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(54) Hydraulic separating method and apparatus

(57) For the separation of solid particles of hydrous slurries, such as those containing minerals including ore solids, coal and sands, the slurry is introduced, e.g. tangentially, at (15) into the upper portion (10*a*) of a tank (10) that has a perforated annular barrier plate (14) between its upper and lower portions (10*a*, 10*b*). Separating conditions are maintained in the upper portion (10*a*) of the tank by introducing water, e.g. tangentially at (16) into the lower portion (10*b*) of the tank so that it flows upwardly, through the perforations in the plate (14), into the upper portion. A weir (11) is provided for removing a separated overflow fraction from the upper tank portion. Separate means in the form of openings (21) in the base of a conical member (18) surrounded by the annular barrier plate (14) serve to remove an underflow fraction from the upper tank portion.

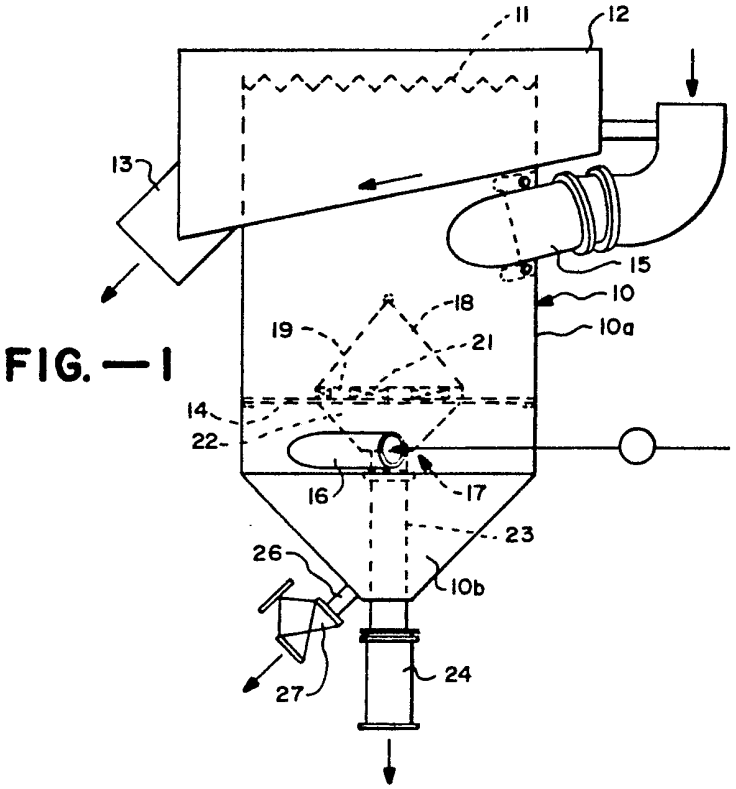

FIG. —1

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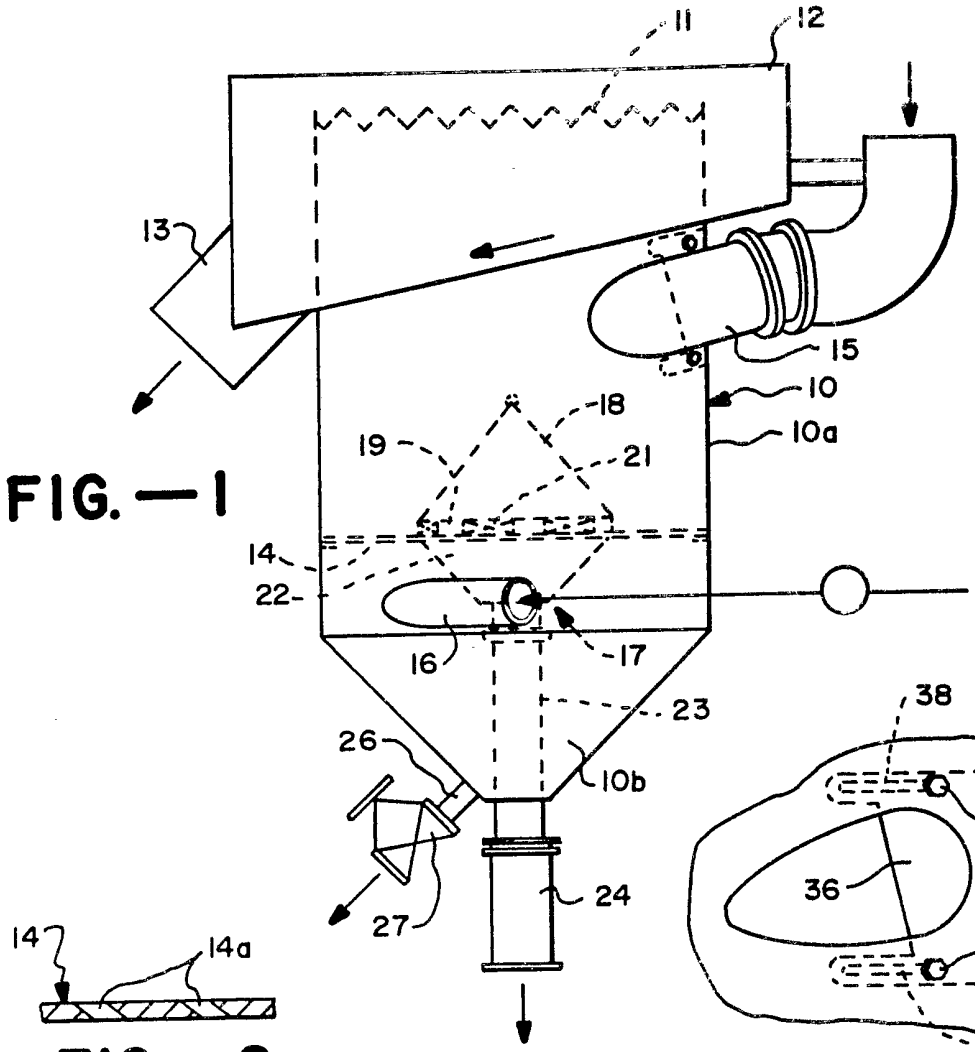

