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(54) IMPROVEMENTS IN OR RELATING TO THE GROWTH OF PARTICLES

(71) We, PIELKENROOD-VINITEX B.V., 13 Industrieweg, Assendelft, Netherlands, a Dutch Body Corporate, 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 to the promotion of particle growth in a flowing liquid suspension prior to separation of the particles from the liquid.

When a liquid in which separate particles are suspended remains stagnant for some time, it appears that, apart from separation, particle growth also occurs. This is a consequence of the fact that, when some difference in the natural separation velocity exists between particles, for instance as a consequence of differing dimensions, there is a probability that one particle will overtake another and the particles will combine with each other.

From laboratory apparatus it is known that such a particle growth can be accelerated by stirring, so that the residence time in a vessel for obtaining separation can be reduced. This is caused by the introduction of velocity differences between different parts of the liquid to increase the probability of one particle overtaking another. Accordingly as the particle dimensions are increasing, the stirring velocity should be reduced so as to prevent the growth from being annihilated by the shearing effect between liquid layers. As the velocity gradient is mainly present in the immediate vicinity of the stirrer, stirring has, in the long run, little or no effect.

For handling large quantities of liquids, stirring is not practical. For this purpose devices have been proposed, comprising a number of parallel baffles arranged in a staggered fashion to impart abrupt directional changes to the liquid passed through the device, and in which, as a consequence of centrifugal forces, particle growth caused by velocity differences will occur. For obtaining

a sufficient effect, however, the dimensions of such a device and the residence times of the liquid in the device should be considerable.

According to the invention there is provided a method of effecting particle growth in a flowing liquid suspension prior to subsequent separation of the grown particles from the liquid in a settling stage, wherein the liquid suspension is caused to flow along a path at least of which is generally vertical, the average flow rate of the liquid suspension is maintained at such a value that substantially all the particles are dragged along in the flow, the residence time in this path is such that, as a consequence of differences in the flow velocity of the particles relative to each other in the flow of the suspension, particle growth by coalescence is obtained so as to promote the desired separation in the subsequent settling stage, and the flow velocity of the suspension at any point in the path is kept lower than the velocity at which the coalesced particles would be disrupted by shearing action as a consequence of velocity gradients in the flow in the vicinity of that point.

Further according to the invention, there is provided a device for carrying out the above process, said device being intended for use with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the liquid suspension and an outlet arranged to discharge the suspension towards the settling apparatus, said enclosure being divided by a number of stationary partitions into a plurality of chambers so arranged that, in use, the suspension flows in series through the chambers, with the suspension flow in each chamber being generally vertical, and the suspension flow in adjacent chambers being in opposite directions, each downstream chamber having a greater flow cross-section than the preceding upstream chamber, the spacing between opposed walls of each chamber being such that with liquid

5 suspension flow at the design flow rate of the settling apparatus wall friction will cause differences in the flow velocity of the particles relative to each other in the flow so that
10 particle growth by coalescence is obtained, and the flow cross-section of each chamber is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing action as a consequence of velocity gradients in the vicinity of that point.

15 Still further according to the invention, there is provided a device for carrying out the above process, said device being intended for use with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure
20 having an inlet arranged to receive the liquid suspension and an outlet arranged to discharge the suspension towards the settling apparatus, said enclosure forming at least one chamber through which, in use, the suspension flows generally vertically, said chamber containing
25 at least one substantially vertical plate dividing the chamber into a plurality of passages so as to provide, in use, suspension flows through the passages of said chamber in parallel, the spacing between opposed walls of the chamber being such that with liquid suspension flow at the design flow rate of the settling apparatus, wall friction will cause differences in the flow velocity of the particles relative to each other in the suspension flow so that particle growth by coalescence is obtained, and the flow cross-section of the chamber is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing action as a consequence of velocity gradients in the vicinity of that point.

