl—normally at a lower speed. The feed to the separator is introduced through a stationary pipe encased within the concentric with a hollow shaft through which the bowl is rotated and flows into the bowl proper through ports located in the hub of the conveyor. The developed centrifugal force compels the solid particles to settle and they are picked up by the conveyor and progressively worked toward the solids discharge end of the bowl. The liquid, after flowing back around the conveyor, discharges at the feed end of the bowl. A predetermined volume of liquid is always retained in the separator and this retention is such that adequate clarification is obtained. The separator does not require the use of filter aids or filter media such as cloths, screens or the like, the separation being achieved entirely by centrifugal sedimentation.

Our separator is particularly distinguished in the provision along the inner bowl wall of means serving to anchor a predetermined depth of the particles to the wall and in the use of a conveyor the working surfaces of which possess a degree of smoothness precluding substantial adherence of the particles thereto. The anchoring means may, with advantage, take the form of spaced strips. The strips may be welded or otherwise fixedly secured to the bowl wall or they may be formed integral therewith as an incident of the casting of the bowl or by grooving. In the latter instances, the strips are probably more accurately termed "ridges." For optimum results the height of the strips should be uniform and should correspond to the size of the coarsest of the particles in the particular slurry being worked. Also, for optimum results, it is important that the spacing between the conveyor and the strips at the points of minimum clearance correspond with the size of the coarsest particles.

We shall describe our invention in detail with the aid of the accompanying drawings illustrating preferred embodiments thereof. In the drawings,

Fig. 1 is an elevation, mostly in section, of one type of centrifugal separator to which our invention is applicable, the separator being equipped according to the invention;

Fig. 2 is a detail in elevation of the bowl shown in Fig. 1, the upper half of the bowl being shown in section;

Fig. 3 is a section on the line 3—3 of Fig. 2;

Fig. 4 is a view analogous to the view of Fig. 1

but showing a separator having a bowl which is cylindrical throughout its length;

Fig. 5 illustrates the invention as applied to a separator having a straight conical bowl; and

Fig. 6 is a section on the line 6—6 of Fig. 5.

Referring first particularly to Fig. 1, the machine will be seen as comprising connecting beams 10 and 11 extending between supports 12 and 14, to the right and left, respectively. Connected to support 12 is a bracket 15 holding a pipe 16 through which the feed to the separator is introduced. Pipe 16 is spaced concentrically within the feed end trunnion 17 of the conveyor unit, which is generally indicated at 18, and which is secured by bolting at its opposite end to a second trunnion member 19.

Conveyor unit 18 is disposed within a bowl 20 having a straight cylindrical section 20*a*, a frusto-conical section 20*b*, and a second cylindrical section 20*c*, of substantially reduced diameter. In a typical machine conforming to Fig. 1, section 20*b* forms an angle with the horizontal of 19°, while an imaginary line connecting the tips of the blades in section 20*c* gives a 3° angle with the line of the inner wall of the section. These particular angles are in no way critical with relation to the present invention, being given by way of illustration only.

Headers 21 and 22 at the right and left end, respectively, of the bowl 20 include sleeve portions 23 and 24, respectively. Sleeve 23, which surrounds and is concentric with trunnion 17 of the conveyor unit, is received on a bearing member 25 mounted on support 12, while sleeve 24, encasing trunnion 19, is received in a like bearing member 26 mounted on support 14. Mediate the sleeves and trunnions are annular bushings 27 and oil seals 28. Each bearing member has an eye bolt 29, useful during maintenance work. The bearing members are of the conventional ball or roller type and include the usual oil and dirt flinger rings.

Secured to a drive flange 30, bolted to the sleeve 23 at the end thereof, is a drive sheave 31 adapted to receive a multiple V belt, not shown. Between the drive sheave and trunnion 17 is a radial thrust ball bearing 32 held in place by a lock nut 33 and a cap piece 34.

Going now to the left hand end of the machine of Fig. 1, it will be seen that conveyor unit 18, which includes helical blades 36, properly pitched to impel the solids component of the feed in the direction indicated by the arrow, is driven through a housed gear unit 37, the output shaft of which is splined to the trunnion 19. Member 38 is a torque device, part of an overload release, which need not be described in detail here as it is unrelated to the present invention.

From the foregoing, it will be understood that the arrangement is such that the conveyor and bowl are separately driven and that they may be driven at different rates. One standard machine having a 54'' bowl (maximum diameter) is customarily operated using a gear ratio of 35:1, the bowl rotating at 650 R. P. M. and the conveyor at approximately 631½ R. P. M. or approximately 18½ R. P. M. slower. These figures, of course, are in no way critical; indeed, in some installations rotation of the conveyor at a rate faster than the rate of rotation of the bowl may be indicated.

