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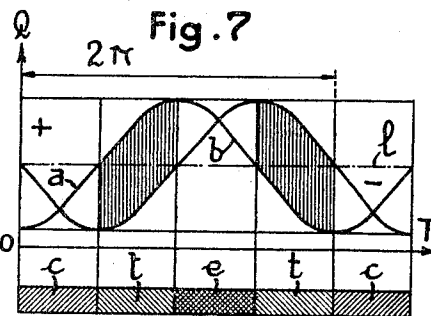
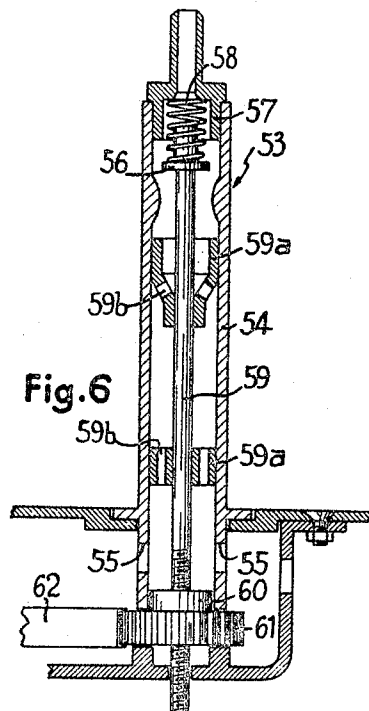
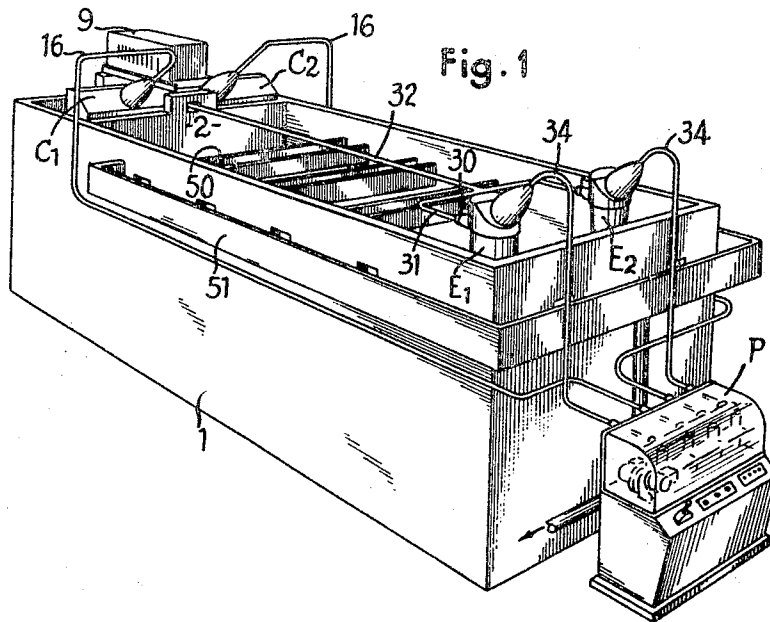
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METHOD AND APPARATUS FOR THE DECONTAMINATION OF LIQUIDS

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METHOD AND APPARATUS FOR THE DECANTATION OF LIQUIDS

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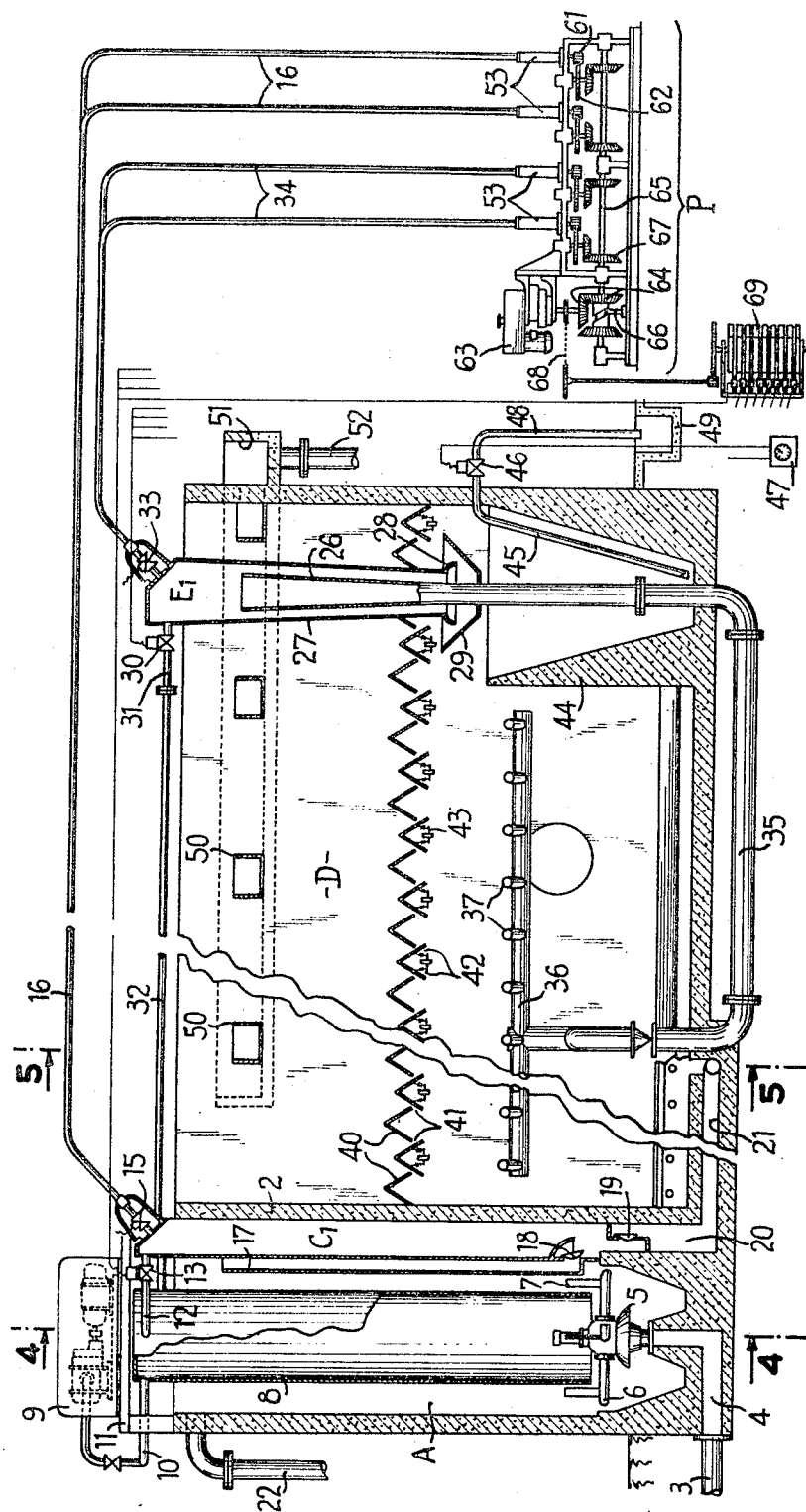