45 Still further according to the invention, there is provided a device for carrying out the above process, said device being in combination with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the suspension and an outlet arranged to discharge the suspension towards an inlet of the settling apparatus, said enclosure forming a chamber through which, in use, the suspension flows generally vertically, said chamber being elongate in cross-section in a direction transverse to the direction of suspension flow, the spacing between opposed walls of the chamber being such that with suspension flow at the design flow rate of the settling apparatus, wall friction will cause velocity differences in the flow velocity of the particles
65 relative to each other in the suspension flow

so that particle growth by coalescence is obtained, and the flow cross-section of the chamber is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing action as a consequence of velocity gradients in the vicinity of that point.

The invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, in which:

Figure 1 is a longitudinal section of a device for promoting particle growth in accordance with the invention;

Figures 2 and 3 are cross-sections of other forms of the device;

Figures 4A and 4B are plan views, from below, of a chamber of such a device with different arrangements of auxiliary plates, and Figure 4C is a section of a number of such plates of different lengths;

Figures 5A and 5B are sections of profiled auxiliary plates in two different positions;

Figure 6 is a section showing adjustable strips for replacing the plates of Figure 5; and

Figures 7 and 8 are, respectively, a perspective view and a section of a device according to the invention connected to a settling apparatus.

As discussed above, particle growth will occur when one suspended particle is allowed to overtake on another. This will occur, in particular, in a vertical liquid column as a consequence of differences in the precipitation or flotation velocity, irrespective of whether this column is stationary or moves in a vertical direction. In a moving column the flow velocity near the boundary walls will, moreover, be smaller than in the centre of the flow on account of friction, so that, as a result of velocity gradients, velocity differences will develop between adjacent liquid layers thus increasing the probability of collision between the particles. While, for initial growth, large velocity differences are advantageous, a limit will be reached during particle growth, when the shearing action between adjacent flow layers with different velocities will lead to disintegration of the coalesced particles. In order to obtain a gradual growth, such velocity differences should be decreased, but then the probability of collisions will also decrease so that it takes a longer time before the same increase of dimensions is obtained as with the preceding steeper velocity gradient.

On the other hand, the flow velocity is limited by the condition that the dragging velocity should be higher than the natural separation (precipitation or flotation) velocity when the flow is in the opposite direction to

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this velocity. The residence time in such a flow is, furthermore, limited to the dimensions of the flow passage, which, in turn, are related to the desired velocity gradients, and by the desired flow volume per unit of time.

5 The device shown in Figure 1 is based on the preceding considerations. By means of supply duct 1 the suspension to be treated is supplied at a given pressure, namely the static pressure of a liquid container situated at a higher level or the pressure provided by a supply pump. The velocity of the liquid suspension in the duct 1 is made sufficiently high to counteract separation of suspended particles therein.

10 The device shown comprises a tank 2 with end walls 3 and lateral walls 4. Stationary partitions 5 are provided in the tank 2 parallel to the end walls 3; the partitions 5 join the bottom of the tank 2 and terminate at some distance from the upper edge of the tank 2, and between these partitions 5 other stationary partitions 6 are provided which extend above the normal liquid level in the tank 2 and terminate at their lower end at some distance of the bottom of the tank 2. In this manner successive chambers 7 are obtained which are interconnected by openings 8 either above the partitions 5 or below the partitions 6 and through which the liquid flows generally horizontally. The duct 1 communicates with the first chamber 7 at the lower side thereof, and in the end wall 3 adjacent the last chamber, a discharge opening 9 is provided in communication with the supply opening of a settling apparatus (not shown) for separating the suspended particles.

15 In the odd chambers the liquid suspension flows upwards, and in the even chambers it flows downwards. Provision is made for ensuring that the upward velocity in the odd chambers is higher than the natural precipitation velocity of precipitation components, and/or that the downward velocity in the even chambers is higher than the natural flotation velocity of flotation components, as the case may be, and the flow in the openings 8 should be such as to counteract separation in these parts.

20 The cross-section of the first chamber 7 is selected so as to reduce the velocity of the liquid suspension leaving the duct 1 sufficiently to obtain a certain residence time in this chamber, and, such that the lateral walls of this chamber produce such a velocity gradient that particle growth will be initiated to a considerable extent. Moreover this chamber permits the flow leaving the relatively narrow duct 1 to be adapted to the larger width of the tank 2.

