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(54) GRAVITATIONAL SEPARATION

(71) We, ENVIROTECH CORPORATION, incorporated in the State of Delaware, United States of America, of 3000 Sand Hill Road, Menlo Park, California 94025, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates generally to gravitational separation by sedimentation and, more particularly, to ways and means for continuously separating suspended solid materials from a feed stream liquor by gravity settling.

Sedimentation devices which incorporate liquid-holding tanks are well known to separate suspended solids from streams of liquid, such as water and wastewater, by gravity settling. To hasten separation, it is well known to employ various chemical flocculating reagents. When added to the influent liquor, the reagents combine with the suspended solids to form rapidly settlable aggregates, called floc. Typically, the mixing of flocculating reagents with feed slurry is accomplished outside the sedimentation tank proper, say in a flowing pipeline or launder and, in the case of dilute suspension (say, less than 0.1%), may be accompanied by a mechanical stirring of the feed liquid to provide contact opportunity and time for the resulting flocs to grow. In some cases where the feed solids concentration is high, say 20% to 30% by weight, it is of known benefit to dilute the feed slurry in order to improve flocculation and, thereby, sedimentation; in known machines, this is accomplished outside the sedimentation tank proper.

Sedimentation devices are termed "clarifiers" or "thickeners" depending upon whether they operate upon liquid streams having relatively low or high concentrations of suspended solids and/or whether the primary objective is a clear overflow or a dense, concentrated underflow (in some cases both conditions may be required of a thickener). As used herein, the term "sedimentation device" refers primarily to thickeners and similar continuously-operating gravity settling devices.

A primary object of the present invention is to provide an improved sedimentation machine for treating mineral slurries, industrial wastes and sewage, and the like, where the sedimentation device has the capacity to handle high flow rates of influent liquor per unit volume of the liquid-holding tank while still providing good clarity in the supernatant liquid. Slurries of finely divided solids which the sedimentation machine of the invention is intended to treat include, for example, ore slurries, pulp and paper recausticizing slurries, flue gas scrubbing slurries, coal refuse slurries, and municipal and industrial wastewater.

Another object of the present invention is to provide a thickening machine for the purposes described above which operates effectively without recycling or recirculating thickened solids.

According to the present invention there is provided a machine for continuously separating suspended solids from a feed stream liquor by gravity settling comprising: a liquid-holding tank for containing a body of liquid in generally quiescent condition; an upstanding tubular column mounted within said liquid-holding tank; means mounted at the upper end of said tubular column to convey a stream of feed liquor into the interior of said tubular column; flocculating-mixing compartments formed within said tubular column, one below another, to sequentially receive the feed liquor; mixing means mounted within each of said flocculating-mixing compartments to blend the liquid therein; reagent introduction means mounted within each of said flocculating-mixing compartments to feed a chemical flocculating reagent into the compartment for enhancing the flocculation of suspended solids within the feed liquor; discharge means in liquid-flow communication with the lowermost one of said flocculating-mixing compartments and with the interior of said liquid-holding tank for discharging the flocculated feed liquor into a pulp blanket stratum at the bottom of said liquid-holding tank; raking means including rake arms mounted within said liquid-holding tank to urge solids settled in the pulp blanket stratum to underflow discharge; and overflow

means mounted at the top of said liquid-holding tank for receiving overflowing clarified supernatant therefrom.

An embodiment of the invention will now be described by way of example with reference to the accompanying illustrative drawings in which:—

Figure 1 is a cross-sectional view of a machine in accordance with the present invention, parts of which are shown schematically;

Figure 2 is a cross-sectional detail, enlarged for purposes of clarity, of a portion of the mechanism in Figure 1; and

Figure 3 is a cross-sectional view, again enlarged for purposes of clarity, of a detail of the mechanism shown in Figure 2.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT.

The sedimentation machine in Figures 1 and 2 includes a liquid-holding tank which is typically circular in configuration and is defined by a marginal upstanding sidewall 11 and a bottom wall 13, the latter which slopes downward toward a sump 15 formed centrally in the bottom wall of the tank. Mounted peripherally about the sidewall 11 is a launder 17 inclusive of an overflow weir wall 19 which defines the liquid level in the tank. Centrally disposed in the tank is an upstanding tubular column 23. The tubular column can be either stationarily supported from the tank floor as shown or can be suspended for rotation from a bridge or other trusswork which traverses the tank.