FIG. —1

FIG. —2

FIG.—6

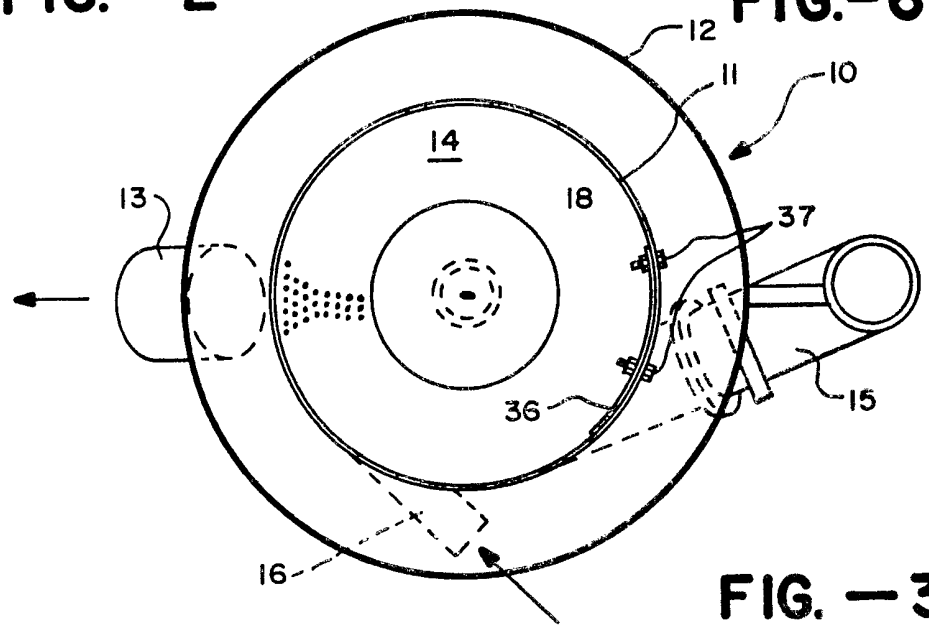

FIG. —3

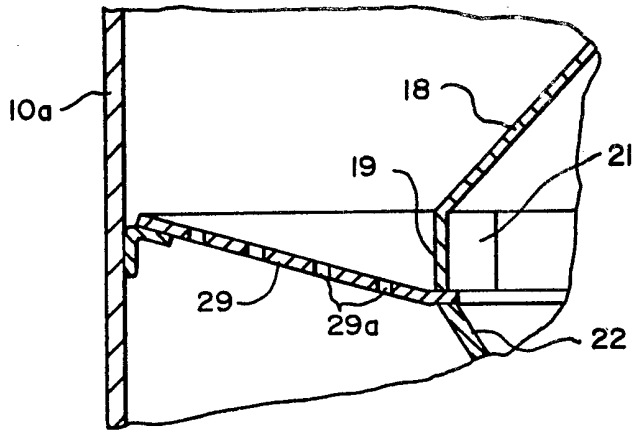

FIG.—4

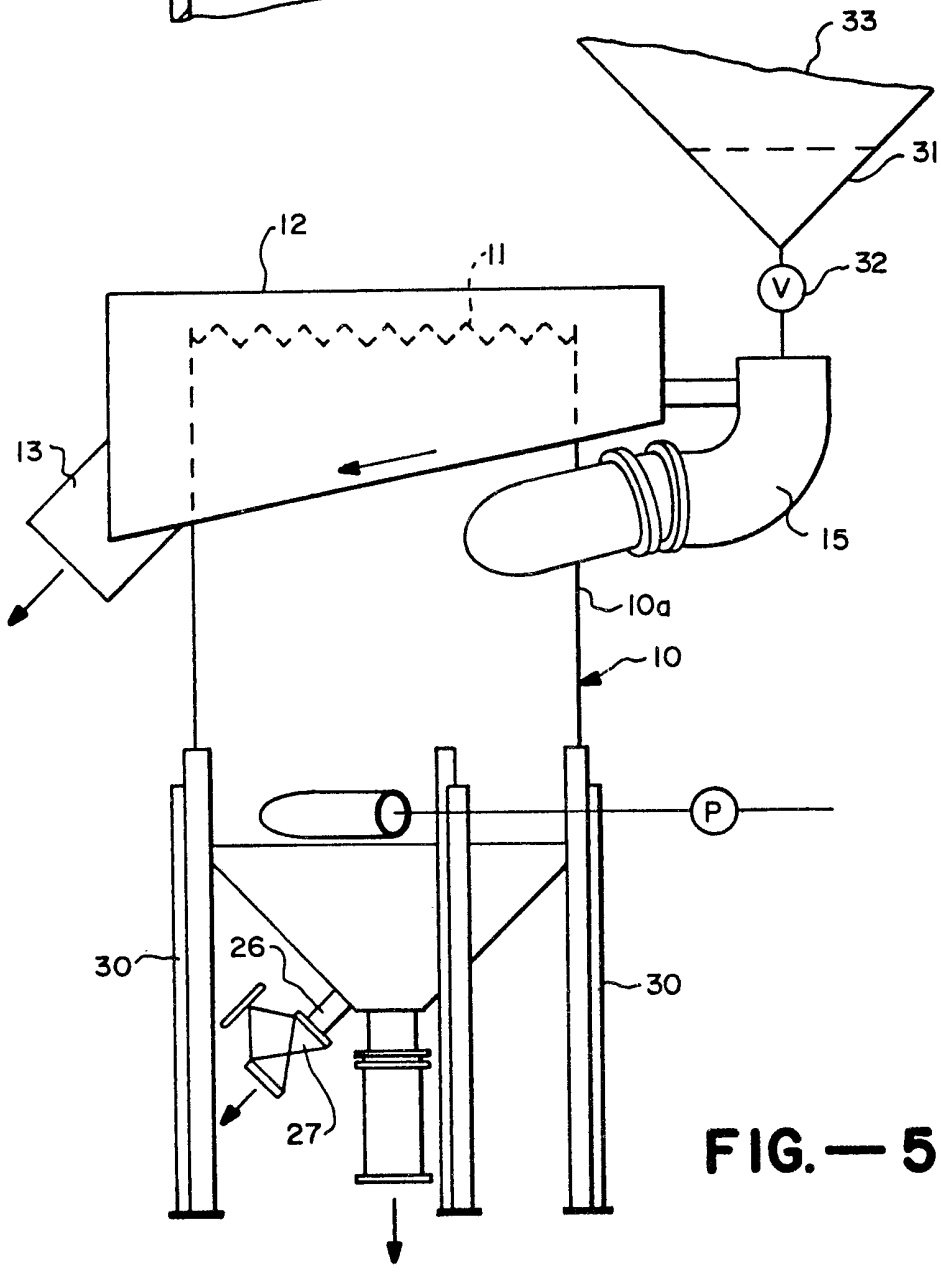

FIG.—5

SPECIFICATION

Hydraulic separating method and apparatus

This invention relates generally to methods and apparatus for separating solid particles of hydrous slurries or pulps into fractions containing particles of different settling velocities. The invention is applicable to various slurries such as those containing minerals like ore solids, coal and sands.

Reference is made to may co-pending applications Serial No. 534,975 filed September 22, 1983, Serial No. 368,625 filed April 15, 1982, and Serial No. 338,341 filed January 11, 1982, now abandoned. Also reference is made to my application entitled Hydraulic Separating Method and Apparatus mailed to the Patent Office on December 28, 1983, and assigned Serial No. 566,481.

Many types of apparatus and methods are used commercially for the hydraulic separation of solid particles of slurries or pulps which have solid particles of different settling velocities. Generally such apparatus consists of a tank having means for introducing the slurry, means at the upper end of the tank for removing an overflow, and means for removing an underflow from a lower portion of the tank. One particular type of apparatus makes use of a so-called constriction plate, or perforated barrier, which separates the upper portion of the tank into which the feed slurry is introduced, from the lower portion of the tank. In operation, water is continuously introduced into the lower portion of the tank and flows upwardly through the perforations or openings in the barrier, whereby separation is carried out in the upper portion of the tank, in accordance with the settling velocities of the solid particles. The means for withdrawing the underflow is arranged to remove the solid particles of greater