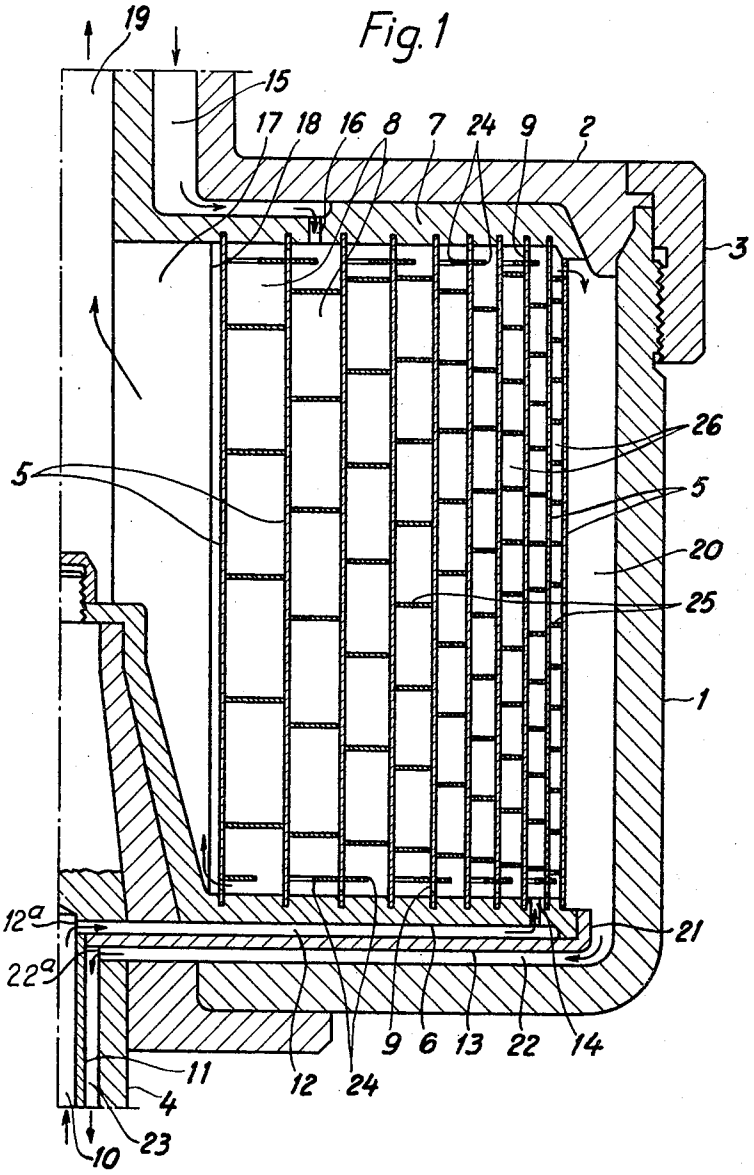
Oct. 29, 1963 F. T. E. PALMQVIST ETAL 3,108,953