Further with regard to the embodiment shown in Figures 1 and 2, a drive unit 25 of conventional construction is mounted atop the stationary center column 23. Below the drive unit and supported therefrom is an annular feedwell 27 which concentrically surrounds the center column. The annular feedwell comprises a cylindrical baffle wall 29 and an annular bottom wall 31 which is in sealing engagement with the column 23. Further, the annular feedwell 27 is coupled by conventional structural means, not shown, to the drive unit 25 to be driven thereby in rotation about the center column. A conduit 33 is mounted to convey a stream of feed liquor containing suspended solids into the feedwell.

As also shown in Figures 1 and 2, a raking mechanism 37 of conventional construction is mounted to be driven in rotation about the column 23 by the drive unit 25 and is arranged to rake thickened solids across the bottom or floor 13 of the tank. In the illustrated embodiment, the raking mechanism 37 should be understood to be fixedly connected to the feedwell 27 which, in turn, is connected to the drive unit 25 for rotation. Also, in the illustrated embodiment, the raking mechanism 37 should be understood to be disposed to urge settled (thickened) solids towards the aforementioned sump 15 formed about the base of the column 23. From the sump 15, the thickened solids are pumped to discharge via an underflow conduit 39.

Concomitant with the removal of thickened, settled solids via the sump 15, clarified supernatant spills over the weir wall 19 and is carried to discharge via the launder 17. This is, of course, a conventional arrangement well known in the sedimentation art.

With reference now particularly to Figure 2, at least one port 43 is formed through the sidewall of the column 23 in liquid flow communication with the interior of the feedwell 27. By means of this port 43, a stream of feed liquor is fed into the interior of the column 23. Thus, it can be understood that feedwell 27 differs from the conventional in that it feeds feed liquor inwardly, not outwardly. It should also be understood that alternative means can be provided to introduce liquor into the tubular column; for example, the feed liquor could be introduced into the tubular column through a central opening in an annular drive gear which operates the raking mechanism.

Below the feedwell 27 there is formed at least one port 45 through the sidewall of the tubular column 23. Port 45 is called the dilution port because it is in liquid flow communication with a clarified liquid zone or stratum in the liquid-holding tank, which stratum contains a relatively low percentage of suspended solids. The clarified liquid (supernatant) conveyed through the dilution port 45 serves to dilute the above-mentioned feed stream. In practice, a pump or impeller means 47 is mounted within the column 23 to draw a stream of the dilution liquid through the port 45 and then to impel the liquid downward for mixing with the feed stream. The illustrated pump means 47 includes an impeller 49 mounted within a bell-like housing 51 and coupled to a drive shaft 53 for rotation therewith. The upper end of the drive shaft 53 is coupled to the aforementioned drive unit 25 or to an auxiliary rotary drive; the lower end of the drive shaft 53 is mounted in a bearing means 55, but other support means could be provided. The interior of the bell-like housing 51 is in liquid flow communication with dilution port 45 via a pipe member 52, thus providing an internal recycle. The term internal recycle is intended to convey the concept that dilution of the feed liquor with clarified supernatant is accomplished within the thickening machine itself and without removing supernatant therefrom. The dimensions of the bell-like housing 51 are such that the feed stream liquor can flow downward around the periphery of the housing and thus into the column 23 below the pumping means 47 for mixing with the dilution liquid. As an alternative, a single axial flow impeller having a diameter less than that of the column 23 can be employed to provide the necessary downward pumping, thus eliminating the need for the housing 51.

It should be appreciated that the pumping means 47 is normally necessary because the hydrostatic head imposed by the tank contents plus the hydraulic head loss due to the flowing feed liquor through the column 23 can result in the liquid level within the column exceeding the liquid level outside the column. But for the pumping means in such instances, the excess head in the column would force liquid out of the dilution port 45. In practice, the dilution ratio is selectively adjustable by either varying the pumping rate directly or by changing the area of the dilution port by an adjustable gate means, not shown. One typical example of dilution occurs in the processing of uranium-bearing minerals where slurries of such minerals having solids concentration above about 20% are normally diluted down to about 10% in order to provide improved flocculation and settling. On the other hand, in some applications where the feed solids concentration is initially low, good flocculation can be achieved without dilution and, hence, the dilution step can be omitted together with the aforedescribed structure to accomplish the same.

Formed within the tubular column 23 below the dilution stream entry ports 45 are a plurality of subadjacent flocculating-mixing compartments or stages 59—61 which sequentially receive the diluted feed liquor. Since the three illustrated stages are generally the same, only stage 60 will now be described in detail. The roof and floor of the stage 60 are defined by annular baffle plates 65 and 67, respectively, which are fixed horizontally to the interior wall of the tubular column. The center openings 71 in the annular baffle plates 65 and 67 are of sufficient size to accommodate the aforementioned drive shaft 53 as well as to permit the flow of diluted feed liquor into and then out of the flocculating-mixing stage 60. Although other means could be provided to convey the diluted feed liquor sequentially to and from the flocculating-mixing stages, the illustrated embodiment is preferred because of its structural simplicity.