Fig. 2

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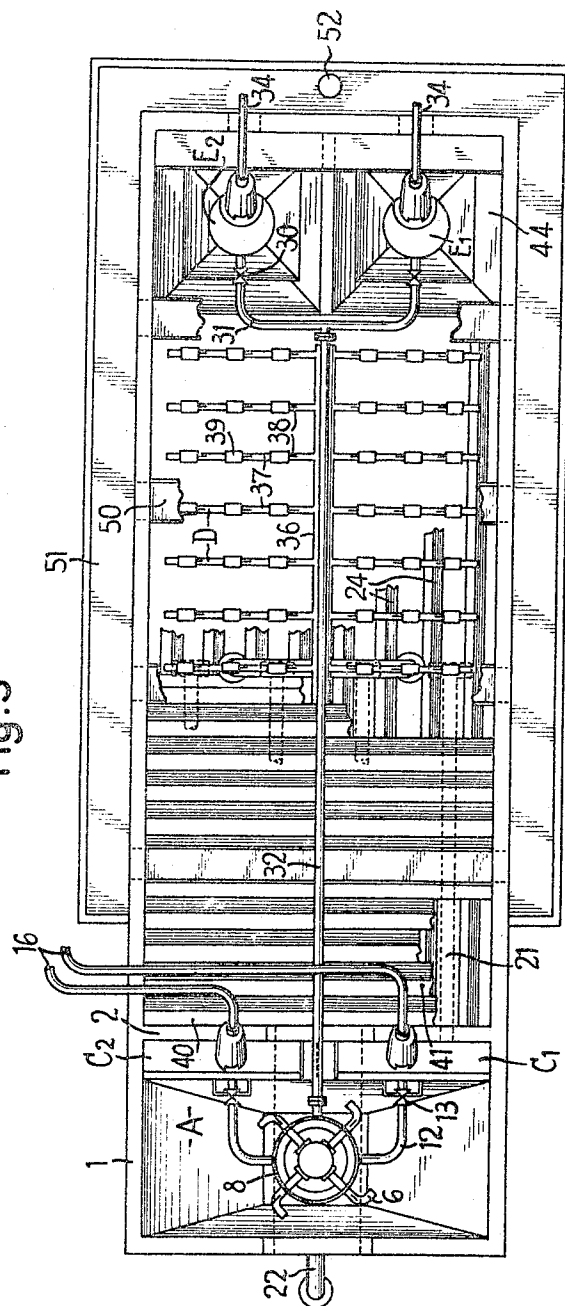
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METHOD AND APPARATUS FOR THE DECANTATION OF LIQUIDS

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Fig. 3



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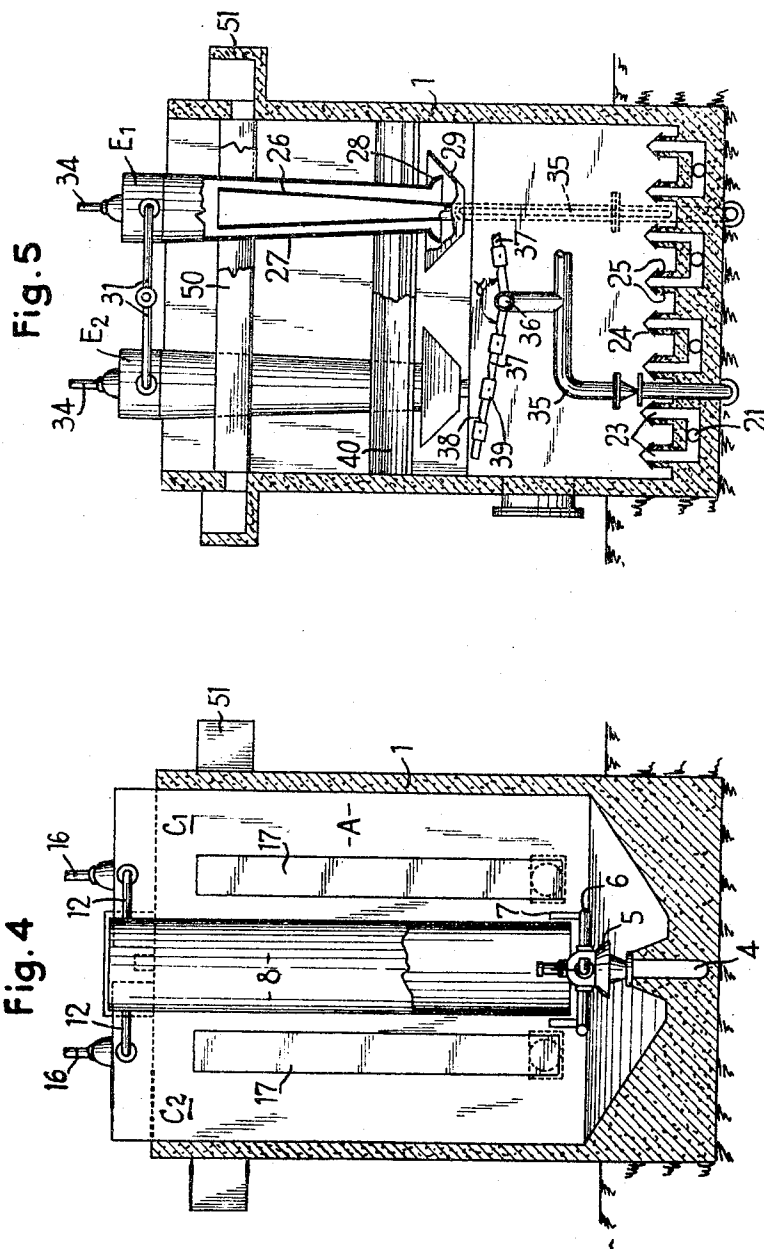
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METHOD AND APPARATUS FOR THE DECANTATION OF LIQUIDS

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946,132

21 Claims. (Cl. 210—19)

The present invention relates to the decantation of liquids for the purpose of eliminating material which is in suspension therein. The decantation being particularly important in industry in the case of water it is in this connection that the invention will be described hereafter. It should be understood, however, that it can be applied to any liquid to be decanted.