settling velocity from a region adjacent and above the constriction plate, and may consist of one or more pipes communicating through the side walls of the tank. Equipment and methods of this type have not provided a separating action which is as precise or sharp as is as desired, and in addition the apparatus is relatively large for a given capacity.

In general it is an object of the present invention to provide an improved hydraulic separating method and apparatus which produces improved separation between solid particles of different settling velocities, and is relatively compact in size compared to conventional prior art separating apparatus of comparable capacity.

Another object is to provide a hydraulic separating method and apparatus which has improved means and method for removing the separated underflow fraction.

Another object is to provide a method and apparatus which is not critical with respect to variations in the solids of the feed slurry, such as variations in the composition of the solid particles, the relative proportions between particles of greater and lower settling velocities.

In general, the present invention comprises an upright tank having overflow discharge means at the upper end of the tank for removing an overflow fraction, and a perforated barrier, or constriction plate disposed between upper and lower portions of the tank. Means is provided for introducing feed slurry into the upper tank portion, and means for introducing water into the lower tank portion whereby water flows upwardly through the perforations of the barrier into the upper tank portion. Separating conditions are maintained in the upper tank portion to cause particles of greater settling velocity to progress downwardly and particles of lower settling velocity to progress upwardly for discharge in the overflow. Means is further provided for removing an underflow from a region immediately above