APPARATUS FOR CONTACTING TWO FLUIDS WITH EACH OTHER COUNTERCURRENTLY

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Fig. 1



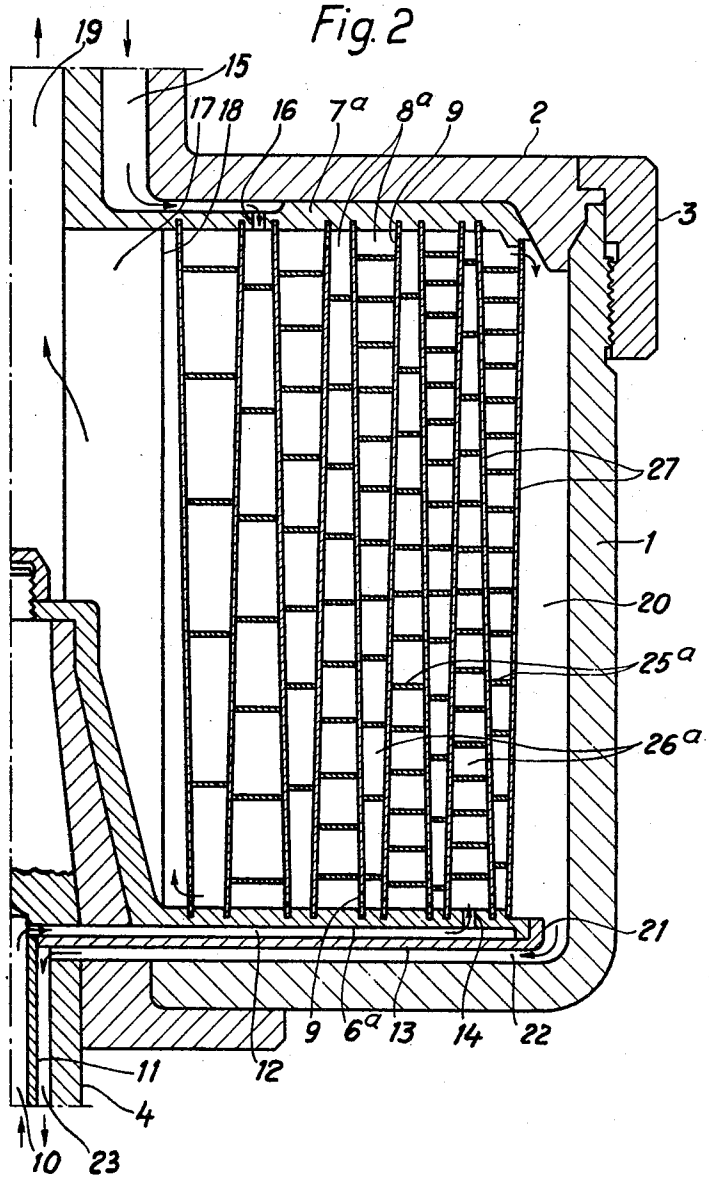
INVENTORS
Stig Beskow
Fredrik T.E. Palmqvist
BY
Davis, Hoxie, Faithfull & Hapgood
Attorneys

Oct. 29, 1963 F. T. E. PALMQVIST ETAL 3,108,953

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Fig. 2



INVENTOR.
Stig Beskow
Fredrik T.E. Palmqvist
BY
Davis, Hoxie, Faithfull & Hapgood
attorneys

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APPARATUS FOR CONTACTING TWO FLUIDS
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Fig. 3

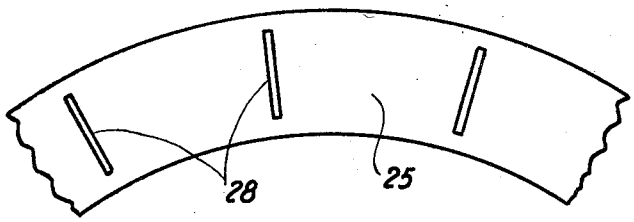


Fig. 4

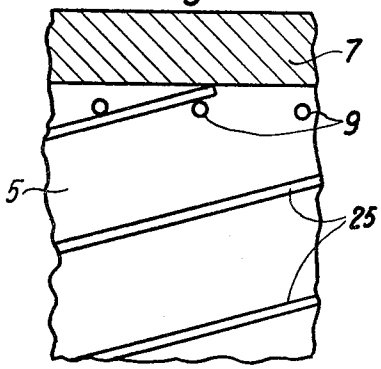


Fig. 5

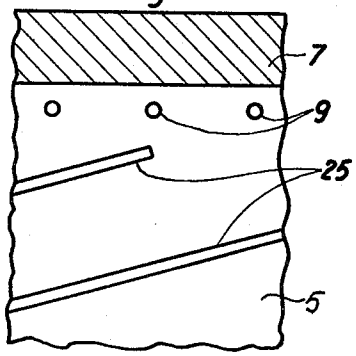
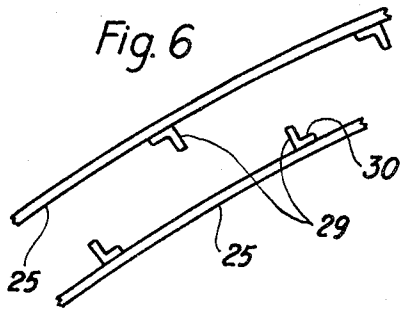


Fig. 6



INVENTOR.
Stig Beskow
Fredrik T.E. Palmqvist
BY
Davis, Hoxie, Faithfull & Hapgood
Attorneys