What may be termed the rotor of the conveyor unit 18 comprises a cylindrical portion 39 of relatively greater diameter and lesser length than a

second cylindrical portion 40 which is surrounded by the conical section 20*b* and the smaller cylindrical section 20*c* of the bowl 20. Within the rotor is a conical baffle 41, which is fixed to the rotor and accordingly rotates therewith. The baffle properly distributes the incoming slurry radial within the rotor and at the same time serves to minimize attrition of the solids component of the feed.

The conveyor rotor is apertured around its cylindrical portion of larger diameter, each of the apertures being provided with an insert 42 of wear-resistant alloy. In operation, the solids component of the feed tends to build up around each insert on the inside of the rotor with the result that there is markedly less wear than is the case where the apertures are not provided with the inserts. It should be noted that the apertures are not in the same plane but follow a laterally curving path.

The conveyor 18 empties to a solids discharge box or champer 43, while the liquid component of the feed is collected and continuously withdrawn from chamber 44 at the opposite end of the bowl. The liquid level at which such a machine is generally operated is indicated by the placement of the annular weir 45. The solids discharge passes over an annular weir 46. The numerals 47 and 48 indicate a discharge plow and a conventional reverse blade, respectively. Inspection of this end of the machine during operation is enabled by the provision of a door 49 in the casing.

It is an essential and critical feature of the invention, as previously indicated herein, that the areas of the conveyor blades 36 contacting the solid particles be of a degree of smoothness precluding adherence of the particles thereto. It is also necessary, of course, that these areas be quite hard in order that they will withstand the abrasive action of the particles. Generally, we use blades provided with a hard alloy facing 50, the facing being ground and/or polished to the requisite smoothness. The width of the facing and also the thickness may vary substantially depending on the position of the blade and operating conditions.

Around the inside of the bowl 20 and running the length thereof are spaced strips 51 of a height corresponding approximately to the diameter of the largest of the solid particles in the feed to be charged to the machine. Each of the strips is shown (see Figs. 2 and 3 as well as Fig 1) as constituted of three sections corresponding to the three sections of the bowl, but this relates to the manufacturing of the bowl and is not critical, unbroken strips being fully equivalent. The strips are preferably generally rectangular in cross section, as shown. Their number may vary considerably but should always be sufficient to provide the requisite anchoring of the indicated depth of solids component to the wall of the bowl.

The strips, or their functional equivalent, constitute a second essential and critical feature of our invention, is being by virtue of co-action between the smooth blades and the strips that we obtain improved separation. Machines equipped with the strips but not having smooth blades or machines having smooth blades but not equipped with the strips, are essentially ineffective when applied to the treatment of fine coal slurries, the coal instead of moving toward the discharge box tending to remain or accumulate in the bowl.

Although considered particularly valuable as applied thereto, our invention is in no way limited to the treatment of fine coal slurries, the more positive conveying action it affords giving markedly improved results in many other cases.

It is believed that the operation of the separator of Fig. 1 is probably clear from what has been said. However, for sake of completeness of description it will now be further described.

The feed material, which will be assumed as a slurry of fine coal, enters the system under substantial pressure via pipe **16**. On striking the rotating baffle **41** it is thrown into the apertured section **39** of the rotor, the developed centrifugal force impelling it radially outwardly through the apertures. Bowl **20**, it is to be remembered, is rotating in the same direction as the conveyor, its rate of rotation being slightly greater than that of the conveyor.

Due to the presence of the strips **51** a layer of coal soon becomes anchored to the inner wall of the bowl providing a surface which, with the smooth blades, precludes the slipping of the coal and the consequent retention thereof in the bowl characterizing the operation of machines not equipped according to the invention.

The smoothness of the blades prevents adherence of the fines thereto. Blades relatively rough compared to the blades herein contemplated are not effective even though the bowl be equipped with the strips, because the rough blades catch and hold the coal and it is not long before bridging ensues between blades, and the bowl becomes clogged.

As the coal is conveyed to the left over the upper part of the sharp beach represented by the inner wall of section **20*b*** of the bowl and over the drainage beach provided by the coal itself in section **20*c***, it becomes progressively drier until at the point of its discharge into the compartment **43** it is sufficiently dry that it will not ball up and discharges freely from a belt conveyor, not shown, normally receiving it from the compartment. The depth of the "pond" is a variable being determined, as previously indicated, by the height of the weir **45**. Ordinarily the liquid level is maintained at a point substantially below the point of juncture of the two beaches, e. g., at a point mediate the fourth and fifth blades counting from the right. The water overflowing the weir is collected, as stated above, in compartment **44** and is ordinarily withdrawn from the compartment by gravity flow.