Referring now to Figures 2 and 3, each of the flocculating-mixing stages 59—61 include mixing means to stir the liquid therein to provide rapid blending of flocculant solution and feed slurry. In the illustrated embodiment, the mixing means is a set of radially-extending mixing blades 69 fixed to the drive shaft 53 for rotation therewith. Also mounted within each of the flocculating-mixing stages is means to introduce a chemical flocculating reagent; in the illustrated embodiment, the shaft 53 is shown as being hollow and it carries the flocculating reagent in liquid form for introduction to the respective flocculating-mixing stages 59—61 via radially-extending reagent-dispersing pipes 73. In the embodiment in Figure 2, the reagent is supplied through the shaft 53 from a reservoir, not shown, via a supply conduit 75. In operation, the reagent liquid is discharged through the despersing pipes 73 upon rotation of the mixing blades 69. The presence of the reagent and the blending action effectuated by the mixing blades 69 serves to cause the solids in suspension in the feed liquor to aggregate and form flocs. Typical dosages when polymer-type flocculants are used are about 10—30 ppm.

In the preferred embodiment and as shown in Figure 2, a plurality of thin baffle plates 77 are vertically mounted at spaced-apart positions within at least some of the flocculating-mixing stages. The purpose of the baffles 77 is to assist in the flocculating action and to prevent disruptive vortexes or swirls from being established in the flocculating-mixing stages. Typically, four baffles are provided per flocculating-mixing stage, but this is a matter of choice.

In summary to this point, the interior of the tubular column 23 can be understood to comprise three zones: a zone for receiving the stream of feed liquor, a subadjacent dilution zone for receiving clarified liquid for diluting the stream of feed liquor, and a zone comprising a plurality of subadjacent flocculating-mixing stages in which downwardly flowing diluted feed liquor is mechanically mixed with a chemical flocculating reagent. The number of flocculating-mixing stages employed is dependent upon the feed rate and flocculation time required by a particular slurry. In some instances, the flocculating-mixing stages need not be immediately adjacent one another, but can be separated by a compartment which does not contain a set of mixing blades.

With reference again to Figure 2, at least one outlet port 79 is formed through the sidewall of the column 23 at or below the lowermost flocculating-mixing stage. Through this outlet port, the diluted and flocculated feed liquor is discharged into the thickening tank proper and, more particularly, said port is positioned so that the liquor is discharged thereform directly into the pulp blanket within the liquid body held in the thickening tank. The term pulp blanket herein refers to a stratum of thickened pulp which extends from the bottom of the thickening tank to some variable level below the tank surface; some workers in this art would also term this the sludge compaction zone. In typical situations, the interface between the pulp blanket and the clarified liquid stratum in the tank is remarkably well defined and can be readily determined by means of conventional sludge level detectors, say of the ultrasonic type. At this juncture it should be appreciated that conventional practice in this art suggests that the feed liquor should be introduced high in the clarified liquid stratum, not into the pulp blanket where the influx might disturb the thickening process; in other words, the introduction of feed liquor into the pulp blanket eliminates the so-called free-settling stratum which typically is found in thickening devices. Although it is within the scope of this

invention to introduce the feed liquor into the thickening tank proper at a location immediately above the pulp blanket, it is much preferred to make such introduction directly into the pulp blanket as discussed above.

Referring again to the liquid-holding tank shown in Figure 1, the tank preferably includes a plurality of inclined plate members 81 mounted at generally regular intervals peripherally along the sidewall 11 of the thickening tank at least partially within the normal stratum of the sludge blanket. More particularly, the plate members 81 are mounted to extend upward at an angle of about 50° to about 60° from horizontal and, preferably, at an angle of 55°. The inclined plates can be mounted at spaced-apart intervals as shown or can be placed more closely together in overlapping relationship. The purpose of the inclined plate members 81 is to provide stabilization of the level of the sludge blanket stratum without the necessity of precise control of flocculant dosage or underflow pumping rates. With the aforedescribed discharge of diluted and flocculated liquor directly into the sludge blanket, the level of the sludge blanket becomes very sensitive to changes in feed rate, dilution ratio, and degree of flocculation. When such conditions suddenly change, the sludge blanket is apt to either rise toward the surface of the liquid-holding tank or to drop below the outlet port 79, neither which action is desirable. However, when the aforementioned inclined plates 81 are utilized, the sludge blanket level remains remarkably stable over a wide range of feed rates without requiring continuous control of the flocculant dosage or underflow pumping rate. The absence of substantial fluctuations in the level of the sludge blanket seems to be due to the increase in physical settling area provided by the inclined plates. In practice, the sludge blanket level has been found to fluctuate only two to three inches when the inclined plates 81 are utilized whereas, without the inclined plates, the level of the sludge blanket fluctuated the full depth of the sidewall 11 of the liquid-holding tank.