The decantation comprising the separation of materials in suspension in water or other liquid is governed by Stokes' law. The speed V of decantation is proportional to the difference of the specific weight of the solid πs and of the liquid πl and to the square of the radius r of the particle, and inversely proportional to the viscosity *v.i.e.*

$$V = \frac{2}{9} \frac{\pi s - \pi l}{\nu} r^2$$

It will be understood that the duration of the operation varies according to the object to be achieved and depends on the dimensions of the apparatus, the nature of the water and the composition and granulometry of the sediment.

Actually there are numerous types of decanters, the function of which consist of applying Stokes' law as well as possible. The choice of the type of decanter depends in the first instance mainly on the flow of water to be treated.

For weak flows, it can be admitted that the decantation called static is that which combines the maximum of advantages since it allows the equipment to be simplified. In fact, a static decanter need only comprise a rectangular or circular basin in which the water circulates continuously. For depositing the sediment it is necessary that the speed of ascent of the water should be lower than the speed of the fall of the particles. Generally, this type of decanter is provided with a bottom inclined at 45° to 60° in order to allow the evacuation of the sediment at the lower point.

In contrast, as soon as the flow reaches or exceeds several tens of cubic metres per hours, purely static decantation is no longer convenient because it implies decantation work of a very high volume. In fact, experience proves that if one does not artificially influence the speed of the fall of the particles, the time of retention in a basin must be in the order of 3 to 4 hours and even more in certain cases.

Attempts were quickly made to improve the yield of decanters by introducing the technique of dynamic decantation.

In a second method of decantation, it is still Stokes' law which supplies the basis of the theory of the process, but the yield of the operation is substantially improved on account of the following factors:

In the course of treatment a so-called coagulation reagent is added to the water which has the object of encouraging the agglomeration of colloidal particles contained in the water, and, consequently, of creating "flocks" which are more easily decantable, and a portion of the sediment formed is mixed with the untreated water.

Numerous industrial decanters using this technique have been developed. Their zone of decantation is fed with water either continuously with a constant flow, or

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intermittently, a period of rest equal to a working period, following each period of feed in the latter case. These decanters, whatever the complexity of their mechanical devices may be, have only a limited efficiency which could be improved.

The invention has the object of obtaining this by providing a new process of decantation and an apparatus for carrying it out.

The process according to the invention is based on a new principle which has been discovered by comparing the flow of a liquid to the intensity of an electric current and by applying to the problems of decantation, electro-technical laws which lend themselves better to mathematical analysis than hydraulic laws. This theory, the justification of which has been proved by the practical results obtained, will not be explained here, except to such an extent as will facilitate the understanding of the invention.

The process of decantation of water or other liquids, forming one aspect of the invention, is characterised particularly in that it consists of continuously introducing water to be treated to which a coagulation reagent has been added, into a zone of decantation according to a sinusoidally modulated flow, removing continuously a portion of the sediments formed and reinjecting it continuously into the zone of decantation according to a sinusoidally modulated flow, in phase shift relation with the modulation of the flow of water, the opposed flows of water and of sediment particles thus creating a stationary sediment bed divided by a neutral zone, in the two sides of which sediment particles are activated by opposite movements, and removing from the bottom of this bed the sediments and from the top of the bed the decanted water, in order to remove them separately from the zone of decantation.

Referring to the above-mentioned analogy of the phenomena of decantation and electrical phenomena, the flows of water and sludges can be compared respectively to the inducing and induced flow of an alternator, and the sediment particles to electric charges provided with a + sign or with a - sign, dependent upon whether they rise or descend from the neutral zone.

The phase shift between the flows of the water and of sludges is preferably $\pi/2$. Each operational cycle which repeats itself indefinitely, is thus subdivided into four stages: a stage of work, a stage of expansion, a stage of work, and a stage of compression.

In the working stages the two flows move in opposite directions. There will thus be produced an almost instantaneous agglomeration of the whole mass of particles situated on both sides of the neutral zone.

In the stage of expansion, the two flows are in the same direction and are positive according to the convention adopted above. This has the result of a withdrawal from the sludge bed and at the same time of a rising force used for removing from the zone of decantation a portion of the purified water, situated above the sludge bed.

Finally, in the stage of compression, the two flows will be in the same direction and are negative. The particles are only subjected to gravity and controlled by the Stokes' law. They thus agglomerate in calm zones where there is no rising current and removed from these zones; they are evacuated from the zone of decantation.

The modulation of the flows of water and sludges is preferably ensured by pneumatic means, which avoids the use of complex mechanical devices and allows a complete automation of the process.

According to another aspect the invention provides apparatus for carrying out the process. This apparatus is characterised particularly in that it comprises a vat divided into a feed compartment for untreated water and

a decantation compartment, communicating means ensuring the passage of water from the feed compartment to the decantation compartment, a device sinusoidally modulating the flow of water passing from the first of these compartments to the second, recycling means for the sediments removing them from the decantation compartment and reinjecting them into this compartment into a zone at an intermediate level, a device sinusoidally modulating the flow of sediment reinjection in phase shift relation with modulation of the flow of the water, and means for removing the decanted water and the sediments formed above and below the intermediate level respectively.