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Fig. 7

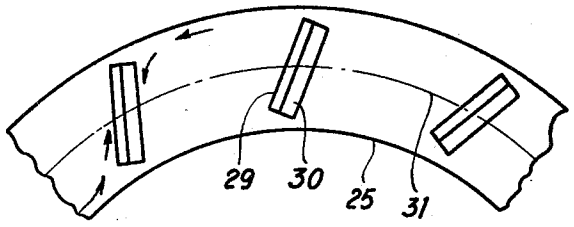
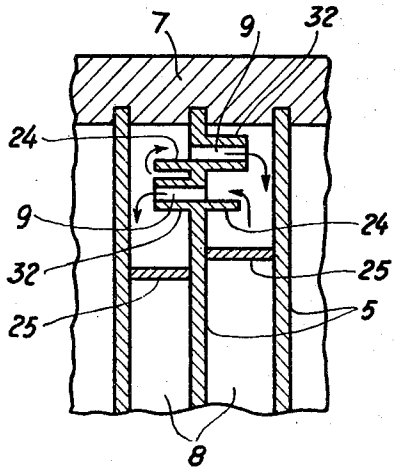


Fig. 8



INVENTOR.
Stig Beskow
Fredrik T. E. Palmqvist
BY
Davis, Hoxie, Faithfull & Hapgood
attorneys

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APPARATUS FOR CONTACTING TWO FLUIDS WITH EACH OTHER COUNTERCURRENTLY

Fredrik T. E. Palmqvist, Solna, and Stig Beskow, Bromma, Sweden, assignors to Aktiebolaget Separator, Stockholm, Sweden, a corporation of Sweden

Filed May 20, 1960, Ser. No. 30,578
9 Claims. (Cl. 233—15)

This invention relates to apparatus for causing two fluids, substantially insoluble in each other and of different specific gravity, to flow countercurrently in contact with one another. More particularly, the invention relates to an improved centrifugal apparatus for this purpose.

A centrifugal apparatus for this purpose, as made heretofore, comprises a hollow centrifugal rotor containing a series of mantles, usually cones or cylinders, which are concentric to the rotor axis and spaced from each other to form annular interspaces in the interior of the rotor, these interspaces being in communication with each other. The rotor also has an inlet for leading the relatively light fluid to an interspace at a relatively great distance from the rotor axis, another inlet for leading the heavy fluid to an interspace situated relatively near the rotor axis, an outlet for the light fluid from a chamber near the rotor axis, and an outlet for the heavy fluid from a chamber near the rotor periphery.

Apparatus of the type described above are advantageously used as extractors or evaporators. In extractors, the contact usually takes place between two liquids, and in evaporators between a gas or vapor and a liquid. As examples of extraction may be mentioned recovery of antibiotics from fungus worts and washing of gas with liquid. Certain washing processes, such as washing of paraffin recovered from mineral oils, and washing of soap with an electrolyte solution in the manufacture of soap, may also be included in this group. As examples of evaporation may be mentioned concentration of black liquor from the making of paper pulp according to the sulphate method, and concentration of sugar juice.

In some cases, the mantles of such an apparatus have been perforated. This has caused the disadvantage that short cuts of radial flow are formed through the various mantle interspaces, so that the same good contact between the various fluids has not been obtained throughout the axial length of the mantle interspaces.

The present invention has for its principal object to overcome this disadvantage and not only to secure good contact between the various fluids throughout the axial length of the mantle interspaces but also to bring about improved contact between the two fluids by causing them to sweep one another along a longer path than has been possible heretofore within a corresponding space in an apparatus of the above type.

According to the invention, channels are formed in the annular interspaces provided by the concentric mantles, the channel in each interspace extending in the form of a spiral or screw in a direction from one end of the rotor to the other, as counted axially. This causes the various fluids to flow through the respective interspaces in their entire axial length, and along a screw-shaped path, before entering the next interspace. By providing the screw-

shaped channel with a suitable pitch, the length of the channel may be made as much greater as desired than the axial length of the interspace, so that the channel length becomes in effect a multiple of the axial length.

