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Schmid et al.

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[54] **SEPARATION PROCESS FOR SOLID PARTICLES OF DIFFERING SHAPE**

[75] Inventors: **Eduard Schmid,** Visp, Wallis; **Beat Bruttel,** Seehof; **Reinold Nascher; Rene Egli,** both of Visp, Wallis, all of Switzerland

[73] Assignee: **Lonza Ltd.,** Gampel/Valais, Switzerland

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[52] **U.S. Cl.** **209/211,** 209/155

[51] **Int. Cl.** **B04c 1/00**

[58] **Field of Search** 209/211, 144; 210/512

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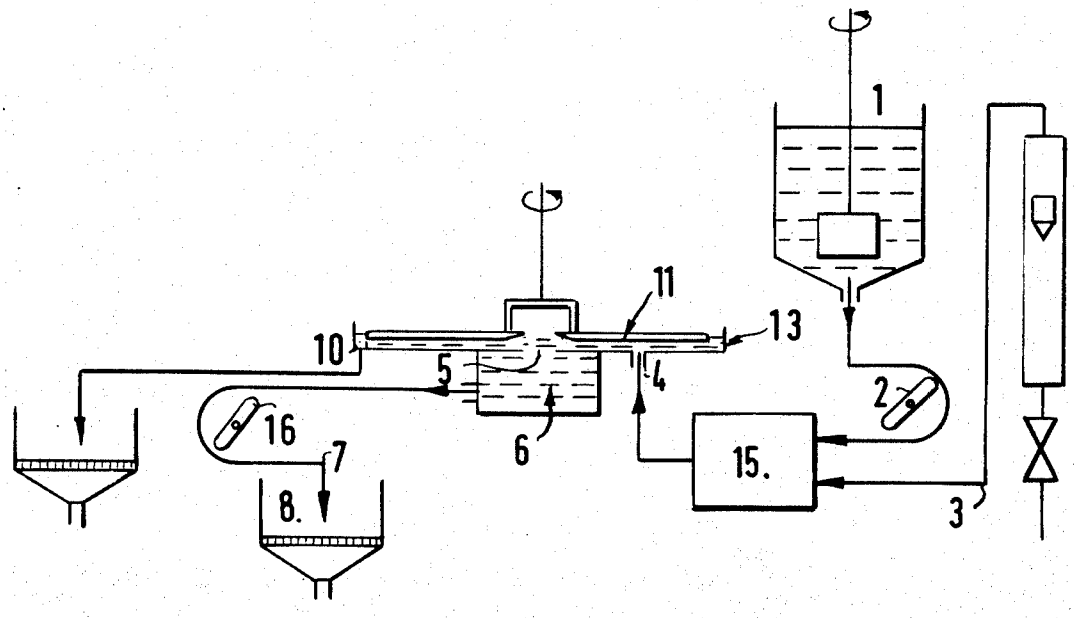
Primary Examiner—Frank W. Lutter
Assistant Examiner—Ralph J. Hill
Attorney—Wenderoth, Lind and Ponack

[57] **ABSTRACT**

The present invention is concerned with a process for the separation of solid particles of different shape but of similar weight, wherein the particles to be separated are suspended in a liquid. In the suspension there is produced, with the exclusion of turbulence, a flow velocity profile by imparting to a 2 - 20 mm. thick layer of the suspension, a rotary movement by the use of two discs, at least one of which is rotating, which discs bound the layer of suspension above and below, there being a difference of rotational speed between the two discs. Those particles which, due to their form, are not carried by the suspending liquid throughout the flow thereof, separate out from the suspension. The separated particles are withdrawn from the suspension at a separation zone.