Other features and advantages of the invention will become apparent from the detailed description which follows. Reference will be made for this purpose to the accompanying drawings showing by way of example only one embodiment of apparatus for carrying out the process. In these drawings:

FIG. 1 is a perspective view of the whole apparatus,

FIG. 2 is a longitudinal section of the apparatus,

FIG. 3 is a top plan view of the apparatus,

FIGS. 4 and 5 are sections on the line 4—4 and 5—5 of FIG. 2 respectively,

FIG. 6 is a sectional view to a larger scale of a detail apparatus,

and FIG. 7 is a graph explaining the functioning of the apparatus.

The apparatus shown will now be described, the explanation of its operation providing a better understanding of the process according to the invention.

The apparatus comprises a vat 1 of parallelepipedal shape, but which can also be made in any other shape.

The vat 1 is divided by a transverse partition 2 into two compartments A and D, the construction of which will be examined in succession below.

(1) *Compartment A.*—This is the feed compartment for untreated water. This water arrives through a pipe 3 opening into the base of the compartment through a passage 4 pierced in the brickwork of the vat 1. At the outlet of the passage 4, there is mounted a rotatable distributor head 5 comprising four distributing tubes 6 discharging tangentially. These tubes 6 each carry a vertical vane 7. This means ensures a stirring of the water to the extent that it rises in the compartment A and facilitates the mixture of this water with the coagulation reagents which are introduced into this compartment from filled tanks not shown for the sake of simplifying the drawing.

A metal flue 8 the vertical axis of which constitutes an extension of the axis of the distributor 5, extends into the compartment A. It is fed with compressed air by a compressor unit 9 capable of compressing air to a pressure of 400 grams per square centimeter, and a pipe 10. The unit 9 is mounted on a platform 11 in the upper portion of the compartment A and is protected by a metal case.

During the working period, the flue 8 fed with compressed air thus forms a true aero-hydraulic chamber, in the interior of which a strictly constant air pressure prevails, which corresponds to the level of immersion of the flue in the water in course of treatment. It will be possible to derive the necessary and sufficient energy from the container so formed at any desired instant to act at any desired point of the apparatus in consideration.

In particular, the flue 8 feeds with compressed air two identical hydro-pneumatic accumulators C_1 and C_2 which are placed side by side and work in parallel.

Each of these accumulators consists of a metal chamber of rectangular shape backing onto the partition 2. The upper part of each accumulator is connected on one side to the flue 8 by means of a pipe 12 and a gate valve 13 with remote-controlled action, and on the other side to the atmosphere via a second remote controlled gate valve 15. This gate valve 15 which is connected with the atmosphere, is indirectly mounted on a flexible pipe 16

connected to a control desk P which will be described hereafter.

Each of these accumulators is fed with untreated water through the intermediary of a metal channel 17, drawing flocculated water to the surface of the compartment A and feeding it to the interior of the accumulator by means of a flap valve 18.

A second flap valve 19 permits the bottom of each accumulator to be connected to a collector 20 from where a number of tubes 21 extend, which are embedded in the base of the vat 1 and traverse the partition 2.

The compartment A is completed by an overflow pipe 22.

(2) *Compartment D.*—It is the tubes 21 which connect the compartment A to the compartment D. Each tube 21 feed in effect simultaneously two of a series of longitudinal channels 23 formed in the base of the vat 1. These channels are capped by a cap 24 of triangular cross-section and their side walls are pierced by equidistant orifices 25, whose axes have the same inclination as the slope of the cap which covers them. These axes thus form an angle of about 60° with the base of the vat 1.

Through the orifices 25, the flocculated water coming from the accumulators C_1 , C_2 is distributed into the compartment D from where it is directed towards the bottom by the inclination of the orifices 25.

In the compartment D, close to the end thereof opposite to the partition 2, there are disposed side by side two sludge elevators E_1 and E_2 which are identical and which operate in parallel.

Each of these elevators consists essentially of a metal conduit of conical shape 26, disposed concentrically in the interior of a metal chamber 27 of a cylindrical-conical shape containing at its base a deflector 28 of cylindrical shape, extending into the interior of a receptacle 29 for sludges, of a pyramidal shape and likewise made of sheet steel.

Like the accumulators C_1 and C_2 , each sludge elevator has at its upper portion the following devices;

A remote-controlled gate valve 30 mounted on an extension 31 of a steel tube 32, connecting the two elevators to the central flue 8 forming the aero-hydraulic container;

A remote-controlled gate valve 33 for connection with the atmosphere, indirectly mounted, with its tube for connection with the atmosphere, on a flexible pipe 34 connected to the control desk P.

The sludge elevators E_1 and E_2 are intended to redistribute the sludges which they raise into the interior of the compartment D. For this purpose, each conical conduit 26 is extended by a steel tube 35 on which is mounted a non-return flap valve. The two tubes 35 corresponding to the two elevators E_1 and E_2 , meet in a common manifold 36. The latter has different branches 37 forming between them an angle α of about 150° (FIG. 5) and comprising a series of calibrated orifices 38 for the distribution of the sludges.

Control bushings 39 mounted on these branches, allow, if necessary, the cross sections of the orifices 38 with respect to one another to be corrected.

The compartment D also contains decelerating baffles for the sludges, extending transversely of the central portion of the compartment.

These baffles consist of angle irons, some fixed 40, and others movable, 41. The fixed angle irons 40 are secured at their two extremities in the longitudinal walls of the vat. Each movable angle iron 41 is disposed between two fixed angle irons 40 in a manner such as to close the space between the latter when it is supported thereon. In the normal position, however, each angle iron 41 is spaced from the angle irons 40 which embrace it; it is, in fact urged downwardly by springs 42 fixed to a small bar 43 which is secured at its extremities in the walls of the vat 1 and thus supports the angle iron 41.

Finally, on both sides of the baffles 40, 41, are provided means for the evacuation of the sludge and of the purified water. The evacuation means for the sludge comprises two tanks 44 formed in the brickwork of the vat 1, immediately below the elevators E_1 and E_2 . Each tank comprises a plunger tube 45 provided with an electro-valve 46 controlled by a timing mechanism 47 which is in fact on the control desk P. The periodical opening of the valve 46 by the timing mechanism 47 ensures the removal of the sludges by a siphon effect, the sludges being drawn up the pipe 45 and evacuated through the pipe 48 into a hopper 49.

The means for collecting and withdrawing the purified water comprises a series of equispaced transverse channels 50 situated at the upper portion of the compartment D. These channels collect the purified water which spills into them and feed a trough 51 which surrounds the exterior of the vat 1. The water is removed from the trough 51 through a tube 52.