The treating effect depends substantially upon the turbulence which the two fluids cause when they contact or sweep one another during the flow. In case of two liquids, a mixing of them is obtained in the boundary layer. The higher the speed gradients, the stronger the mixing effect and, therefore, the extracting effect. However, in the more peripheral parts of the rotor, the separating effect is stronger due to the centrifugal force being greater there than in the central parts. This means that the mixing effect is more strongly counteracted by the centrifugal force in the peripheral parts of the rotor because the separating effect is greater there than in the central parts of the rotor. Consequently, the flow speeds of the two fluids must be kept proportionally higher in the peripheral parts of the rotor, if the treating effect desired is to be attained. This can be obtained by reducing the channel throughflow areas toward the periphery of the rotor. The reduction of the channel area can, in principle, be made in two ways. Either the distances between the mantles are reduced toward the periphery of the rotor, or the pitch of the screw-shaped channels in the interspaces is reduced toward the periphery of the rotor. In practice, it is advantageous to combine both these measures. In that case, the throughflow area of a channel is given a size varying between

$$r^{\frac{A}{0}} \text{ and } r^{\frac{A}{2.5}}$$

preferably between

$$r^{\frac{A}{0.5}} \text{ and } r^{\frac{A}{2}}$$

in which A represents a constant and r the distance of the channel area from the rotor axis.

When treating sludge-containing liquids, it may be desirable to make the mantles in the form of cones with substantially the same cone angle, in order to facilitate sliding of the separated sludge along the mantle surfaces and out toward the periphery of the rotor. In such cases, the cones are inserted in the rotor in such a way that their narrow ends alternate with their wide ends at one and the same end part of the rotor, so that the sludge, as seen in an axial section through the rotor, will follow an inclined zigzag path out toward the periphery of the rotor. Also, in such cases it is desirable that the screw form of the channel in an interspace have such a pitch that the cross sectional area of the channel remains constant. The flow speeds will thus be unchanged throughout the interspace.

Although the present invention is applicable theoretically to an apparatus in which two or more interspaces are connected in parallel, it is preferable, in order to gain a good treating effect, that the interspaces communicate with each other in series so that a long treating path is obtained. In that case, the necessary communication openings are arranged at the ends of the mantles. In view of the increased flow resistance at the communication openings, it is desirable that the openings in a mantle end have at least the same total area as the cross sectional area of one channel.

A fluid discharging from the apparatus should, of course, be as free as possible from the other fluid. For this reason, clean-separating zones may be provided at the end of the flow path of each fluid. This can be obtained by an arrangement in which the inlet for the light fluid opens into an interspace which is situated at a distance of one or more interspaces from the periphery of the rotor, while the inlet for the heavy fluid opens into an interspace situated at a distance of one or more interspaces from the rotor axis. In this way, the interspaces situated nearest the periphery and nearest the axis of the rotor, respectively, will serve as clean-separating chambers for the heavy fluid and the light fluid, respectively.

The screw-shaped channels may be formed of spiral strips or bands which are arranged as flanges on the mantles, as by welding them to the inner or outer surfaces of the mantles. To facilitate manufacture and dismantling, however, it is desirable to insert bands of spiral or screw shape loosely in the annular interspaces and, possibly, to hook their ends to the mantles. In so doing, the band should by its width cover the entire distance between adjacent mantles so that the various fluids must follow the channel. Otherwise, slots will be formed between the band edges and the mantle walls, through which slots a fluid following a mantle wall takes short cuts axially through the corresponding mantle interspace, from one end of it to the other. These short cuts will be located within one and the same fluid layer and therefore will not be useful to produce mixing of the various fluids.

In order that the desired layer formation of the various fluids in the channels may take place in the manner intended, it is preferable to provide the communication openings with overflow outlets at a level located a distance into the respective interspaces, as reckoned radially.

The desired treating effect is dependent upon the intimate contact into which the two fluids come with one another. The interfluid contact can be enhanced by causing extra turbulences of them at certain points. This can be done by providing the spiral or screw-shaped members, which form the channels, with openings located in the central portion of the width of these members. The different fluids thus flow in opposite directions through such openings, with resulting turbulence-formation. The openings provide short cuts, however, for the two fluids so that the effective channel path is shortened. This can be counteracted by reducing the pitch of the screw-shaped channels.