20 Claims, 5 Drawing Figures



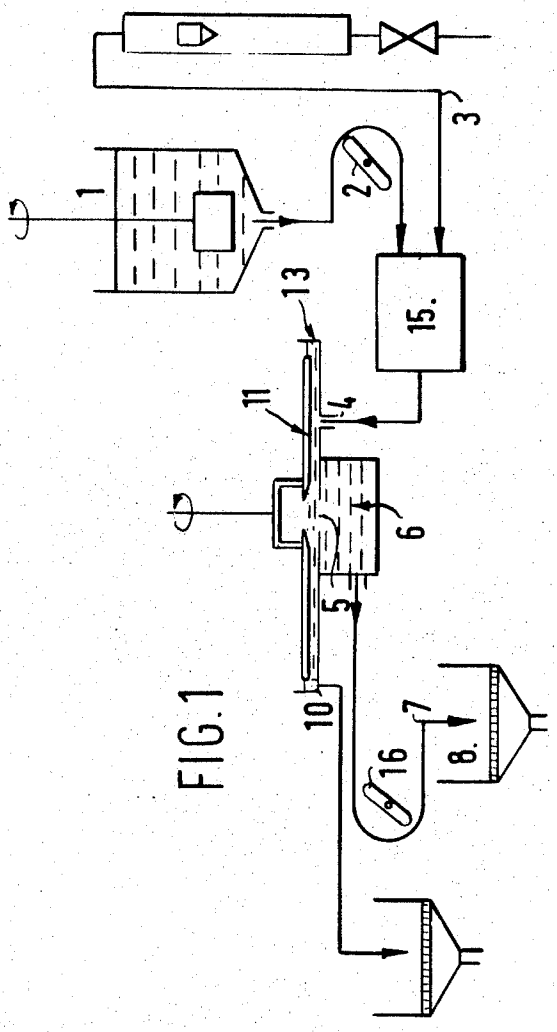


FIG. 1

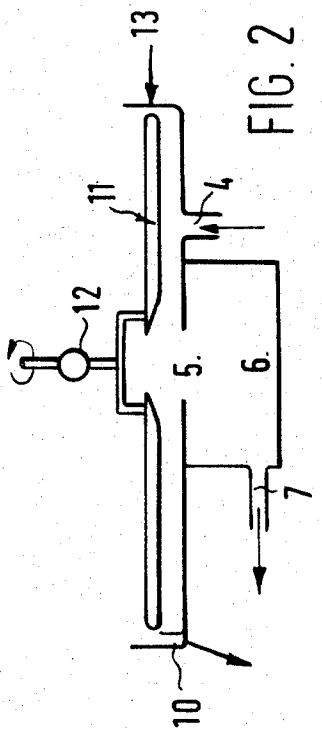


FIG. 2

EDUARD SCHMID,
BEAT BRUTTEL,
REINOLD NASCHER and
RENE EGLI, Inventors

BY Wenderoth, Lind & Ponack
Attorneys

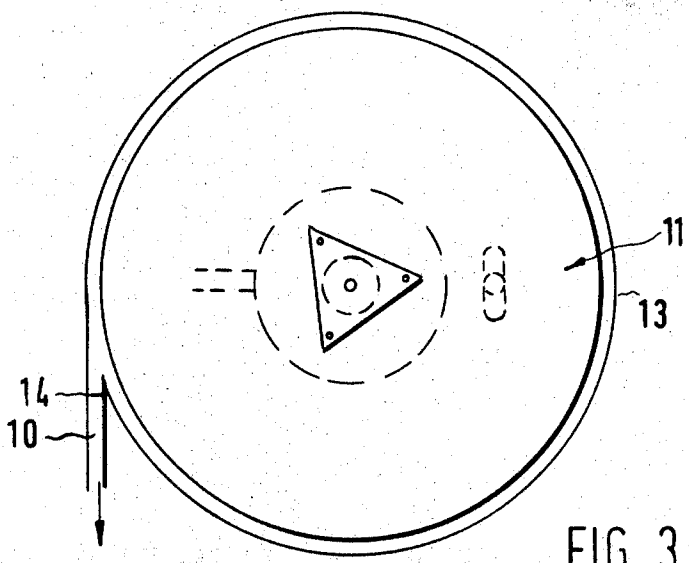


FIG. 3

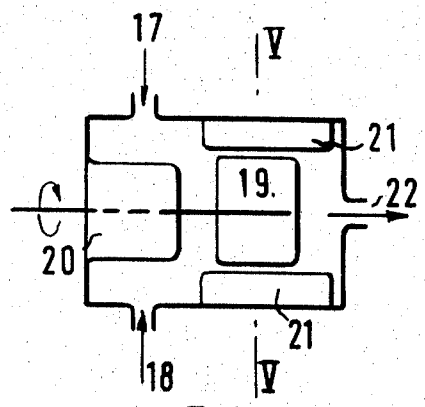


FIG. 4

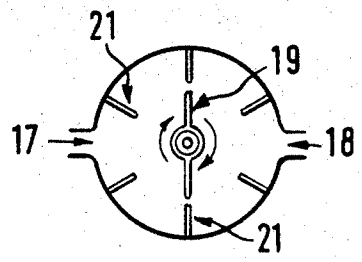


FIG. 5

EDUARD SCHMID,
BEAT BRUTTEL,
REINOLD NASCHER and
RENE EGLI, Inventors

By: Wenderoth, Lind & Ponack
Attorneys

SEPARATION PROCESS FOR SOLID PARTICLES OF DIFFERING SHAPE

The present invention is also concerned with a device for carrying out the process, the device comprising a separation vessel, consisting of a flat cylindrical part with a central flowout opening in the bottom, constituting a lower rigid disc, the central flowout opening leading into a settling vessel, at least one inlet situated between the central flowout opening and the periphery, at least one outflow, for the withdrawal of the suspension, on the periphery of the vessel constructed tangentially as an overflow, for the removal of those particles not separated as a result of their different shape, and a vertically freely moving, rotating disc, the diameter of which is slightly smaller than the inner diameter of the separation vessel and which, on the upper surface, is attached to a drive mechanism for rotating the disc.

BACKGROUND OF THE INVENTION.

Conventional separation processes, such as sieving, centrifuging and sedimentation, all prove to be unsuitable for the separation of mixtures of the above-mentioned type. In the case of sieving, particles in the form of extremely fine rodlets readily undergo felting. Depending upon the mesh size, small nodules also pass through a sieve. By means of sedimentation, for example in water, separation also cannot be achieved since the nodules and rodlets undergo the process to about the same extent. Furthermore, during this process, additional agglomeration can easily occur, which disturbs the process.

Gravitational separation also scarcely gives the desired result because of the unsatisfactory shape of the particles therefor, as well as because of the similar specific weights. This expensive process also cannot be considered because of the considerable dilution which is necessary.

It has also been found that hydrocyclones do not give a sufficient separation effect.

The problem forming the basis of the present invention is to bring about a separation of particles of different shape but the same weight by means of a simple and effective process and with the use of a simple device.

SUMMARY OF THE INVENTION.