(3) *The control desk.*—This desk is the nerve centre of the apparatus, and allows its automatic operation according to the process of the invention. Before describing this desk in detail, it seems necessary to define its many functions.

As has been seen above, the main devices of the apparatus, the accumulators C_1 and C_2 and the elevators E_1 and E_2 are provided in pairs so that one of the devices of each pair can be filling, while the other is delivering. In order that one of the accumulators or elevators should be in the filling condition, it is necessary that the gate valve (13 or 33 respectively) which connects it to the flue 8 should be closed and that the gate valve (15 or 30 respectively) for connection with the atmosphere, should be open. Conversely, in order that one of the accumulators or elevators should be in the delivering condition, it is necessary that the gate valve 13 or 33 should be open and the gate valve 15 or 30 should be closed.

Thus a primary function of the control desk will be to control cyclically the opening and the closing of the eight gate valves 13, 15, 33 and 30 in a manner such that alternately one of the accumulators C_1 and C_2 and one of the elevators E_1 and E_2 are in the filling condition whilst the other accumulator and the other elevator are in the delivering condition.

Furthermore, in order that the apparatus should function according to the process described, it is necessary that the accumulator delivering ensures a sinusoidally distributed flow of water and that the elevator delivering distributes its sludges equally according to an out of phase sinusoidal rule with respect to the former e.g. cosinusoidally. In order to achieve this and since the distribution is carried out in both cases under the influence of air pressure in the flue 8, this pressure of air is modulated according to the desired rule. For this purpose, the pipes 16 and 34 comprise air escape valves 33, shown in detail in FIG. 6, and permit this air pressure to be modulated.

Each escape valve 53 comprises a body 54 communicating at its upper part with one of the pipes 16 or 34, and at its base with the atmosphere through orifices 55. A flap valve 56 movable against a spring 58 towards a seating 57 provides a throttle between the two ends of the body 54. The flap valve 56 is mounted on a threaded rod 59 which is actuated by a nut 60 which is integral with a pinion 61 meshing with a second pinion 62. The rod 59 is guided in the body 54 by rings 59a provided with orifices 59b for the passage of air, the actuation of the assembly being such that during the rotation of the nut 61, air escapes through the orifices 55 according to a sinusoidal flow.

A second essential function of the desk P is the control of the four valves 53 in such a manner that the desired phase-shifting between the sinusoidal modulations

of the flows from the accumulator and from the elevator when delivering should be assured at every instant.

This being so, the desk P comprises an electro-reducing transformer unit 63 providing a drive by a mechanical transmission (two bevel gears 64) to a common control shaft 65. This shaft comprises a reversing mechanism 66 permitting the conversion of the continuous rotation movement imparted by the motor-reducing transformer unit into an alternative rotating movement.

There are likewise disposed on this control shaft, 4 pairs 67 of bevel gears, disposed oppositely to another. Each of these pairs drives the pinion 61 for advancing the air escape valves 53.

Due to the disposition of the above-mentioned mechanical elements, it will be readily understood that the two first escape valves 53 have strictly opposite advancing movements. This also applies to the second two valves. Thus, if the first two valves are in communication with the two accumulators and the two second valves are in communication with the two sludge elevators, the intended cycle, i.e. one accumulator delivering and the other filling, and one sludge elevator delivering and the other filling, will be readily realized.

The reversing mechanism 66 disposed at the end of the control shaft enables this movement to be renewed indefinitely and, consequently, the cycle in question can be maintained.

There is also mounted on the output shaft of the motor-reducing transformer unit 63, a pinion which transmits through the intermediary of a chain 68, a gear reducing movement of the slow rotating type to a common controller consisting mainly of a drum 69 provided with 8 cams.

In its rotation, this drum provides the desired contacts according to sequences determined by means of the time of revolution of the drum, in order to open or close the electro-valves 13, 15, 30 and 33 which are provided on the accumulators C_1 and C_2 and the sludge elevators E_1 and E_2 respectively.

The operation of the apparatus and the manner in which it enables the process according to the invention to be carried out will now be considered.

Since the apparatus is supposed to be empty at the start, the untreated water is fed at 3 to the lower part of the compartment A and distributed into the interior of the latter by the distributor 5 which serves equally as a slow vaned mixer. The filling of the decanter with water being complete, the operator starts the electro-air compressor unit 9 manually, feeding its compressed air into the interior of the flue 8 dipping to a depth H into the water of the decanter. Under the action of the air pressure, the water level in the interior of the flue 8 drops to the lower part of the latter. The excess air expands in the water and is evacuated to the atmosphere. One obtains in this manner by the intermediary of this flue dipping into the liquid to be treated, an aero-hydraulic reservoir capable of providing its energy at any desired moment at any desired point of the apparatus.

This operation thus being carried out, the operator starts the motor-reducing transformer unit 60 mounted in the interior of the control desk P.

By starting the motor-reducing transformer unit 63, the following operations will take place:

The remote-controlled valve 15 for the connection with atmosphere, of one of the accumulators, e.g. the accumulator C_1 closes, the connecting valve 13 between this accumulator and the central flue 8 opens, there is thus abruptly available a pressure equal to the height of the flue above the water level of the accumulator, which results instantly in causing this accumulator to start delivering, the flap valve 18 being closed and the flap valve 19 being open due to the difference in pressure between the accumulator and the decanter.

It is now that the function of the valve 55 in conjunction with this circuit comes into operation since it creates

an escape of air which would result in reducing the initial available pressure and consequently ensures control of the delivery of water.

This valve is remote controlled, as has been mentioned, by the common transmission shaft 55. Consequently its valve member 56 is given a uniform advancing movement and approaches its seat 57, the shape of which is specially designed for creating artificial pressure losses tending constantly to modify the air pressure which exists in the upper portion of the accumulator and, consequently, to modify the programme of water delivery. This water is delivered into the compartment D through the orifices 25 of the channels 23.

When the accumulator is emptied of its volume of water, the reversing mechanism 66 changes the direction of rotation of the transmission shaft 65, thus causing the movement of the valve 56 to be in the opposite direction, which has the effect of returning it to its starting position.