In the Figure 1 embodiment, the inclined plates 81 are mounted such that the arms of the raking mechanism 37 pass beneath the bottom edges of the inclined plates. This positioning of the inclined plates 81 is believed to provide an "unloading" action according to which the raking arms remove accumulations of sludge from the areas between the inclined plates. The result is increased underflow density.

In one test of the aforedescribed sedimentation machine incorporating the inclined plates 81 versus the machine without the plates, the underflow density in terms of percent weight solids doubled from 12% to 24%. In that test, the inclined plates were constructed so as to increase the settling surface area in the tank by 120%; the phrase "settling surface area" in this context means the projected area of the inclined plates onto a horizontal plane and is compared to the horizontal expanse of the tank floor. With the addition of the inclined plates, the capability of the tank to handle influent liquor per unit of tank volume was consequently increased by about 270%.

In comparison to a conventional thickening device, pilot tests indicate that the aforedescribed sedimentation machine should provide superior results. For example, a typical thickener for coal refuse can be loaded at only about 0.05 to 0.1 tons per day per square foot of thickener floor area; tests on the aforedescribed machine indicated satisfactory thickening with loadings from 0.8 to 1.0 tons per day per square foot of thickener area. This is with typical underflow concentrations of 30—40% solids by weight and clarified effluents containing 100—300 ppm of suspended solids.

As an alternative embodiment, not shown, a second set of inclined plates can be mounted at generally regular intervals peripherally about the sidewall 11 of the thickening tank above the aforedescribed set of inclined plates 81; in this alternative embodiment, the second set of plates would be mounted above the level of the pulp blanket and would have the purpose and effect of settling out discrete particles or flocs which escape upward from the pulp blanket zone.

As another alternative embodiment, the tubular column 23 could be mounted for rotation within the liquid-holding tank, instead of being stationarily mounted as hereinbefore described.

WHAT WE CLAIM IS:—

1. A machine for continuously separating suspended solids from a feed stream liquor by gravity settling comprising:

a liquid-holding tank for containing a body of liquid in generally quiescent condition;

an upstanding tubular column mounted within said liquid-holding tank;

means mounted at the upper end of said tubular column to convey a stream of feed liquor into the interior of said tubular column;

flocculating-mixing compartments formed within said tubular column, one below another, to sequentially receive the feed liquor;

mixing means mounted within each of said flocculating-mixing compartments to blend the liquid therein;

reagent introduction means mounted within each of said flocculating-mixing compartments to feed a chemical flocculating reagent into the compartment for enhancing the flocculation of suspended solids within the feed liquor;

discharge means in liquid-flow communication with the lowermost one of said flocculating-mixing compartments and with the interior of said liquid-holding tank for discharging the flocculated feed liquor into a pulp blanket

stratum at the bottom of said liquid-holding tank;

raking means including rake arms mounted within said liquid-holding tank to urge solids settled in the pulp blanket stratum to underflow discharge; and

overflow means mounted at the top of said liquid-holding tank for receiving overflowing clarified supernatant therefrom.

2. A machine according to claim 1 further including dilution means mounted in communication with the interior of said tubular column to admit clarified liquid into said tubular column from a stratum of supernatant liquid held within said tank for addition to the feed stream liquor.

3. A machine according to claim 1 or claim 2 further including vertically-extending plate members mounted at intervals peripherally along the sidewall of said liquid-holding tank immediately above the bottom of said tank.

4. A machine according to any preceding claim, including a hollow drive shaft which is connected to carry chemical flocculating reagent to said flocculating-mixing compartments.