the barrier, which provides outlet openings adjacent the upper side of the barrier and radially spaced from the adjacent side walls of the tank. Preferably the means for introducing the feed slurry connects tangentially with the upper tank portion, thereby causing swirling movement of the body of material in the upper tank portion. The means for removing an underflow fraction preferably consists of a conical member in the upper tank portion that is aligned with the axis of the tank and positioned with its annular base coincident with the barrier, the outlet openings being in the base portion. Also the last named means includes means below the barrier for collecting and removing the underflow. The method comprises continuously supplying feed slurry to the upper tank portion, continuously supplying water to the lower tank portion below the barrier to cause water to flow continuously through the barrier and into the upper tank portion. The introduction of the feed slurry and water is such that separation of solid particles takes place within the upper tank portion whereby particles of greater settling velocity progress downwardly into a region adjacent the barrier and solid particles of lesser settling velocity progress upwardly and discharge from the upper end of the tank in an overflow. The solid particles of greater settling rate are removed from an annular region adjacent the upper side of the barrier, the removal being a direction toward the axis of the tank. The removed solids of greater settling velocity are collected below the barrier and delivered to the exterior of the tank as an underflow fraction. Preferably the solid particles of greater settling velocity are directed toward the annular region of the barrier as they progress downwardly. Also the feed slurry is preferably introduced tangentially into the upper

tank portion to cause swirling movement about the axis of the tank.