During the same period of time, the connecting valve 13 between the accumulator and the flue has been closed by the action of the drum 69, the valve 15 for connection with the atmosphere is open, likewise under the action of the drum 69. Under these conditions, the distribution valve 19 closes because the water pressure in the decanter becomes higher than the pressure existing in the accumulator, and the upper valve 18 opens for the same reason. Since this valve is in communication with the feed channel 17, the accumulator starts a filling stage. It will remain so for a determined duration equal to the period of delivery of the second accumulator C₂.

Thus, by the intermediary of the common control block situated in the desk P, a cycle is established which can be renewed indefinitely, the action of the valves 53 effecting the different variations of flow brought about when one of the accumulators is in the delivery stage.

According to the process discussed above, the variations of these flows are such that an accumulator is emptied within a strictly determined period according to a sinusoidal rule.

An analogous process is employed for the recirculation of the sludges. Always through the intermediary of the control desk P, the two sludge distributor elevators E₁ and E₂ of the apparatus work in the following manner:

Whilst one accumulator is delivering as has been seen previously, one sludge elevator-distributor, for example E₁, is equally delivering. For this purpose, the connection valve 30 between the flue and the elevator distributor, is open and the valve 33 for connection with the atmosphere, is closed. Thus, an air pressure is exerted in the upper part of the elevator distributor, which corresponds to that prevailing in the central flue.

However, the corresponding escape valve 53 for a variable flow, always controlled by the transmission shaft 65 of the control block, creates a conditioned escape of air which has the result of lowering the sludge level in the conduit 26, the cross section of the seat of the escape valve 53 being calculated to create a sinusoidal sludge distribution ratio which is, however, out of phase with respect to the water distribution ratio. The sludge distribution ratio will, for example, be cosinusoidal. The sludges will be distributed, according to this ratio, in the compartment D through the pipe 35, the manifold 36, the branches 37 and the orifices 38.

When the sludge level in the conduit 26 has reached the bottom of the deflector 28 under the action of the drum 69, the connection valve 30 between the flue and the elevator closes and the valve for connection with the atmosphere 33 opens.

Under this action, the volume of sludges which is concentrated in the receptacle with a pyramidal bottom 29, rises in the annular zone created by the conduit 26 and the body 27 of the elevator. Consequently it fills the conduit 26. This action takes place while the other elevator-distributor E₂ is delivering.

As in the case of the accumulators C₁ and C₂, the co-

ordinated action of the drum 69 and of the motor reducing transformer unit 63 allows one to carry out a strictly defined cycle which can be renewed indefinitely.

There will now be examined, with reference to FIG. 7, the consequences of the out-of-phase sinusoidal modulation of the flows of water and sludge. FIG. 7 is a graph in which the time T is shown as the abscissa and the instantaneous flow Q of water and of sludges as the ordinate. The curve *a* illustrates the variation of the flow of water or inductive flow, and the curve *b* that of the flow of sludges or induced flow. These two curves are sinusoidal and out-of-phase, here by $\pi/2$, and have as a common axis the line *l*, called the neutral line. Above this line, the flows will be considered positive, and below this line as negative.

Depending on the relative position of the two flows with respect to the neutral line, a functional cycle of 2π is divided into four phases or stages, a working phase *t*, an expansion phase *e*, a new working phase *t* and a compression phase *c*. The explanation of the terms qualifying these phases will be apparent from the following analysis.

Depending on the progress of the flows of untreated water and sludges in recirculation, there will be formed within the decanter a neutral zone diagrammatically shown as neutral line *l* in FIG. 7. This neutral zone corresponds to the necessary and sufficient flow in order to maintain in the liquid mass a particle in equilibrium. On both sides of this neutral line this particle will be:

Either urged by the thrust of the propelling fluid which will allow it to be taken along with the latter, or on the contrary urged by the laws of gravity, the propelling fluid not having a sufficient flow to sustain the particle.

Supposing the decanter to be already operating for several hours since it is necessary when putting water into the apparatus for the first time, to carry out an "inoculation" before being able to obtain valid results, the following different phases will occur:

(a) *1st phase called the "working stage."*—The two flows, inductive and induced, have opposite signs + and −, the inductive flow having a kinetic energy whilst the induced flow is deprived thereof and subjected to the action of gravity.

The disposition of the sludge particles, which will form on both sides of the neutral zone, allows with reference to the above-mentioned electrical analogy, the application of formulae resulting from the work of Coulomb and Gauss for determining the effective force which will be obtained by placing particles charged with energy of opposite signs, opposite to one another.

This resultant force *F* can thus be readily calculated as being:

$$F = \frac{\beta^2 S \cdot 1}{8\pi \cdot 981}$$

in which

F = grams

$\beta = 4\pi m$

S = surface of the decanter in cm.²

m = mass which, placed at 1 cm. from an identical mass charged with energy of the opposite sign, produces on the latter force of attraction of 1 dyne.

During this working phase the apparatus will thus carry out an almost instantaneous agglomeration of the whole mass of particles situated on both sides of the neutral zone. The working phase is thus that which allows one to produce in the apparatus a sludge bed, the top of which is bounded by the angle irons 40 and 41.

(b) *2nd phase called the "stage of expansion."*—The two flows, inductive and induced, have the same positive sign. The two flows have a kinetic energy and the particles are thus entrained by the currents of untreated water and sludges. They do not attract but repel. There is a withdrawal from the bed which is in expansion.

It is possible to determine the trajectories of the particles by the theorem of kinetic energy and the equation of

Bernoulli. By bringing all factors inherent in the environment into play, the following formula is reached:

$$Z = \frac{p}{\delta} + \frac{\alpha V^2}{2g} = \text{constant}$$

wherein

Z =energy of position, expressed by its altitude above the plane of reference

α =coefficient 2 since the work is effected in a laminar ratio,

$V^2/2g$ =kinetic energy of the particle

p/δ =energy of pressure for introducing the particle of weight p into a medium under a pressure P

δ =specific weight of the particle.

Under the action of the intensity of the two flows, the angle irons 41 are urged by the rising force of the currents. They rise slightly in the vertical direction until they seal almost completely the longitudinal diffusion inlets between the angle irons 40. By doing so they prevent the sludge bed which is in suspension, from rising into the upper zone of the apparatus but during the same period of time their ascent causes an increase of the level of the water plane above that of the decanted water which, consequently feeds the channels 50 with treated water.