25 In order to obtain steeper velocity gradients without considerably reducing the cross-section, which would have an unfavourable influence of the residence time, the distance between the first partition 5 and the wall 3

is less than the width of the wall 3, so that the velocity gradients are mainly determined by the partition 5 and the wall 3, while still providing a sufficient cross-section for this chamber, the first chamber (and the subsequent chambers) thus being of elongate rectangular cross-section in a plane transverse to the flow direction.

30 The distance between the partitions 5 and 6 in the successive chambers increases stepwise so as to obtain a stepwise decrease of the velocity gradients in these chambers, in order to counteract, in this manner, the annihilation of growth by shearing action. This involves an increase of the cross-section and, therefore, of the residence time which is favourable for maintaining a gradual particle growth. Moreover the average flow velocity in the successive chambers 7 decreases, which decrease, in particular, is chosen so that the velocity near the discharge opening 9 is substantially equal to the desired supply velocity to the settling apparatus communicating with the tank 2, in which device the grown particles are separated from the liquid. Such a settling apparatus is, for instance, a plate separator with corrugated plates.

35 The position of the opening 9 is not critical and this opening may, for instance, alternatively be situated near the bottom of the tank 2 when this would be more favourable for the connection with the settling apparatus. Also the position of the supply duct 1 may be changed at will.

40 In the modified arrangement shown in Figure 2, the partitions 5 and 6 (and/or the boundary walls of the tank 2) are oriented obliquely to the direction of flow whereby a gradual (that is, progressive) reduction of the velocity and of the velocity gradient is obtained. Figure 3 shows an embodiment with a circular tank 2 and circular coaxial partitions 5 and 6 and which operates in a similar manner to the embodiment of Figure 1; if the coaxial partitions are frusto-conically shaped, the device can operate in a similar manner to the device of Figure 2. In a modified form of the device shown in Figure 3, the partitions 5 and 6 may be of polygonal cross-section.

45 The velocity gradients may be increased, while preserving the velocity distribution in the successive chambers 7 and the average velocity in each chamber, by sub-dividing each chamber 7 by means of auxiliary plates into a group of auxiliary chambers or passages which are connected in parallel so that, while preserving the overall flow cross-section in the chamber 7, the spacing between the walls of the auxiliary chambers is reduced and, thus, the velocity gradients are increased.

50 As shown in Figure 4A, the auxiliary plates 10 may be arranged parallel to the end wall 3 and, therefore, to the partitions

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5 and 6 (which form the longer sides of the chamber 7), and Figure 4B shows similar plates 10 which extend transversely to the partitions 5 and 6. In the case of Figure 2 either fan-like diverging plates or parallel triangular plates adapted to the chamber shape may be used. In the case of Figure 3 the plates may be cylindrical, or may be situated in planes extending through the axis of the assembly.

The plates 10 will, generally, extend along the major part of the total height of the chamber 7 in question, and provision should be made to ensure that the liquid flow in the adjacent opening or passage 8 is not obstructed. In the arrangement of Figure 4B the plates 10 may also extend to the passages 8, and, there, join corresponding plates in adjacent chamber 7. It is, however, also possible to provide the plates 10 in only a part of the chamber 7. It is also possible, in the manner shown in Figure 4C, to make some of the plates 10 shorter than the remaining plates in order to reduce the effect of these plates. It is also possible to make some of the plates slidable in the direction flow in order to allow a certain degree of control to be obtained. In the successive chambers the distance between adjacent plates and between the outer plates and the adjacent walls of the chamber may increase progressively or stepwise in the direction of flow in order to obtain a progressive or stepwise reduction of the velocity gradients. The number of auxiliary plates 10 may be reduced in successive chambers 7; in this manner, the number of parallel flow passages in successive chambers is reduced in the direction of flow.