Additional objects and features of the invention will appear from the following description in which the preferred embodiments are set forth in detail in conjunction with the accompanying drawing.

Referring to the drawing:

Figure 1 is a side elevational view of apparatus in accordance with the present invention.

Figure 2 is a detail in section of a portion of the barrier 14.

Figure 3 is a plane view of Fig. 1.

Figure 4 is a detail in section illustrating another embodiment of perforated barrier.

Figure 5 is a schematic view illustrating the apparatus as in a commercial installation.

Figure 6 is a detail in section showing a gate for controlling discharge of feed material into the apparatus.

The apparatus as shown in Figs. 1 and 2 consist of an upright tank 10 which is annular in horizontal section. The upper end of the tank is provided with overflow discharge means consisting of a weir 11, which may be of the saw-tooth type as illustrated, together with the collection launder 12. The collected overflow is discharged through conduit or pipe 13. The upper and lower portions 10a and 10b of the tank are separated by the annular barrier 14. This barrier is of the constriction plate type, being provided with perforations or openings through which water may pass. Pipe 15 serves as means for introducing feed slurry into the upper tank portion, and preferably connects tangentially through one side of the tank, as illustrated in Figs. 1 and 2. Pipe 16 serves as means for introducing water into the lower tank portion 10b, and may likewise be connected tangentially through one side wall of the tank.

The means for removing underflow material is indicated generally at 17. In the form illustrated it includes a conical shaped member 18 which has its axis coincident with the vertical axis of the tank, and its base coincident with the barrier 14. The lower base portion 19 is provided with a plurality of evenly and circumferentially spaced outlet openings 21, which serve to receive solids from a region immediately above the barrier 14. Extending below the barrier there is a collecting member 22 which in this instance is an inverted cone, and which serves to collect material flowing through the openings 21. The uppr end of member 22 has a diameter substantially the same as the diameter of the base of cone 18, and it is disposed coincident with the barrier 14. A pipe 23 connects with the lower end of the collecting member 22, and extends through the lower end of the tank. It is shown provided with a valve 24, which may be of the pinch tube type, and which may be arranged for manual or automatic operation. An additional pipe and valve 26 and 27 are shown connected to the lower portion of the tank, and may be used for clean-out operations.

Fig. 2 shows a portion of the barrier plate 14. The holes 14a are evenly distributed about the circumferential area of the annular plate 14 and preferably are sloped whereby discharging water tends to impart swirling movement to material immediately above the plate, the direction of such swirling movement being the same as that produced by tangential introduction of feed slurry through pipe 15. The axes of holes 14a are normal to radii extending from the central axis of the tank.

Operation of the apparatus described above, and the method of the invention, are as follows. A hydrous feed slurry (e.g. one containing a natural sand) is continuously introduced into the upper tank portion through pipe 14, at a relatively constant rate. Water is continuously introduced into the lower tank portion below the barrier 14, through pipe 16. The water pressure maintained in the tank below the barrier 14 is sufficient to maintain flow of water upwardly through the openings 14a in the barrier, and into the material in the upper tank portion. It has been found that by maintaining the body of material in the upper tank portion swirling about the central tank axis, some solid particles of greater settling velocity (e.g. the coarser particles of sand) tend to progress outwardly toward the sides of the tank, and downwardly toward the barrier 14. Solid particles of lower settling velocity progress upwardly and are discharged over the weir 11 as an overflow. The solid particles of greater settling velocities accumulate in the region immediately above the annular barrier 14 and surrounding the base of the conical member 18. In this region the material is in continual swirling movement and also movement inwardly toward the base of the cone 18 and outlet openings 21. Such solid particles progress through the outlet openings 21 and from thence into the collecting member 22, for discharge through the underflow pipe 23. Movement of material adjacent the upper surface of the barrier prevents accumulation of solids in localized regions of the barrier such as would interfere with proper flow through the openings 21. Although the body material in the upper tank portion 10a is caused to swirl about the central axis of the tank, it is sufficiently quiescent as not to interfere with effective separating action. The water pressure in the tank portion 10b is such as to maintain upward flow of water through the barrier opening, that is of sufficient rate to prevent solids from passing downwardly through the openings.