In short, there is produced during this period:

(1) An overflow from the sludge bed which can be compared to a cleaning, such as is obtained by filtration: by a raising of the "filter mass."

(2) The two flows: untreated water and sludges, reach their maximum intensity and equally cause a maximum return flow of treated water during this period as a consequence of the rising of certain angle irons supporting the sludge bed and acting as decelerators.

(c) *3rd phase called the "working phase."*—The same phenomena as those observed during the first working phase, take place. The two flows still have opposite signs but in the reverse direction with respect to the first working phase. The phenomena remain identical: production of sludges by successive agglomeration of particles charged with energy of the opposite sign.

(d) *4th phase called the "stage of compression."*—The two flows, inductive and induced, again cross the neutral line. Their intensity declines which has the result of reducing and then of cancelling their kinetic energy.

From now on, the particles are exclusively subjected to the law of Stokes which allows determination of their speed of fall towards the calm zones (concentrators 44) where there is no rising current.

In short, the working stages have the object of producing sludges, the constituent bodies of which always have the tendency of increasing the volume and also the specific weight.

The stage of expansion has the object of an overflow of the sludge bed, and of maintaining it in a homogeneous form.

The stage of compression has the object of a systematic elimination of the heavy particles which are the first attained by Stokes' law.

The possibility of breaking down into four distinct periods, repeating indefinitely according to a predetermined cycle, the operation of decantation and of applying only during the fourth period the law of Stokes, is a source of advantages because the particle to be separated from the primary liquid is, in fact, subjected to the above law only when it has reached a speed of expulsion. Furthermore, this speed rises rapidly because at the same time the dimension of the particle and the difference of specific weight between the particle and the liquid surrounding it, are acted upon.

The apparatus according to the invention occupies in the classification of existing decanters a very particular position, in that sense that in operation its behaviour is much more similar to that of a filter of the open type, working from the bottom in the upward direction, and the

filtering material of which would consist of grains disposed, with respect to the lower plane, in decreasing sizes.

Furthermore, the possibilities of regulating the apparatus are much greater than in the conventional apparatus. Referring to the curves of the operation of the apparatus, it is apparent that it is possible to act:

(a) On the time unit, i.e. to increase or decrease the period;

(b) On the amplitude, i.e. by increasing or decreasing the difference between minimum flow and maximum flow for a given period;

(c) On the phase shift between the two flows, which influences the length of the phases comprised in a period, with respect to one another.

These factors of possible correction can play an important part in the interpretation of the results of analysis of water to be obtained, in the laboratory.

The invention is, of course, not limited to the manner of carrying it out, as described and illustrated, which has been given by way of example only.

What we claim is:

1. A process for the decantation of waters and other liquids comprising the steps of continuously introducing water to be treated, to which a coagulation reagent has been added, into a decantation zone according to a sinusoidally modulated flow, continuously removing a portion of the sediments formed and reinjecting them continuously into the decantation zone according to a sinusoidally modulated flow in phase shift relation with the modulation of the flow of water, the said modulated flows of said water and of said sediments in phase shift relation thus creating a stationary sediment bed in said decantation zone and distributed over both sides of a neutral zone, from both sides of which the sediment particles are activated by opposite movements, removing from the bottom of said bed the sediments and removing separately from the top of said bed the decanted water.

2. A process as claimed in claim 1, wherein the phase shift between the modulated flows of water and sediments is $\pi/2$.

3. A process as claimed in claim 1, wherein the modulation of the flows of water and of sediments is effected by a pneumatic method, the introduction of water and the reinjection of the sediments into the decantation zone being carried out under the influence of a compressed gas, the pressure of which is modulated.

4. A process as claimed in claim 3, wherein the compressed gas is derived from a source at a constant pressure, the pressure on the water and on the sediments being modulated by modulating the escape of compressed gas above the water and sediments.

5. A process as claimed in claim 1, wherein the modulation in phase shift relation of the flows of water and sediments causes a cyclic operation in four successive phases of working, expansion, working and compression, the phases of working causing the agglomeration of sediments and the formation of the stationary bed thereof, the expansion phase causing a withdrawal from said bed and the removal by overflowing of a portion of the decanted water, present above said bed, and the compression phase causing the heaviest particles of the bed to be removed from the bottom of the latter.

6. An apparatus for the decantation of waters and other liquids, comprising a vat, means dividing the vat into a feed compartment for untreated water and a decantation compartment, a connecting means interconnecting the feed compartment and the decantation compartment to pass water from the feed compartment to the decantation compartment, a means sinusoidally modulating the flow of water passing from the feed compartment into the decantation compartment, a recycling means for the sediments connected to the decantation compartment for removing the sediments from the decantation compartment and reinjecting them into the decantation compartment in a zone

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at an intermediate level therein, a means sinusoidally modulating the reinjection flow of the sediments in phase shift relation with the modulation of the flow of water, and means for removing the decanted water and the sediments formed from above and below said intermediate level respectively.

7. An apparatus as claimed in claim 6, wherein the connecting means and recycling means each consists of a conduit, and means to supply a pressure modulated compressed gas to said conduit.

8. An apparatus as claimed in claim 7, wherein each of said conduits is present in pairs, one half unit being in a filling stage while another is in the delivering stage.