Thus, according to the present invention, there is provided a process for the separation of solid particles of different shape but of similar weight, wherein the particles to be separated are suspended in a liquid. In the suspension there is produced, with the exclusion of turbulence, a flow velocity profile or distribution by imparting to a 2 – 20 mm. thick layer of the suspension, a rotary movement by the use of two discs, at least one of which is rotating, which discs bound the layer of suspension above and below, there being a difference of rotational speed between said two discs. Those particles, which, due to their form, are not carried in suspension by the suspending liquid throughout the flow profile thereof, separate out from the suspension. The separated particles separate out from the suspension. The separated particles are withdrawn from the suspension a separation area.

The particles which, as a result of their form, will not be carried by the suspending liquid, will migrate in the rotating liquid to an increased extent in the direction of the centre point of the rotating discs and thus in the direction of diminishing flow profile, where they separate out from the suspension.

The rotational speed difference of the discs can be produced by allowing the two discs to rotate at different speeds. It is also possible to rotate the discs in opposite directions. Preferably, for reasons of simplicity of structure of the apparatus, one of the discs, in general the one which contains an inlet and an outlet, will be stationary, only the second disc being allowed to rotate.

The relative rotational speed of the rotating discs depends upon a. their diameter, b. the nature, composition, difference in shape and size, as well as the specific weight, of the particles to be separated and c. the viscosity of the suspension liquid.

In the case of purification of whiskers, the process is generally carried out in such a manner that, when using water as a suspension liquid, the product of diameter and frequency difference of the discs gives a constant of between 300 and 350 cm./min., especially of 320 – 330 cm./min.

The thickness of the layer of liquid between the discs and thus also the distance between the discs should be constant over the whole surface and, in the case of water, is expediently 4 – 6 mm. and especially about 5 mm. In order to obtain good flow conditions, it is advantageous, when only one of the discs rotates, to provide this disc, at its centre point, with a gradually tapering opening (see FIG. 2 of the accompanying drawings).

It is advantageous to ensure that the individual particles are freely movable in the suspension. Therefore, the solids content, in the case of the separation of whiskers, should preferably be between 5 – 100 mg. solids, more preferably 20 – 50 mg. solids, per litre of suspension liquid.

In the case of the use of a very effective homogeniser, the efficiency can be considerably increased so that the product of diameter and frequency of the disc gives a constant of between 300 and 1,000 cm./min., especially of 500 to 900 cm./min. The solids content per litre can be increased to 50 – 100 mg. and preferably to 200 – 500 mg.

As suspension liquid, depending upon the nature of the particles to be separated, there can be used all known liquids, for example, water, acetone, alcohols or hydrocarbons, water and/or acetone preferably being used.