Another embodiment for introducing velocity differences into the flow is shown in Figure 5 wherein use is made of plates 11 at least a part of which have a repetitive profile in the form of corrugations directed transversely to the flow direction, the latter being indicated by an arrow in Figure 5. In Figure 5A the corrugations of two adjacent plates are in phase opposition so that the intermediate passages have alternating narrowing and widening parts whereby the flow cross-section of these passages alternately narrows and widens; in this manner both transverse and also longitudinal velocity differences are generated thereby providing an additional promotion of growth. When the plates 11 are moved so that they are arranged in phase, the arrangement shown in Figure 5B is obtained. In this case, the width of the passages is constant throughout, so that, generally, the same effect as with plane plates is obtained, but the path length is increased. The repeated changes of direction, however, will also in the latter case lead to additional velocity differences, so that in the arrange-

ment of Figure 5B, the growth effect will be larger than occurs with plane plates.

Such corrugated plates may be arranged in the manner of either Figures 4A or Figure 4B. The flow in the outer passages bordered by one corrugated plate and a plane wall is different from the flow between two corrugated plates 11. In the arrangement of Figure 4B the influence of the outer passages is, on the whole, much smaller. By a suitable choice of the distance to the plane wall, or of the width of the outer corrugated plates, it can be arranged that the effect of the outer passages does not deviate too much from the average effect of the remaining passages.

It is also possible to provide the walls in question with corresponding corrugations, and it is also possible to provide corrugated and plane plates alternately. In the latter case, it is not possible to provide an arrangement according to Figure 5, but, it is still possible to provide an arrangement according to Figure 4C.

The provision of auxiliary plane or corrugated plates in a chamber leads to an increase of the flow resistance of the chamber, and, moreover, the resistance in the arrangement of Figure 5A will be higher than in the arrangement of Figure 5B. The flow resistance is apparent from the difference in the liquid level of successive chambers. This level difference is a measure of the power required to overcome the flow resistance. From standard formulae for liquid flow in a restricted passage, the following relationship may be deduced:

$$\bar{\gamma} = \sqrt{\frac{P}{\eta \cdot V}}$$

in which $\bar{\gamma}$ is the average velocity gradient transversely to the flow direction, P is the supplied power, η is the viscosity, and V is the volume of the liquid. From this it follows that, when Δh is the level difference:

$$P \propto (\Delta h)^2,$$

and, therefore,

$$\bar{\gamma} \propto \Delta h.$$

When, for instance by experiments, a suitable value of $\bar{\gamma}$ has been determined, the latter can be adjusted by longitudinally shifting alternate plates in such a manner that Δh obtains the required value. This can, of course, be obtained automatically by means responsive to the pressure difference between succeeding chambers, in particular when it is desired to maintain a given velocity gradient.

A reduction of the flow resistance, in particular by removing plates, may be used, in order to obtain a strong liquid flow for flushing the device.

5 In the case of a chamber which is subdivided by a small number of corrugated plates, an increase of the flow resistance of the inner passages by shifting the corrugated plates will cause the flow through the outer passages to be increased, so that in the latter passages an increase of the velocity gradients will take place, although the residence time will be shorter. On the other hand, a reduction of the flow resistance in the inner passages will cause the flow through the outer passages to be reduced, so that the velocity gradients are reduced but the residence time is increased. These opposing effects in the inner and outer passages advantageously enable load fluctuations to be smoothed out to a certain extent.

10 Instead of corrugated plates, plates with another repetitive profile may be used, e.g. a triangular or trapezoidal profile, or plates with transverse ribs or other projections.

15 As will be apparent, by suitably shifting the plates, the length and/or flow cross-section of the passages will be varied and this, in turn, will control the velocity differences induced by these passages.

20 In the arrangement shown in Figure 6, strips 12 are arranged in parallel rows, and at least the strips in alternate rows can be pivoted about longitudinal axes 13 from the positions indicated by solid lines. In this manner there is obtained an effect similar to that obtained by the arrangement shown in Figures 5A and 5B. Moreover, the passages are, in this case, interconnected so that load differences will be balanced. This is also possible by providing apertures in the plates 10 or 11.

25 It is also possible to arrange the plates of Figure 5 in such a manner that the corrugations extend in the flow direction whereby the plates will not cause velocity differences in the flow direction.