Commercial operations of the apparatus and method have demonstrated that it provides

improved separation between the overflow and underflow fractions, and that the apparatus has relatively high capacity for its size. Another feature of the apparatus and method is that it is not unduly sensitive to changes in the composition of the slurry solids, or in the rate with which the solids are introduced into the tank. For example, when the apparatus and method are used to separate the coarse and fine particles of a slurry consisting of sand, the relative amount of coarse and fine sand particles may vary considerably without intefering with the desired sharpness of separation. The same applies to the rate of introduction of slurry solids into the tank. The separating action does not depend upon maintenance of a condition of teter, which is deemed to be due to the continual swirling of material in the upper tank portion.

Another embodiment of the invention is shown in Fig. 4. The constriction plate 29 in this instance is dished downwardly, or in other words it conforms generally to the surface of a truncated cone. Such a sloped constriction plate tends to aid movement of the solid particles of greater settling velocity toward the openings 21. Preferably the holes 29a are likewise sloped as shown in Fig. 2.

Fig. 5 shows a commercial installation of the apparatus. The tank 10 is carried by the uprights 30, and pipe 15 is connected to a feed hopper 31. The feed hopper has a screen 33 through which feed slurry is introduced, and the lower end of the hopper is connected through valve 32 with pipe 16.

Figs. 1 and 6 show an adjustable flow control gate 36 for controlling discharge of feed slurry into the tank from pipe 15. It is adjustably carried by bolts 37 which are accommodated in slots 38 in the gate. Adjusting the position of this gate serves to control the rate of swirling movement of material in the upper tank portion 10a for optimum separation under given operating conditions (e.g., character of feed slurry).

An example of the invention is as follows:

Example 1

The apparatus was constructed substantially as shown in Figs. 1 and 2, and was installed as shown in Fig. 4. The portion 10a of the tank was cylindrical and 4.5 feet in diameter. The top of the tank was about 5 feet above the constriction plate 14. The cone 18 was 1.5 fee in height, with a base diameter of 2.25 feet. The slope of the cone 18 was about 45°. The base of the cone was provided with six openings 21, each having a circumferential length of about 6 inches, and a height of about 3 inches. A natural sand was used to prepare the feed slurry. The coarse particles of the sand were plus 48 mesh (Tylor Standard Screen). The remainder of the solids were relatively finer particles. The slurry was prepared to have an optimum solids content of about 17%, although in practice this varied somewhat during an operating run. The slurry was fed from the hopper 31 through pipe 15 into the tank at a hydrostatic head of about 18 inches. The feed rate was about 100 tons per hour of solid particles contained in the slurry. A screen analysis made of the solid particles in the underflow was as follows.

PRODUCT	SCREEN ANALYSIS (% CUMULATIVE, TYLER)			
	+ 14	+ 28	+ 48	+ 100
Coarse	2.9	49.4	94.3	99.3
Fines	—	0.3	15.2	60.1

It will be evident from the above that the apparatus and method makes possible relatively sharp separation between the coarse and fine solid particles. Over an operating period of one hour, during which the feed slurry delivered 100 tons of sand as provided by a sand dredging operation, typical sampling showed that 94.3% of the coarse solids of the underflow were plus 48 mesh, and only 15.2% of the fines were contained in the underflow.