According to an especially advantageous embodiment of the present invention, the process is carried out continuously by feeding in the crude suspension through an inlet on the bottom of the separation vessel between the periphery and the centre thereof, for example, at a point half way along the radius of the disc.

The total flowthrough amount is linearly dependent upon the disc surface area and, in the case of water, is, as has been found by experience, 200 – 600 litres, preferably 400 – 500 litres, of crude suspension per hour per square metre of disc surface.

The particles separated from the suspension are removed from the separation vessel at the point of the lowest speed. As described in more detail hereinafter, this point is expediently formed as a central circular opening in the bottom of the separation vessel, which constitutes one of the discs, and is present below the centre of the rotating disc. Expediently, the diameter of the outlet opening should be at least 10 – 20 percent, preferably about 15 percent, of the disc diameter. The

outlet opening opens into a settling vessel. The separated particles are withdrawn from the settling vessel. This can take place through an outlet in the settling vessel.

The particles remaining in the suspension are withdrawn in the form of a suspension, expediently on the periphery through a tangentially arranged outflow constructed as an overflow. These particles, which have a different shape from those particles withdrawn in the region of the lowest speed, can be separated from the liquid by filtration.

Due to the difference of the rotational speed, the liquid is also moved. The liquid exhibits a large velocity profile of flow, not only in the dimension between the discs but also, in particular, in the direction between the edge and the centre point of the discs. The phenomenon of separation is believed to be due to several factors. Since the speed of rotation of the discs and the speed of flow of the suspension are relatively low, centrifugal forces do not substantially act on the particles. However, due to the difference in shape of the particles, certain of the particles will be carried up by and flow with the liquid as it moves through flow velocity profile. For instance, the rodlet particles of whiskers have a relatively large surface area and therefore move with the suspending liquid. However, the nodule particles of the whiskers have a much smaller relative surface area and ar not carried by the suspending liquid. Rather, these nodule particles endeavor to cover the shortest possible path, which is increasingly the case in the direction of the centre point of the discs, in the region of which they can be withdrawn.

The suspension intended for the particle separation in expediently taken from a storage vessel.

The process according to the present invention can be carried out batchwise or continuously, a continuous method of working being preferred. Several separation steps can also be connected in parallel.

The process according to the present invention is especially for the separation of the rodlets of whiskers from, for example, the spheroidal small nodules consist of the same material as the whiskers. In this case, the agglomerates are spheroidal small nodules consisting of intimately felted, extremely fine hairs made of the same materials as the rodlets. The process of the present invention is, however, not limited to the separation of rodlets from nodules of whiskers. On the contrary, it can be used in all cases where, in a liquid, there are present light and homogeneously suspendable particles, the shapes of which differ sufficiently in order to undergo the described separation effect.

For the carrying out of the process according to the present invention, there is preferably used a separation vessel which comprises a flat, cylindrical part provided with a central outlet opening in the bottom thereof. This outlet opening in the bottom opens into a settling vessel. The inlet opening or openings are provided between the central outlet opening and a peripheral overflow, for example, at a point above half way along the radius of the disc. However, depending upon the mixture to be separated, they can also be arranged either near to the centre or near to the disc edge. They can be of round or flattened oval shape, in which case the longer axis must lie tangentially. If, for example, in the case of a comparatively large separation unit, several inlet openings are provided, then these should be equidistant from the centre point of the disc.

The withdrawal of the still remaining suspension, including the particles which are not separated, takes place through at least one outlet tangentially arranged on the periphery of the vessel, this outlet being constructed as an overflow. In order that the distance between the discs, for example, between the rotating disc and the bottom of the vessel, is overall equal, the rotating disc is constructed, for example, as a vertically freely moving floating body, driven by means of a motor via a ball-and-socket joint. The rotating disc should extend uniformly up to the region of the edge of the separation vessel.

According to the preferred embodiment of the present invention, the suspension intended for the particle separation is passed from the storage vessel into the separation vessel by means of a pump, the speed of which can be precisely regulated to insure that the flow is without turbulence. The central flow off, which passes through the settling vessel, can also be controlled by a slowly running pump. It is also possible to control the flow-off pipe by means of a magnetic valve provided with a time relay, an impedance coil thereby being placed before the magnetic valve. The cross-section of the pipe should thereby be completely open or completely closed.

According to another embodiment, the central flow-off pipe opens into an air-tight, closed vessel. When filling this vessel, the liquid must force out the air present therein. The amount of escaping air can be regulated by a stopcock so that, in end effect, the amount of suspension flowing out through the central flow-off opening can also be regulated. With this arrangement, it is possible to omit stopcocks, which is advantageous because stopcocks can become blocked.