30 In practice, the first chamber 7 of the device of Figure 1 is used to effect uniform distribution across the width of the tank 2 of the liquid flow emerging from the duct 1. This chamber may be provided with one corrugated plate parallel to the end wall 3 and the adjacent partition 5. The subsequent chambers may be provided with corrugated plates arranged as shown in Figure 4 or 5 and which may be made adjustable. The last chamber 7 need not be provided with corrugated plates, and can have a smaller cross-section than the preceding chamber 7, whereby in the last chamber only the effect of the bordering walls is used. The last chamber 7 may, however, be provided with guide baffles to guide the flow uniformly towards the discharge opening 9.

Groups of partitions and/or plates can be combined into separate units, for instance, made of plastics, and the tank 2 can be fabricated from a strong metal. In this manner assembly of the device is simplified, and the units can be easily removed as a whole from the tank for cleaning and repair, and can, if necessary, be replaced by other units.

70 In the preceding description it is assumed that the liquid is supplied to the first chamber from below, but it is also possible to supply the liquid from above. This will, for instance, depend on the number of chambers and on the fact whether the circumstances allow the supply duct to be mounted in the manner shown in Figure 1.

75 Figures 7 and 8 show a combination of a plate-type settling apparatus and a simple embodiment of a growth-promoting device in accordance with the invention. This settling apparatus comprises a tank 14 containing a number of parallel corrugated plates 15 which are inclined to the vertical, the corresponding crests and valleys of said plates lying in substantially vertical planes, as described in British Patent Specification No. 1,351,801. This tank has, in one side wall, a supply opening 16, and in the opposite side wall a discharge opening 17, so as to obtain a mainly horizontal liquid flow in the passages between the plates 15. At their lower ends the passages between the plates 15 communicate with a collecting funnel 18 for precipitation components sliding downwards in the valleys of the plates 15 after being separated from the liquid flow in the passages. Flotation components of the liquid will be collected in the crests of these plates, and move upwardly, and can be removed at the upper end of the plates 15 in a suitable manner. The opening 17 communicates with a discharge chamber 19 for the carrier liquid.

80 The growth-promoting device comprises, in the embodiment shown, only two chambers 7. The supply duct 1 opens, at the upper side, into the first chamber, and the discharge opening 9 of the second and last chamber communicates with a horizontal connecting chamber 20 which, in turn, communicates with the supply opening 16 of the plate separator. In the second chamber 7, plates 10 are indicated by dotted lines. The upper ends of these plates are staggered in the vertical direction so as to obtain a uniform distribution of the liquid over the cross-section of the opening 9.

85 In the connecting chamber 20 flow guiding means may be inserted for improving the uniformity of the flow distribution. These guiding means may, for instance, consist of transverse strips or louvres, which may be adjustable if required, or may be a spatial grid consisting of mutually intersecting bars.

Preferably such guiding means are constructed as a separate unit which may be removably inserted in guides on the walls of the connecting chamber. As shown, the bottom of the latter chamber has a downward slope so as to guide precipitation components already separated in this chamber towards the collecting funnel 18. Also the discharge chamber 19 has such a sloping bottom for the same purpose.

Of course the number of chambers 7 may be greater than two and plates 10 may be also provided in the first chamber 7. In some cases, one chamber 7 may be sufficient, and then the supply duct 1 will be connected to the lower end as indicated at 1'.

The growth-promoting device can be connected in series with a similar device when the effect of one such device is insufficient and the construction of a device with an accordingly larger number of chambers is not economical.

In the embodiments particularly described, the considerable particle growth obtained will lead to a substantially increased separation for a given capacity, so that the efficiency of the settling apparatus is increased, and the dimensions of a separation system from which this settling apparatus is a part may be reduced and its yield may be increased.