5. A machine substantially as described herein and illustrated in the accompanying drawings.

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1596122 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

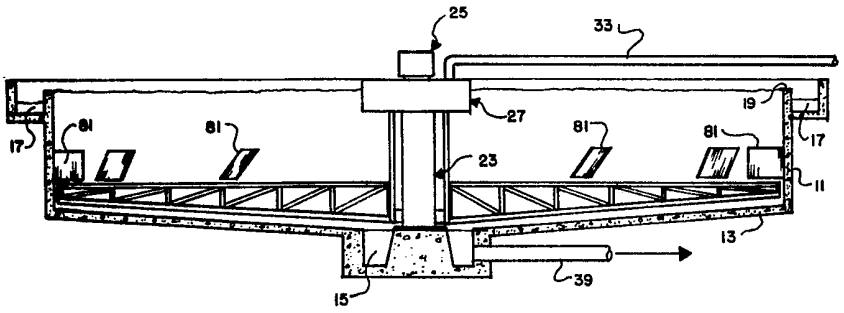


FIG. 1

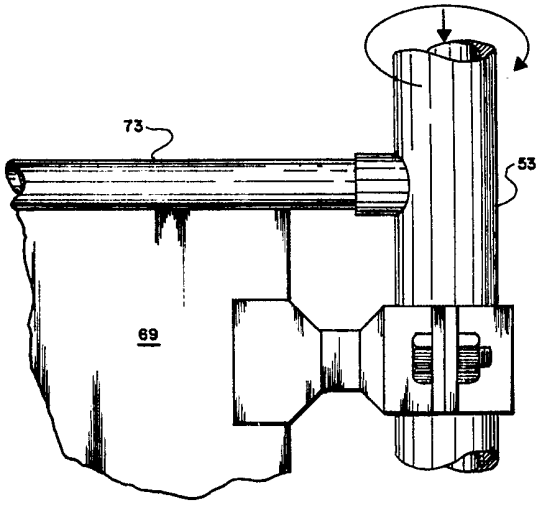


FIG. 3

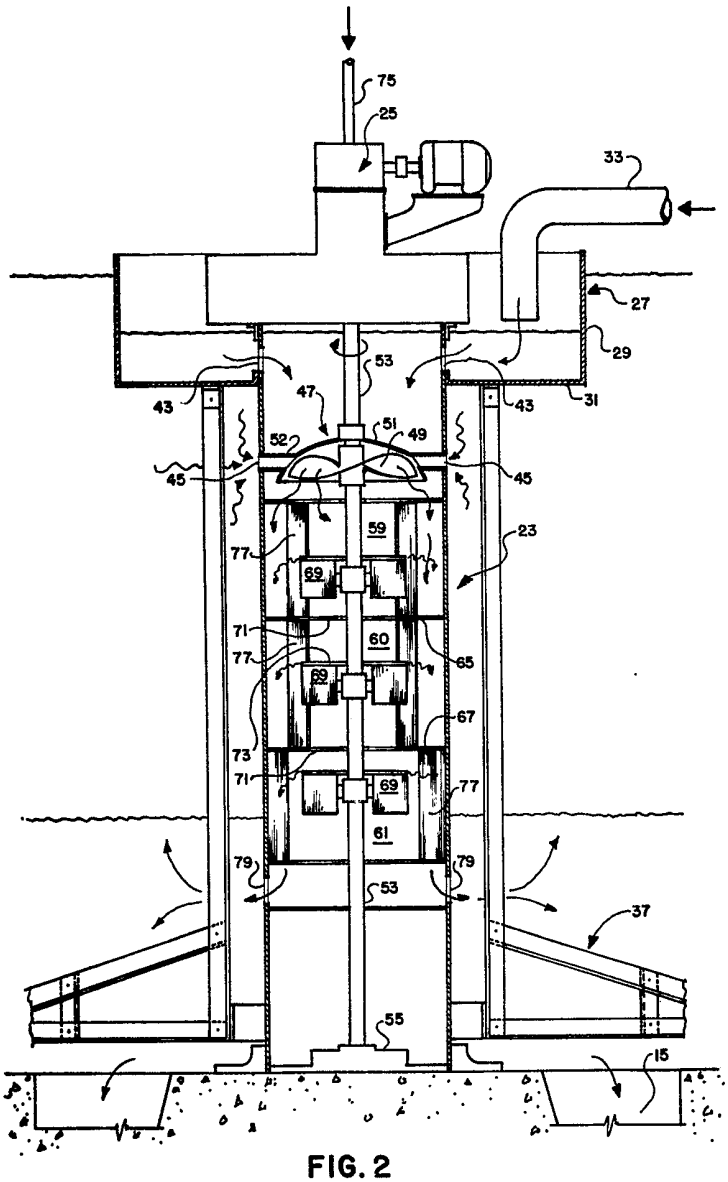

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FIG. 2