The suspension containing the purified rodlets of the whiskers, which leaves the separation device via a peripheral overflow, is expediently passed to a filter for recovery of the rodlets.

In order to be able to keep the storage vessel small or to prolong the period of operation of the separation device, it is expedient to pass a substantially concentrated suspension, by means of a pump, into a homogeniser, where it is suitably diluted before passing into the separation vessel. The homogeniser thereby serves, in particular, substantially to separate the still substantially agglomerated whiskers and to separate the nodules as efficiently as possible. It is thus possible to supply the separation device with a very homogeneous suspension.

It should also be mentioned that the values given herein only apply to very well dispersed suspensions. If the suspensions are not well dispersed, then the capacity of the device decreases considerably.

BRIEF DESCRIPTION OF THE DRAWING

For a better understanding of the present invention, it will now be described in more detail, with reference to the accompanying drawings, in which:

FIG. 1 is a flow diagram of a plant using one separation unit;

FIG. 2 is a vertical cross-section of a separation vessel;

FIG. 3 is a horizontal cross-section of the separation vessel;

FIG. 4 is a diagrammatic cross-section through a homogeniser; and

FIG. 5 is a section along the line V—V of FIG. 4.

DETAILED DESCRIPTION OF THE INVENTION

Referring now to the accompanying drawings, the device comprises a storage vessel (1), which contains the material to be separated suspended in a liquid. In order to prevent precipitation of the particles, the suspension is usually stirred. By means of a pump (2), the speed of which can be precisely regulated, the suspension is fed through an inlet (4) into a separation device, a homogeniser (15) preferably being inserted between the storage vessel (1) and the separation device. It is also possible to store the suspension in concentrated form in the storage vessel (1) and, before separation, to dilute it to the desired extent, the agglomerate present also being substantially broken up due to the action of the homogeniser (15). The homogeniser (15) is supplied with dilution liquid through a pipe (3), proved with a stopcock and a flowmeter. The separation device comprises a rotatable disc (11), which is provided with a central hole (5) and which floats on the liquid. The disc (11) is rotated by means of a shaft connected via a ball-and-socket joint (12) to a motor. The disc is of such a size that it extends almost to the edge (13) of the separation vessel. The separated particles pass through the central opening (5) into a settling vessel (6) and then through a pipe system (7), into which is incorporated a pump (16) for regulation of the flow-off, to a filter (8). The suspension containing the whiskers leaves the separation device through a tangential outlet (10) constructed as an overflow (14), which can lead, for example, to a filter or centrifuging device.

In FIGS. 2 and 3, further details are illustrated, the same reference numerals being used as in FIG. 1. Thus, it is clearly shown that the inlet (4) for the crude suspension is provided on the bottom, which constitutes the lower disc, between the periphery and the centre, for example, at a point half way along the radius of the disc.

FIGS. 4 and 5 of the accompanying drawings show schematically the construction of the homogeniser (15). This comprises an inlet (17) for water and inlet (18) for the concentrated suspension. The rotor (19) is provided with a bearing (20) which is cooled directly by inflowing water. The rotor has a diameter of 75 mm. and an edge length of 50 mm. and rotates at a speed of 1,500 r.p.m. The dilute and thoroughly dispersed whisker suspension leaves the homogeniser through an outlet (22). The efficiency of the homogeniser can be improved by the provision of baffle plates (21).

The following Examples are given for the purpose of illustrating the present invention:

EXAMPLE 1

300 mg. of whiskers were suspended in 200 ml. glycol and diluted with water to 10 litres. This suspension was fed at a rate of 0.3 litres/minute into a disc separation plant of 30 cm. diameter. The distance between the discs was 5 mm. and the speed of rotation was 12 r.p.m. 260 mg. nodule-free whiskers were thereby obtained, together with 30 mg. of nodules and agglomerate.

Instead of glycol, equally good results are obtained when using aqueous acetone as the suspension liquid.