WHAT WE CLAIM IS:—

1. A method of effecting particle growth in a flowing liquid suspension prior to subsequent separation of the grown particles from the liquid in a settling stage, wherein the liquid suspension is caused to flow along a path at least a point of which is generally vertical, the average flow rate of the liquid suspension is maintained at such a value that substantially all the particles are dragged along in the flow, the residence time in this path is such that, as a consequence of differences in the flow velocity of the particles relative to each other in the flow of the suspension, particle growth by coalescence is obtained so as to promote the desired separation in the subsequent settling stage, and the flow velocity of the suspension at any point in the path is kept lower than the velocity at which the coalesced particles would be disrupted by shearing action as a consequence of velocity gradients in the flow in the vicinity of that point.

2. A method according to claim 1, wherein the flow path comprises alternating upwards and downwards generally vertical portions, with the suspension flowing generally horizontally between the adjacent ends of the adjacent vertical portions, the upwards and downwards flow velocity of the suspension along the upwards and downwards vertical portion being greater than the natural precipitation and flotation velocity respectively of the particles in these portions and the

velocity of the generally horizontal flow between the adjacent vertical portions being sufficient to prevent separation of the particles from the liquid during this flow.

3. A method according to claim 1 or claim 2, wherein the flow velocity of the suspension decreases progressively or step wise in the flow direction.

4. A method according to claim 3, wherein the final velocity of the suspension flow is substantially equal to the supply flow velocity desired for the subsequent settling stage.

5. A method according to any one of claims 1 to 4, wherein the suspension flow is divided into a number of groups of parallel flows whereby to promote additional particle growth by introducing additional velocity differences between the particles.

6. A method according to claim 5, wherein a plurality of such groups of parallel flows are provided in succession and the velocity gradient in successive groups of parallel flows decreases either progressively or step-wise.

7. A method according to claim 6, wherein the number of parallel flows decreases in successive groups.

8. A method according to claim 6 or claim 7, wherein the flow cross-section and/or the flow direction are varied along the length of each of the groups of parallel flows.

9. A method according to any one of claims 6 to 8, wherein the said additional velocity differences are adjusted by varying the length and/or the shape of the flow cross-section of the parallel flows.

10. A method according to claim 9, wherein said adjustment is provided in response to the pressure difference between successive parts of the flow.

11. A device for carrying out the method claimed in claim 1, said device being intended for use with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the liquid suspension and an outlet arranged to discharge the suspension towards the settling apparatus, said enclosure being divided by a number of stationary partitions into a plurality of chambers so arranged that, in use, the suspension flows in series through the chambers, with the suspension flow in each chamber being generally vertical, and the suspension flow in adjacent chambers being in opposite directions, each downstream chamber having a greater flow cross-section than the preceding upstream chamber, with spacing between opposed walls of each chamber being such that with liquid suspension flow at the design flow rate of the settling apparatus wall friction will cause differences in the flow velocity of the particles relative to each other in the flow so that particle growth by coalescence is obtained, and the flow cross-section of each chamber

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5 Preferably such guiding means are constructed as a separate unit which may be removably inserted in guides on the walls of the connecting chamber. As shown, the bottom of the latter chamber has a downward slope so as to guide precipitation components already separated in this chamber towards the collecting funnel 18. Also the discharge chamber 19 has such a sloping bottom for the same purpose.

10 Of course the number of chambers 7 may be greater than two and plates 10 may be also provided in the first chamber 7. In some cases, one chamber 7 may be sufficient, and then the supply duct 1 will be connected to the lower end as indicated at 1'.

15 The growth-promoting device can be connected in series with a similar device when the effect of one such device is insufficient and the construction of a device with an accordingly larger number of chambers is not economical.

20 In the embodiments particularly described, the considerable particle growth obtained will lead to a substantially increased separation for a given capacity, so that the efficiency of the settling apparatus is increased, and the dimensions of a separation system from which this settling apparatus is a part may be reduced and its yield may be increased.

WHAT WE CLAIM IS:—

35 1. A method of effecting particle growth in a flowing liquid suspension prior to subsequent separation of the grown particles from the liquid in a settling stage, wherein the liquid suspension is caused to flow along a path at least a point of which is generally vertical, the average flow rate of the liquid suspension is maintained at such a value that substantially all the particles are dragged along in the flow, the residence time in this path is such that, as a consequence of differences in the flow velocity of the particles relative to each other in the flow of the suspension, particle growth by coalescence is obtained so as to promote the desired separation in the subsequent settling stage, and the flow velocity of the suspension at any point in the path is kept lower than the velocity at which the coalesced particles would be disrupted by shearing action as a consequence of velocity gradients in the flow in the vicinity of that point.