When the invention is used for the processing of sand and similar mineral slurries, it may be referred to as a sizer, since the larger coarse sand particles are separated from the smaller fine particles. However, the invention is applicable to other mineral containing slurries where the objective is to effect separation according to differences in settling velocities, rather than sizing. While the sharpness of separation obtained in a single stage operation is generally sufficient for most commercial purposes, a fraction (e.g. underflow) can be subjected to a second stage separating operation using the same apparatus, or using conventional equipment such as hydrocyclones.

CLAIMS

1. Apparatus for separating the solid particles of a hydrous feed slurry into overflow and underflow fractions having solid particles differing in their settling velocities, comprising an upright tank, the upper end of the tank having overflow discharge means for removing an

overflow fraction, a barrier having holes therethrough disposed between upper and lower portions of the tank, the upper tank portion being annular in horizontal section, means for introducing feed slurry tangentially into the upper tank portion to thereby cause material in the upper tank portion to swirl about the central vertical axis of the tank, means for introducing water into the lower tank portion whereby water flows upwardly through the barrier and into the upper tank portion, thereby maintaining separating conditions in the upper tank portion to cause particles of greater settling velocity to progress downwardly and to cause particles of lower settling velocity to progress upwardly for removal in an overflow fraction, and means for removing an underflow fraction from said last named region, said last named means forming outlet openings adjacent the upper side of the barrier, the openings being radially spaced from the adjacent side walls of the tank and from the central vertical tank axis.

2. Apparatus as in Claim 1 in which said outlet openings are circumferentially spaced about the central axis of the tank.

3. Apparatus as in Claim 1 in which said means forming outlet openings includes a conical member in the upper tank portion aligned with the axis of the tank and positioned with its annular base coincident with the barrier, the outlet openings being in the base portion of the conical member, said conical member serving to restrict the exposed area of the barrier to an annular portion between the base of the conical member and the side walls of the tank.

4. Apparatus as in Claim 3 together with means below the barrier for collecting the underflow fraction passing through the outlet openings and for delivering the same exterior of the tank.

5. Apparatus as in Claim 3 in which the collecting means comprises an inverted conical shaped member in the lower tank portion and aligned with the central axis of the tank, said member having its upper open end disposed adjacent the barrier and below said outlet openings.

6. Apparatus as in Claim 1 in which the openings in the barrier are sloped to discharge water flowing therethrough in the direction of the siwrling movement of material in the upper tank portion.

7. Apparatus as in Claim 2 in which the barrier is sloped downwardly toward the outlet openings.

8. Apparatus as in Claim 1 together with gate means for controlling the introduction of feed slurry into the upper tank portion to control the swirling movement of material therein.

9. The method of separating a feed slurry of solid particles having different settling velocities into an underflow fraction containing solid particles of greater settling velocity and an overflow fraction containing solid particles of lower settling velocity, the method making use of an upright tank having means for removing an overflow fraction from its upper end, a barrier having openings therethrough and disposed between the upper and lower portions of the tank, the upper portion of the tank being annular in horizontal section, and also having means for introducing a feed slurry into the upper tank portion, the method comprising continuously supplying feed slurry tangentially to the upper tank portion to cause the material therein to swirl about the central vertical axis of the tank, continuously supplying water to the lower tank portion whereby water flows continuously through the openings in the barrier and into the upper tank portion, the introduction of the feed slurry and water being such that hydraulic separation of solid particles takes place within the upper tank portion whereby particles of greater settling velocity progress downwardly toward the barrier and solid particles of lower settling velocity progress upwardly and discharge from the upper end of the tank in an overflow, directing the solids of greater settling velocity toward an annular region adjacent the barrier which extends inwardly from the side walls of the tank and surrounds a central tank region, removing the solid particles of greater settling rate from said annular region, said removal being in a direction toward said central region, and then collecting the removed solids of greater settling velocity and delivering the same exterior of the tank as an underflow fraction.

10. A method as in Claim 9 in which as the solid particles of greater settling velocity progress downwardly they are caused to swirl about the axis of the tank.

11. A method as in Claim 9 in which the water flowing through the openings of the barrier is discharged in the direction of swirling movement of material in the upper tank portion.

12. A method as in Claim 9 in which introduction of the feed slurry is adjusted to control the rate of swirling movement.

13. Separating apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

14. A separating method substantially as hereinbefore described with reference to the accompanying drawings.

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