9. An apparatus for the decantation of waters and other liquids, comprising a vat, means dividing the vat into a feed compartment for untreated water and a decantation compartment, a connecting means interconnecting the feed compartment and decantation compartment to pass water from the feed compartment to the decantation compartment, a means sinusoidally modulating the flow of water passing from the feed compartment into the decantation compartment, a recycling means for the sediments connected to the decantation compartment for removing the sediments from the decantation compartment and reinjecting them into the decantation compartment in a zone at an intermediate level therein, a means sinusoidally modulating the reinjection flow of the sediments in phase shift relation with the modulation of the flow of water, and means for removing the decanted water and the sediments formed from above and below said intermediate level respectively, the connecting means and recycling means each comprising a conduit, means for supplying a pressure modulated compressed gas to said conduit, and each of said conduits consisting of two half units, one half unit being in a filling stage while the other is in a delivering stage, each of said half units comprising a channel, said means for supplying said compressed gas including connection means to a constant pressure source of gas, an electro-valve controlling the channel for the delivery of said compressed gas from the source of gas, each of said half units including an escape pipe for the gas, an escape valve inserted in each said escape pipe to cause a sinusoidally modulated escape of gas, said escape valve opening to the atmosphere, an electro-valve in each said escape pipe, a rotatable electric commutator means for opening one said recycling means escape pipe electro-valve during the delivery stage of one connecting means half unit, and closing said one recycling means escape pipe electro-valve when said one connecting means half unit is connected with the atmosphere during its filling stage, and simultaneously closing the other recycling means escape pipe electro-valve during the filling stage of the other connecting means half unit and opening the other recycling means escape pipe electro-valve when the other connecting means half unit is in the delivery stage.

10. An apparatus as claimed in claim 9, wherein each of said escape valves provides a modulated pressure drop and comprises a body connected at one end to the corresponding escape pipe and at the other end to the atmosphere, a seat being provided between these two ends, a valve member cooperating with the seat, a threaded rod which is integral with the valve member and a nut screwed on the threaded end of said rod to set said valve member in motion with respect to said seat, a pinion driving the threaded rod with an alternating rotary motion, the motion of the valve causing sinusoidal modulation of the pressure drop.

11. An apparatus as claimed in claim 10, comprising a shaft driving the pinions of four said escape valves in rotation, a reversing means, a motor-reducing unit drivingly connected to the rotary electric commutator means and drivingly connected to the shaft through the reversing means for driving the shaft in an alternating rotary motion.

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12. An apparatus as claimed in claim 9, wherein the source of gas at constant pressure feeding said conduits comprises a flue extending from a constant height into the feed compartment and communicating with said compartment at its base, and electro-compressor unit feeding the flue in the upper part of the latter with compressed air.

13. An apparatus for the decantation of waters and other liquids comprising a vat, means dividing the vat into a feed compartment for untreated water and a decantation compartment, a connecting means interconnecting the feed compartment and decantation compartment to cause the passage of water from the feed compartment to the decantation compartment, a means sinusoidally modulating the flow of water passing from the feed compartment into the decantation compartment, a recycling means for the sediments connected to the decantation compartment for removing the sediments from the decantation compartment and reinjecting them into the decantation compartment in a zone at an intermediate level therein, a means sinusoidally modulating the reinjection flow of the sediments in phase shift relation with the modulation of the flow of water, and means for removing the decanted water and the sediments formed from above and below said intermediate level respectively, the connecting means and recycling means each comprising a conduit, means for supplying a pressure modulated compressed gas to said conduit, each of said conduits consisting of two half units, one half unit being in a filling stage while the other is in a delivering stage, each of the half conduit units forming the connection means and serving as a water accumulator, a channel opening into the upper part of the feed compartment, a network of longitudinal channels disposed in the bottom of the decantation compartment, said network of channels having orifices pierced in their lateral walls, a plurality of flap valves, one said half conduit accumulator communicating at its base, on one side via at least one of said flap valves with said channel opening into the upper part of the feed compartment, and on the other side, likewise via another of said flap valves, with said network of longitudinal channels disposed in the bottom of the decantation compartment, said network of channels opening into said decantation compartment through said orifices pierced in the lateral walls of the channels.

14. An apparatus for the decantation of waters and other liquids comprising a vat, means dividing the vat into a feed compartment for untreated water and a decantation compartment, a connecting means interconnecting the feed compartment and decantation compartment to cause the passage of water from the feed compartment to the decantation compartment, a means sinusoidally modulating the flow of water passing from the feed compartment into the decantation compartment, a recycling means for the sediments connected to the decantation compartment for removing the sediments from the decantation compartment and reinjecting them into the decantation compartment in a zone at an intermediate level therein, a means sinusoidally modulating the reinjection flow of the sediments in phase shift relation with the modulation of the flow of water, and means for removing the decanted water and the sediments formed from above and below said intermediate level respectively, the connecting means and recycling means each comprising a conduit, means for supplying a pressure modulated compressed gas to said conduit, each of said conduits consisting of two half units, one half unit being in a filling stage while the other is in a delivering stage, each of the said half conduit units forming the recycling means for the sediments comprising a casing opening at its bottom into a vessel collecting the sediments in the vicinity of said intermediate level, a sediment elevator, a tube for the sediments which is located in the interior of the casing, the top of said tube opening into said casing, a channel communicating with said tube and extending across the vessel, and a circuit

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means for sediment distribution connected to said channel.

15. An apparatus as claimed in claim 14, wherein the circuit for the sediment distribution comprises a central manifold, branches pierced by orifices extending on both sides of said manifold to cause a regular distribution of the reinjected sediments.

16. An apparatus as claimed in claim 14, wherein above said intermediate level, the decantation compartment is provided with a horizontal partition, said partition having pierced inlets, flap valves cooperating with said inlets to close said inlets under the influence of a rising thrust exerted on the partition.

17. An apparatus as claimed in claim 16, wherein said partition is formed of an assembly of transverse fixed angle irons having spaces therebetween, a movable angle iron located in each of said spaces forming a flap valve and springs for urging each said movable angle iron in an opening direction.

18. An apparatus as claimed in claim 17, wherein above said partition, a trough surrounding said vat, transverse channels opening at both their ends into said trough surrounding the vat, said channels being fed with decanted water by over-flow under the influence of the opening of the movable angle irons.

19. An apparatus as claimed in claim 16, comprising

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receiving tanks for the sediments which are carried by the bottom of the vat and open into the decantation compartment below said partition, and evacuation means for removal of collected sediments from said tanks.

20. An apparatus as claimed in claim 19, wherein the tanks are situated directly below each of the half conduit units for recycling the sediments, said evacuation means comprising a plunger tube for the evacuation of the sediments by a siphon action, the plunger tube having a valve, a timing means to periodically control the opening of said value.

21. An apparatus as claimed in claim 14, wherein the feed compartment is provided at its bottom with a pipe for the delivery of water, said pipe having a distribution means opening into the compartment, said distributor means serving as a slow mixing device for water and coagulation reagents which are introduced into the feed compartment.

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