50 2. A method according to claim 1, wherein the flow path comprises alternating upwards and downwards generally vertical portions, with the suspension flowing generally horizontally between the adjacent ends of the adjacent vertical portions, the upwards and downwards flow velocity of the suspension along the upwards and downwards vertical portion being greater than the natural precipitation and flotation velocity respectively of the particles in these portions and the

65 velocity of the generally horizontal flow between the adjacent vertical portions being sufficient to prevent separation of the particles from the liquid during this flow.

3. A method according to claim 1 or claim 2, wherein the flow velocity of the suspension decreases progressively or stepwise in the flow direction.

4. A method according to claim 3, wherein the final velocity of the suspension flow is substantially equal to the supply flow velocity desired for the subsequent settling stage.

5. A method according to any one of claims 1 to 4, wherein the suspension flow is divided into a number of groups of parallel flows whereby to promote additional particle growth by introducing additional velocity differences between the particles.

6. A method according to claim 5, wherein a plurality of such groups of parallel flows are provided in succession and the velocity gradient in successive groups of parallel flows decreases either progressively or step-wise.

7. A method according to claim 6, wherein the number of parallel flows decreases in successive groups.

8. A method according to claim 6 or claim 7, wherein the flow cross-section and/or the flow direction are varied along the length of each of the groups of parallel flows.

9. A method according to any one of claims 6 to 8, wherein the said additional velocity differences are adjusted by varying the length and/or the shape of the flow cross-section of the parallel flows.

10. A method according to claim 9, wherein said adjustment is provided in response to the pressure difference between successive parts of the flow.

11. A device for carrying out the method claimed in claim 1, said device being intended for use with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the liquid suspension and an outlet arranged to discharge the suspension towards the settling apparatus, said enclosure being divided by a number of stationary partitions into a plurality of chambers so arranged that, in use, the suspension flows in series through the chambers, with the suspension flow in each chamber being generally vertical, and the suspension flow in adjacent chambers being in opposite directions, each downstream chamber having a greater flow cross-section than the preceding upstream chamber, with spacing between opposed walls of each chamber being such that with liquid suspension flow at the design flow rate of the settling apparatus wall friction will cause differences in the flow velocity of the particles relative to each other in the flow so that particle growth by coalescence is obtained, and the flow cross-section of each chamber



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is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing action as a consequence of velocity gradients in the vicinity of that point.

12. A device according to claim 11, wherein the flow cross-section of the successive chambers is increased by means of partitions and/or enclosure walls which are inclined relative to the direction of the flow.

13. A device according to claim 11 or claim 12, wherein each chamber is of elongate cross-section in a plane transverse to the direction of flow.

14. A device according to claim 13, wherein the partitions define the longer sides of the chambers of elongate cross-section.

15. A device according to any one of claims 11 to 14, wherein the partitions are in the form of co-axial walls, with a curved or polygonal cross-section in a plane transverse to the direction of flow.

16. A device according to any one of claims 11 to 15, comprising substantially vertical plates positioned in the chambers and dividing the chambers into a plurality of passages so as to provide, in use, suspension flows through the passages of each chamber in parallel.

17. A device for carrying out the method claimed in claim 1, said device being intended for use with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the liquid suspension and an outlet arranged to discharge the suspension towards the settling apparatus, said enclosure forming at least one chamber through which, in use, the suspension flows generally vertically, said chamber containing at least one substantially vertical plate dividing the chamber into a plurality of passages so as to provide, in use, suspension flows through the passages of said chamber in parallel, the spacing between opposed walls of the chamber being such that with liquid suspension flow at the design flow rate of the settling apparatus, wall friction will cause differences in the flow velocity of the particles relative to each other in the suspension flow so that particle growth by coalescence is obtained, and the flow cross-section of the chamber is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing activity as a consequence of velocity gradients in the vicinity of that point.