EXAMPLE 2

2 g. of crude whiskers were dispersed in 500 ml. glycol with the use of a modified, high-speed kitchen mixer. This dispersion was then made up to 1 litre with glycol in a storage vessel. By means of an accurately controllable pump, the suspension was passed at a rate of 3.6 litres per hour into an operating homogeniser filled with fresh water. Through another inlet, 30 litres per hour of fresh water were supplied to the homogeniser. After passing through the homogeniser, the very homogeneous dispersion obtained was passed directly into a disc separation device of 30 cm. diameter. The distance between the discs was 5 mm. and the speed of rotation was 30 r.p.m. After an experimental period of about 17 minutes, the concentration in the separation unit reached 200 – 250 mg./litre. 1.2 g. of nodule-free material was removed from the periphery of the separation vessel and 0.8 g. of nodules leave the separation unit through its central opening.

We claim:

1. A process for the separation of a first type of solid particles from a second type of solid particles, said first and second types of solid particles being of a different shape but of a similar weight, said process comprising:
   - suspensing said first and second types of particles in a liquid;
   - passing the thus formed suspension without forming turbulence therein, into a space between two vertically spaced apart discs at a point intermediate the periphery and the center of said discs and forming a 2 – 20 mm. thick layer of said suspension between said discs;
   - creating a difference in rotational speed between said two discs, and thus creating a velocity profile of the flow of said suspension between said discs;
   - whereby one of said types of particles, due to the shape thereof, is not carried by said suspending liquid throughout said flow velocity profile, and separates from said suspension; and
   - withdrawing one of said types of particles centrally of said discs and the other of said types of particles peripherally of said discs.

2. Process according to claim 1, wherein only the upper of said discs is rotated.

3. Process according to claim 1, wherein said suspending liquid comprises water and/or acetone.

4. Process according to claim 3, wherein said suspending liquid is water, the layer thickness is 4 – 6 mm; and the distance of the upper rotating of said discs from the bottom of the lower of said discs is thereby also 4 – 6 mm.

5. Process according to claim 3, wherein said suspending liquid is water and the layer thickness is approximately 5 mm.

6. Process according to claim 1, wherein the product of the diameter and the frequency difference of said discs gives a constant value of between 300 and 1,000 cm./min.

7. Process according to claim 6, wherein the product of the diameter and the frequency difference of said discs gives a constant value of between 500 and 900 cm./min.

8. Process according to claim 1, wherein said suspension is supplied through an inlet in the bottom of a separation vessel formed by the lower of said discs, said inlet lying between a central and a peripheral outlet of said separation vessel.

9. Process according to claim 8, wherein said inlet is at a point about half-way along the radius of said lower disc.

10. Process according to claim 1, wherein a part of said suspension is withdrawn through a central, circular opening in the bottom of a separation vessel formed by the lower of said discs, the diameter of said opening being between 10 – 20 percent of the diameter of said lower disc.

11. Process according to claim 10, wherein the diameter of said opening is approximately 15 percent of the diameter of said lower disc.

12. Process according to claim 1, wherein a part of said suspension is withdrawn through a tangentially arranged outlet constructed as an overflow.

13. Process according to claim 1, wherein the solids content of said suspension is 5 – 100 mg. per litre of suspension liquid.

14. Process according to claim 13, wherein the solids content of said suspension is 20 – 50 mg. per litre of suspension liquid.

15. A device for the separation of a first type of solid particles from a second type of solid particles, said first and second types of solid particles being of a different shape but of a similar weight, wherein said particles are suspended in a suspending liquid, said device comprising:

a separation vessel having a cylindrical peripheral wall and a disc-shaped bottom, said bottom having a central flowout opening therein, said bottom further having at least one suspension inlet situated between said central opening and said peripheral wall, said peripheral wall having at least one suspension outlet in the form of a tangential overflow;

a freely vertically movable rotating disc positioned above said bottom to rotate on the top of a layer of said suspension, said rotating disc having a diameter slightly smaller than the inner diameter of said peripheral wall; and

means attached to said rotating disc to rotate the same at a predetermined speed.

16. Device according to claim 15, comprising a storage vessel for said suspension to be fed to said separation vessel.

17. Device according to claim 15, further comprising an open storage vessel which, for the continuous operation of said device, is adapted to be filled at intervals, and which has a pump attached to an outlet thereof.

18. Device according to claim 15, further comprising a dilution and homogenizing device provided with an inlet, a stopcock and a flowmeter for dilution liquid, said dilution and homogenizing device being connected to the inlet of said separation vessel.

19. Device according to claim 15, wherein between the rotating disc and said means to rotate, there is provided a ball-and-socket joint, said rotating disc being constructed as a floating body, the distance between said rotating disc and said bottom being constant over the entire cross-sectional area of said bottom and said rotating disc.

20. Device according to claim 15, further comprising a settling vessel connected to said central opening, and a pump connected to said settling vessel.

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