Referring now to Fig. 4, in which certain parts functionally similar to parts shown in Fig. 1 are similarly numbered, the numbers, however, being primed, it will be noted that the bowl **52** in this case is cylindrical throughout its length and further that the strips **53** are not coextensive with the length of the bowl. Moreover, the baffle member **54** has the form of a disc rather than a cone and the blades **55** of the conveyor conform in lesser degree to the shape of the bowl, the ends of the blades at the left being spaced farther from the bowl wall.

In operation of the separator (Fig. 4) the solids component builds up on the wall of the bowl to the left, even though this portion of the wall is not stripped. This follows because of the reduced diameter of the blades and the consequent greater spread between the ends of the blades and the wall. The shape of the solids layer is determined, of course, by the contour of the conveyor which will be noted as generally similar to that of the conveyor in Fig. 1. Thus, in effect, the solids component of itself forms both drainage beaches (sections **20*b*** and **20*c*** in Fig. 1), although the contribution of the solids discharge weir **46′** in this connection should not go unnoted. Except for this difference the separator operates substantially as the separator of Figs. 1–3.

In Figs. 5 and 6 we show our invention as applied to a straight conical bowl **56**. As in the case of the construction first described, the strips **57** are coextensive with the length of the bowl and the blades **58** conform substantially with the shape of the bowl. Parts in Fig. 5 functionally similar to parts in Fig. 1 are designated by like numerals doubly primed. It is considered that the operation of a separator comprising such a bowl and conveyor is obvious from the foregoing.

It is to be understood that the foregoing disclosure is made by way of illustration only and not by way of limitation of the invention. Those skilled in the art will immediately appreciate that many changes and modifications may be made without departure from the invention as defined in the appended claims.

We claim:

1. In a centrifugal separator including: a rotatable bowl adapted to receive a fluid mixture of fine solid particles and liquid, a solids discharge chamber at one end of the bowl, a liquid discharge chamber at the opposite end thereof, means for maintaining a predetermined depth of liquid in the bowl, a rotatable conveyor within the bowl and coaxial therewith, said conveyor comprising helical blades having working surfaces possessing a degree of smoothness precluding substantial adherence of the particles thereto, and means for rotating the conveyor and the bowl at different speeds whereby the particles are caused to move toward the solids discharge chamber, the combination with the bowl of a plurality of spaced strips about the inner wall thereof serving to anchor a layer of the particles to said wall in the operation of the separator, each of said strips being generally disposed in a plane containing the axis of rotation of the bowl and conveyor.

2. A centrifugal separator according to claim 1 in which the height of the strips and the clearance between the strips and the tips of the blades surrounded thereby conform substantially to the size of the coarsest of the particles.

3. In a centrifugal separator including: a rotatable bowl adapted to receive a fluid mixture of fine solid particles and liquid, a solids discharge chamber at one end of the bowl, a liquid discharge chamber at the opposite end thereof, means for maintaining a predetermined depth of liquid in the bowl, a rotatable conveyor coaxially supported within the bowl and shaped in general correspondence therewith, said conveyor comprising helical blades having working surfaces possessing a degree of smoothness precluding substantial adherence of the particles thereto, and means for rotating the conveyor and the bowl at different speeds whereby the particles are caused to move toward the solids discharge chamber, the combination with the bowl of a plurality of spaced strips about the inner wall thereof serving to anchor a layer of the particles to said wall in operation of the separator, these strips being generally disposed in planes containing the axis of rotation of the bowl and conveyor, the height of the strips and the clearance between the strips and the tips of the blades surrounded thereby conforming substantially to the size of the coarsest of the particles.

4. A centrifugal separator according to claim 3 in which the bowl comprises a first cylindrical

section, a truncated cone section and a second cylindrical section having a diameter substantially less than that of the first cylindrical section.

5. A centrifugal separator according to claim 3 in which the bowl is shaped as a truncated cone.

6. In a centrifugal separator including: a rotatable cylindrical bowl adapted to receive a fluid mixture of fine solid particles and liquid, a solids discharge chamber at one end of the bowl, a liquid discharge chamber at the opposite end thereof, means for maintaining a predetermined depth of liquid in the bowl, a rotatable conveyor within the bowl and coaxial therewith comprising helical blades having working surfaces possessing a degree of smoothness precluding substantial adherence of the particles thereto, said blades being of substantially uniform diameter over a predetermined length of the bowl but progressively decreasing in diameter as they approach the solids discharge end of the bowl, and means for rotating the conveyor and the bowl at different speeds whereby the particles are caused to move toward the solids discharge chamber, the combination with the bowl of a plurality of spaced strips about the inner wall thereof in the area of the blades of substantially uniform diameter, these strips

being generally disposed in planes containing the axis about which the bowl and conveyor are rotated and serving to anchor a layer of the particles to said wall in operation of the separator.

7. A centrifugal separator according to claim 6 in which the height of the strips and the clearance between the strips and the tips of the conveyor blades of uniform diameter conform substantially to the size of the coarsest of the particles.

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