18. A device according to claim 17, wherein the chamber is elongate in cross-section in

a plane transverse to the direction of suspension flow.

19. A device for carrying out the method claimed in claim 1 in combination with settling apparatus for separating the particles of the suspension from the liquid, said device comprising an enclosure having an inlet arranged to receive the suspension and an outlet arranged to discharge the suspension towards an inlet of the settling apparatus, said enclosure forming a chamber through which, in use, the suspension flows generally vertically, said chamber being elongate in cross-section in a direction transverse to the direction of suspension flow, the spacing between opposed walls of the chamber being such that with suspension flow at the design flow rate of the settling apparatus, wall friction will cause difference in the flow velocity of the particles relative to each other in the suspension flow so that particle growth by coalescence is obtained, and the flow cross-section of the chamber is such that at any point in the suspension flow, the flow velocity is sufficient to prevent separation of particles in the suspension flow, but is lower than the velocity at which the coalesced particles will be disrupted by shearing action as a consequence of velocity gradients in the vicinity of that point.

20. A device according to claim 19, comprising at least one substantially vertical plate positioned in the chamber and dividing the chamber into a plurality of passages so as to provide, in use, suspension flows through the passages of the chamber in parallel.

21. A device according to claim 13 and 16, and claim 18 or claim 20, wherein the or each chamber contains a plurality of vertical plates and adjacent plates in the or each chamber are of differing lengths in the direction of flow.

22. A device according to claims 13 and 16, claim 18, or claim 20, wherein the or each chamber contains a plurality of vertical plates, and the distance between mutually adjacent plates and between the plates and the adjacent walls of the chamber increases in the direction of flow.

23. A device according to claims 13 and 16, claim 18, claim 20, claim 21 or claim 22, wherein at least a part of the or each vertical plate is provided with a respective profile.

24. A device according to claims 13 and 16, claim 18, claim 20, claim 21, claim 22, or claim 23, wherein the or each vertical plate extends transversely to the longer side of the elongate cross-section of its associated chamber.

25. A device according to claim 23 or claim 24, wherein the or each chamber contains alternately arranged profiled plates and plane plates.

26. A device according to claim 25, 130

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wherein the alternate plates are movable longitudinally of the flow direction.

5 27. A device according to claim 16, wherein each chamber contains alternately arranged plane and profiled vertical plates, the alternate plates are movable longitudinally of the flow direction, and means are provided for moving alternate plates in response to the pressure difference between succeeding chambers.

10 28. A device according to claim 17 or claim 20, comprising a plurality of said chambers arranged in succession, and wherein each chamber contains alternately arranged plane and profiled vertical plates, the alternate plates are movable longitudinally of the flow direction, and means are provided for moving alternate plates in response to the pressure difference between succeeding chambers.

20 29. A device according to any one of claims 11 to 28, wherein the plates and/or partitions are grouped into units which may be inserted into, and removed from, the enclosure as a whole.

25 30. A device according to claim 16, wherein the chamber immediately preceding the outlet has vertical plates of different lengths so arranged that the ends of these plates lie adjacent the outlet at different levels so as to obtain a uniform flow distribution in the outlet.

30 31. A device according to claim 17 or claim 20, wherein a plurality of said chambers

are arranged in succession and wherein the chamber immediately preceding the outlet has vertical plates of different lengths so arranged that the ends of these plates lie adjacent the outlet at different levels so as to obtain a uniform flow distribution in the outlet.

32. A device according to any one of claims 16, 17, or 20, wherein at least a part of each plate is perforated.

33. A device according to any one of claims 11 to 32, further comprising a substantially horizontal connecting chamber for connecting the outlet with the inlet of the settling apparatus.

34. A device according to claim 33, wherein flow guiding means are provided in the connecting chamber.

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

36. A device according to claim 11, claim 17 or claim 19 substantially as hereinbefore described with reference to the accompanying drawings.

MATHISEN & MACARA,
Chartered Patent Agents,
Lyon House,
Lyon Road,
Harrow,
Middlesex, HA1 2ET.
Agents for the Applicants.

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