A further measure for causing more intimate contact between the different fluids consists in making the interspaces, at their end portions as counted axially, free from channel-forming screw-shaped members. That is, the spiral flanges, bands, or the like, start and terminate at a distance from the inner end walls of the rotor chamber. In the free spaces thus formed, a sliding of the two fluids takes place, owing to the rotation, whereby a good mixing of them is obtained.

Another measure for obtaining more intimate intermixing of the two fluids, and thus good contact between them, consists in providing the channels with projections throttling the cross sectional area of the channels in the axial direction. This can be done by welding projecting plate pieces to the flanges, bands or other spiral members, which pieces stand out from the surfaces of these members. An improvement of the mixing effect is obtained if the projections extend obliquely in relation to the radial direction.

In reference to the above-mentioned communication openings between the various interspaces, it has been assumed that the two fluids pass through these openings at the same time in opposite directions. This causes, of course, a mixing of the two fluids. If it is desired, however, that the fluids flow into the various interspaces without such a mixing effect, the communication openings may be made so that they open into the interspaces at a level which is situated a distance into the respective interspaces, as counted radially.

The invention is described more in detail below, reference being made to the accompanying drawings, in which

FIG. 1 is a vertical sectional view of the right-hand half of one embodiment of the invention;

FIG. 2 is a similar view of another embodiment of the invention;

FIG. 3 is an enlarged plan view of part of one of the spiral bands shown in FIG. 1;

FIGS. 4 and 5 are enlarged detail views illustrating alternative arrangements of the spiral bands in FIG. 1, the bands being shown in edge view against parts of the corresponding surrounding mantles;

FIG. 6 is an edge view of parts of spiral bands as seen from the rotor periphery, showing projections carried by the bands for increasing the inter-mixing of the different liquids;

FIG. 7 is a plan view of part of one of the spiral bands illustrated in FIG. 6, showing a modified arrangement of the projections; and

FIG. 8 is a vertical sectional view of part of another embodiment of the invention, showing a different arrangement of the communication openings between the various mantle interspaces.

In FIG. 1, the rotor is designated by reference numeral **1**. The rotor has a cover **2** retained by means of a locking ring **3** and is driven by a vertical hollow spindle **4**. It is possible, however, to arrange the rotor and spindle for rotation about a horizontal axis. In the interior of the rotor, concentric mantles or cylinders **5** are secured at their ends to end parts **6** and **7**, the spacing between adjacent mantles decreasing toward the periphery of the rotor. As shown, there are ten cylinders **5**. The annular interspaces **8** formed by the cylinders communicate with each other by means of holes or communication openings **9** situated at the end portions of the cylinders.

In the following, it is assumed that an extraction process is carried out in the apparatus described, light liquid being fed into the rotor through a channel **10** which is formed by the interior of a pipe **11** inserted concentrically in the hollow spindle **4**. From the channel **10**, the light liquid enters an interspace **12** between the lower end part **6** and a plate **13**, where the liquid is brought into rotation by radially extending vanes, one of which is shown at **12***a*, and flows outward to a circular series of openings in end part **6** which lead to the second outermost of the interspaces **8**, one of these openings being shown at **14**. Heavy liquid is fed through a channel **15**, which is annular in cross section and formed of cylindrical, concentric flanges on the cover **2** and the upper end part **7**, the channel **15** leading to the second innermost of the cylinder interspaces **8** through a circular series of openings in the end part **7**, one of these openings being shown at **16**. The two liquids now pass through the various interspaces **8** countercurrently, the light liquid in each interspace forming an inner cylindrical layer, and the heavy liquid an outer cylindrical layer. Through each hole **9**, the liquids flow in opposite directions to one another so that the light liquid travels from interspace to interspace radially inward, while the heavy liquid passes through the various interspaces radially outward. Finally, the light liquid is collected in a hollow space **17** formed within the innermost cylinder and is discharged through a channel **19** by means of radial vanes **18** arranged in the hollow space. In the innermost of the interspaces **8**, as well as in the hollow space **17**, a clean-separation of the light liquid takes place. The separating effect may be improved by replacing the vanes **18** with a set of conical discs (not shown). The heavy liquid, on the other hand, is clean-separated by the time it has passed through the outermost of the interspaces **8** and through a space **20** situated between the outermost cylinder **5** and the periphery of the rotor. From the outer space **20**, the heavy liquid passes the outer edge **21** of the plate **13** and flows inward through the interspace **22** formed between plate **13** and

the rotor bottom, and then out through the channel 23 of annular cross section formed by the spindle 4 and the pipe 11. The interspace 22 may be provided with radial vanes, one of which is shown at 22*a*, leading the liquid inward toward the spindle 4. The inlets 10 and 15 and the outlets 19 and 23 may be hermetically connected thorugh conventional sealing means to corresponding stationary pipe lines (not shown), whereby the liquids may be fed into the rotor by means of pumps producing the pressure desired in the feed lines.

To prevent the interspaces 8 from being filled substantially with only one of the liquids or the other, which may impair the efficiency of an extraction made in the rotor, overflow outlets for one or both of the liquids may be arranged near the holes 9 so that a certain layer thickness for one or both of the liquids is obtained in each interspace 8. For this purpose, annular flanges 24 may be provided on the inside or the outside, or both, of the various cylinders along their peripheries. As shown, a flange 24 extends into each interspace 8 from each of the bordering cylinders 5, so that the heavy liquid must flow over an inwardly extending flange 24 just before reaching a hole 9, and the light liquid must flow over an outwardly extending flange 24 just before reaching a hole 9.

In order to intensify the extraction, a long path of contact is established between the liquids by means of spiral bands 25 inserted in the cylinder interspaces 8 and extending in the form of screws along the cylindrical surfaces of the cylinders from their upper to their lower end portions. Because the separating effect exerted by the centrifugal force upon the liquids increases toward the periphery of the rotor, the cross sectional area of the spiral or screw-shaped channels 26 formed by the bands 25 must be made smaller in the outer interspaces 8 so that the flow speed of the liquids is higher, if it is desired to attain an equally intensive mixing of the liquids and thereby an equally good extraction in all the interspaces. This is so because the forces acting to mix the liquids are increased through the speed gradients thus increased between the liquids, whereby a counteractant is obtained to the increased separating effect. The reduced spacing between the outer cylinders makes the channel area smaller, but in addition to this the channel area can be further reduced by reducing the pitch of the screw-shaped bands. Bands may be inserted in the chamber 20, in the same manner as the bands 25 in the interspaces 8.

The embodiment shown in FIG. 2 is suitable for treating one sludge-containing liquid with another. In this embodiment, which is essentially similar to the embodiment according to FIG. 1, the cylinders 5 are replaced by slightly conical mantles 27. The wide and narrow ends of these mantles are alternately engaged with the same end part 6*a* or 7*a*, so that the sludge (which is assumed to be heavier than the heavy liquid) will be entrained by the heavy liquid flow along a generally zigzag path along the surfaces of the mantles 27 from the inlet holes 16 in the end part 7*a* and out to the holes 9 in the outermost mantle. From the latter, the sludge is carried along the inside of the rotor wall to the edge 21 and is discharged with the heavy liquid through the outlets 22, 23. With the conical mantles 27 as shown, the sludge path along the inner surfaces of the mantles is in a radially outward direction throughout, thus facilitating outward flow of the heavy sludge.

As it is desirable to keep the flow speed in one and the same mantle interspace 8*a* fairly equal, the pitch of the corresponding spiral band 25*a* must be varied owing to the conicity of the mantles 27. More particularly, this pitch must be varied so that it becomes smaller in the wider part of the respective interspace, whereby the channel area 26*a* in one and the same interspace is substantially constant.

The communication openings 9 are distributed around

the peripheries of the mantles. By providing these openings in sufficiently large number, the sum of the areas of the openings may be made at least as large as the cross sectional area of one of the channels 26*a* which they connect. This ensures that the channels 26*a* in the various interspaces will merge with each other without a throttling effect.

As shown in FIG. 3, each spiral band 25 may be provided with radially extending slots 28 permitting the liquids to take short cuts from a channel convolution to the next one lying above or below. The purpose of this is to intensify the extraction process by further mixing up of the liquids. The reduction of the path of inter-liquid contact, which is the result of these slots, may be counteracted by a corresponding reduction of the band pitch.

In FIGS. 4 and 5, we have shown two alternatives as regards the extension of the spiral or screw-shaped bands 25 to the rotor end parts. In FIG. 4, the bands 25 are shown extending up to the upper end part 7, whereby they will contribute to bringing the liquid, which enters the corresponding interspace 8, into rotation. As shown in FIG. 5, however, the portion of the interspace 8 near the upper end part 7 is free from bands. The purpose with the latter measure is to cause sliding of the liquids entering an interspace, so that an increased mixing and an intensified extraction are obtained.

The bands 25 in FIG. 6 are shown with attached projections 29 extending over the whole or part of the band width and secured to the flanges, preferably through welding, by means of flanges 30 on the projections. The projections thus throttle the channel throughflow area, as counted in the axial direction of the rotor, so as to cause an increased mixing of the liquids.

In FIG. 6, it has been assumed that the projections 29 extend in the radial direction of the rotor. A desired improved mixing of the liquids may be obtained, however, of the projections 29, as shown in FIG. 7, are arranged to extend obliquely in relation to the radial direction. The dash-dotted line 31 in FIG. 6 indicates the boundary surface between the two liquids, while the arrows show how one liquid or the other is deflected by the projections 29. This disturbance of the liquid layer formation contributes to the mixing of the liquids.

In case of a low surface tension between the two liquids, too intensive a mixing, as at the mantle ends, may cause formation of an emulsion which is difficult to separate. In FIG. 8, we have shown an embodiment for avoiding such mixing and emulsion formation as the liquids pass from one interspace 8 to the next. In the embodiments described above, the different liquids must pass one another in opposite directions through the holes 9, while being mixed with one another. More exactly, when the hole size is moderate, one liquid passes through certain holes 9 and the other liquid through the other holes, one liquid passing through a layer of the other liquid after it has passed through a hole. If it is desired to avoid this, the holes 9 are caused to open at a level (as counted radially) which is displaced a distance into the next interspace, as by means of pipe sockets 32 or the like. Because the pipe sockets 32 extend alternately from one side and the other of a mantle 5, either liquid will pass to the corresponding liquid layer in the adjacent interspace without being mixed with the other liquid to any substantial degree. The effect of this arrangement is improved by maintaining fixed liquid levels in the interspaces 8 by means of the flanges 24 mentioned earlier.

According to the invention, it is also possible to introduce into the apparatus a third fluid which is soluble in one or both of the other fluids. The supply of the third fluid should take place in a mantle interspace situated between those interspaces into which the other fluids are introduced.

It may finally be mentioned that in treating sludge-

containing liquids, it may be desirable to facilitate removal of the sludge from the rotor by providing the rotor wall with outlet nozzles (not shown), as in centrifugal separators.

We claim:

1. In a centrifugal apparatus for flowing two fluids of different specific gravity in contact with each other countercurrently, the combination of a hollow rotor having opposite end portions and a series of mantles disposed between said end portions concentrically to the rotor axis and spaced radially from each other to form a series of annular interspaces terminating at said end portions, said interspaces including innermost and outermost interspaces and intermediate interspaces, the rotor defining four separate passages, namely, a light fluid inlet passage leading directly only to an outer one of said intermediate interspaces, a heavy fluid inlet passage leading directly only to an inner one of said intermediate interspaces, a light fluid discharge passage leading directly from said innermost interspace and a heavy fluid discharge passage leading directly from said outermost interspace, the rotor having additional passages at one end portion connecting each alternate interspace to the next outer interspace and also having additional passages at the other end portion connecting each said alternate interspace to the next inner interspace, the rotor mantles being substantially imperforate between each said additional passage and the remote end portion of the rotor whereby the interspaces are interconnected in series through said additional passages, and spiral members disposed in said annular intermediate interspaces with the turns of said members extending generally radially of the rotor axis to form channels spiralling screw-fashion around the rotor axis from one of said end portions to the other, whereby each fluid flows in countercurrent intercontacting relation to the other fluid through the intermediate interspaces by way of said spiral channels and thence to its corresponding discharge passage by way of an interspace which is substantially free of the other fluid.

2. Apparatus according to claim 1, in which the throughflow area of each channel has a size varying between

$$\frac{A}{r^0} \text{ and } \frac{A}{r^{2.5}}$$

in which A represents a constant and r the distance of the channel area from the rotor axis.

3. Apparatus according to claim 1, in which the throughflow area of each channel has a size varying between

$$\frac{A}{r^{0.5}} \text{ and } \frac{A}{r^2}$$

in which A represents a constant and r the distance of the channel area from the rotor axis.

4. Apparatus according to claim 1, in which the mantles are cones, each spiral channel in each interspace having a varying pitch to provide the channel with a substantially constant throughflow area.

5. Apparatus according to claim 1, in which said additional passages form between each interspace and an adjacent interspace a throughflow area of at least the same area as the throughflow area of an adjacent channel.

6. In a centrifugal apparatus for flowing two fluids of different specific gravity in contact with each other countercurrently, the combination of a hollow rotor having opposite end portions and a series of mantles disposed between said end portions concentrically to the rotor axis and spaced radially from each other to form a series of annular interspaces terminating at said end portions, the rotor defining four separate passages, namely, a light fluid inlet passage leading to an outer interspace located at a substantial distance from the rotor axis, a heavy fluid inlet passage leading to an interspace located nearer said axis than said outer interspace, a light fluid discharge passage leading from an interspace near the rotor axis, and a heavy fluid discharge passage leading from an interspace near the rotor periphery, the rotor having additional passages at one end portion connecting each alternate interspace to the next outer interspace and also having additional passages at the other end portion connecting each said alternate interspace to the next inner interspace, the rotor mantles being substantially imperforate between each said additional passage and the remote end portion of the rotor whereby the interspaces are interconnected in series through said additional passages, and spiral members disposed in said annular interspaces with the turns of said members extending generally radially of the rotor axis to form channels spiralling screw-fashion around the rotor axis from one of said end portions to the other, said spiral members having openings forming short-cut paths between adjacent turns of said spiral channels.

7. In a centrifugal apparatus for flowing two fluids of different specific gravity in contact with each other countercurrently, the combination of a hollow rotor having opposite end portions and a series of mantles disposed between said end portions concentrically to the rotor axis and spaced radially from each other to form a series of annular interspaces terminating at said end portions, the rotor defining four separate passages, namely, a light fluid inlet passage leading to an outer interspace located at a substantial distance from the rotor axis, a heavy fluid inlet passage leading to an interspace located nearer said axis than said outer interspace, a light fluid discharge passage leading from an interspace near the rotor axis, and a heavy fluid discharge passage leading from an interspace near the rotor periphery, the rotor having additional passages at one end portion connecting each alternate interspace to the next outer interspace and also having additional passages at the other end portion connecting each said alternate interspace to the next inner interspace, the rotor mantles being substantially imperforate between each said additional passage and the remote end portion of the rotor whereby the interspaces are interconnected in series through said additional passages, spiral members disposed in said annular interspaces with the turns of said members extending generally radially of the rotor axis to form channels spiralling screw-fashion around the rotor axis from one of said end portions to the other, and projections on said spiral members extending into said channels for throttling their throughflow areas.

8. Apparatus according to claim 7, in which each of said projections extends obliquely relatively to an intersecting radius from the rotor axis.

9. In a centrifugal apparatus for flowing two fluids of different specific gravity in contact with each other countercurrently, the combination of a hollow rotor having opposite end portions and a series of mantles disposed between said end portions concentrically to the rotor axis and spaced radially from each other to form a series of annular interspaces terminating at said end portions, the rotor defining four separate passages, namely, a light fluid inlet passage leading to an outer interspace located at a substantial distance from the rotor axis, a heavy fluid inlet passage leading to an interspace located nearer said axis than said outer interspace, a light fluid discharge passage leading from an interspace near the rotor axis, and a heavy fluid discharge passage leading from an interspace near the rotor periphery, the rotor having additional passages at one end portion connecting each alternate interspace to the next outer interspace and also having additional passages at the other end portion connecting each said alternate interspace to the next inner interspace, the rotor mantles being substantially imperforate between each said additional passage and the remote end portion of the

rotor whereby the interspaces are interconnected in series through said additional passages, and spiral members disposed in said annular interspaces with the turns of said members extending generally radially of the rotor axis to form channels spiralling screw-fashion around the rotor axis from one of said end portions to the other, the radial spacing between said mantles and the pitches of the respective spiral members being correlated to provide the spiral channels with cross-sectional areas which decrease toward the rotor periphery.

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