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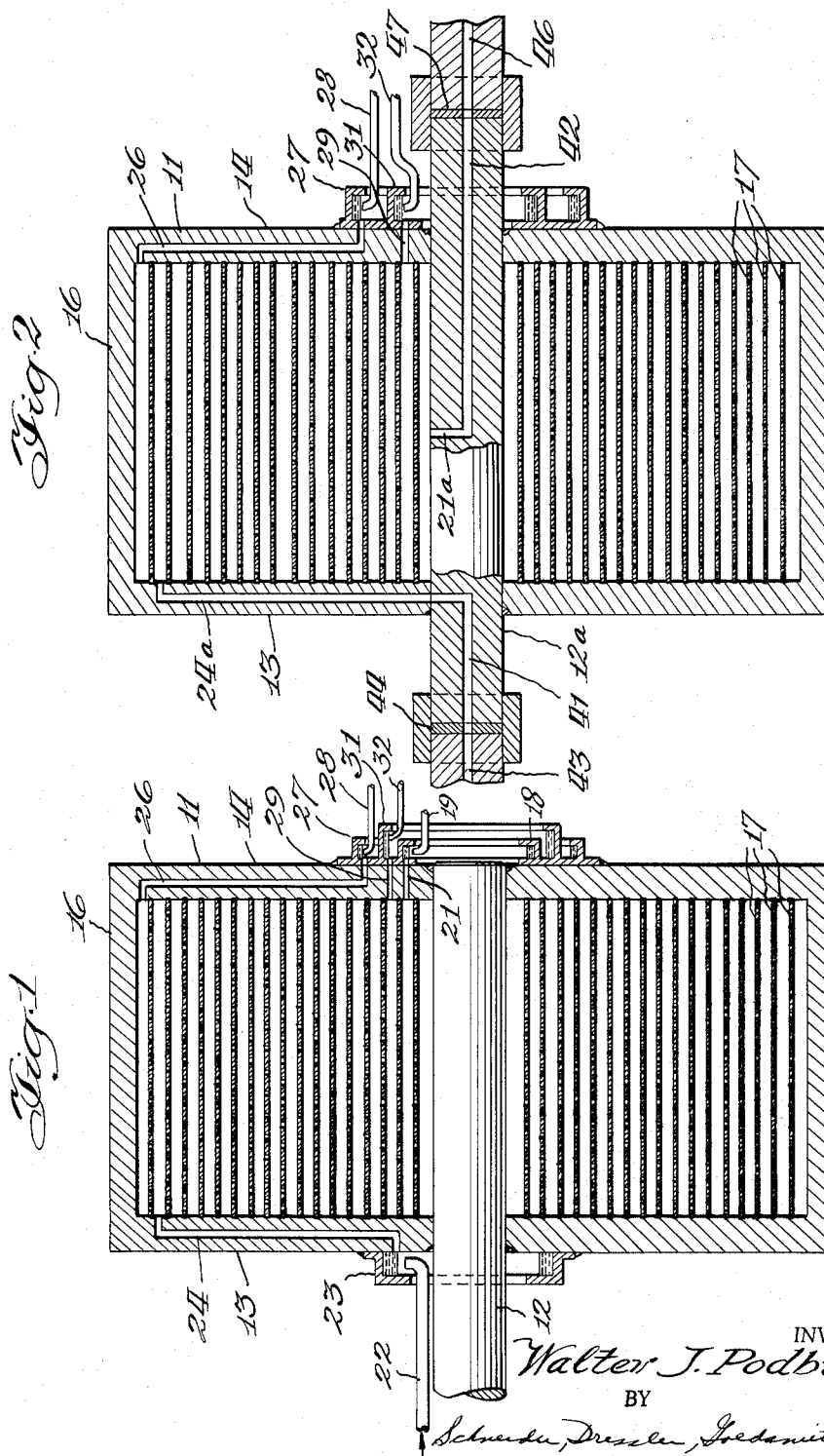
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LIQUID CONTACT PROCESS AND APPARATUS

Filed Jan. 7, 1963

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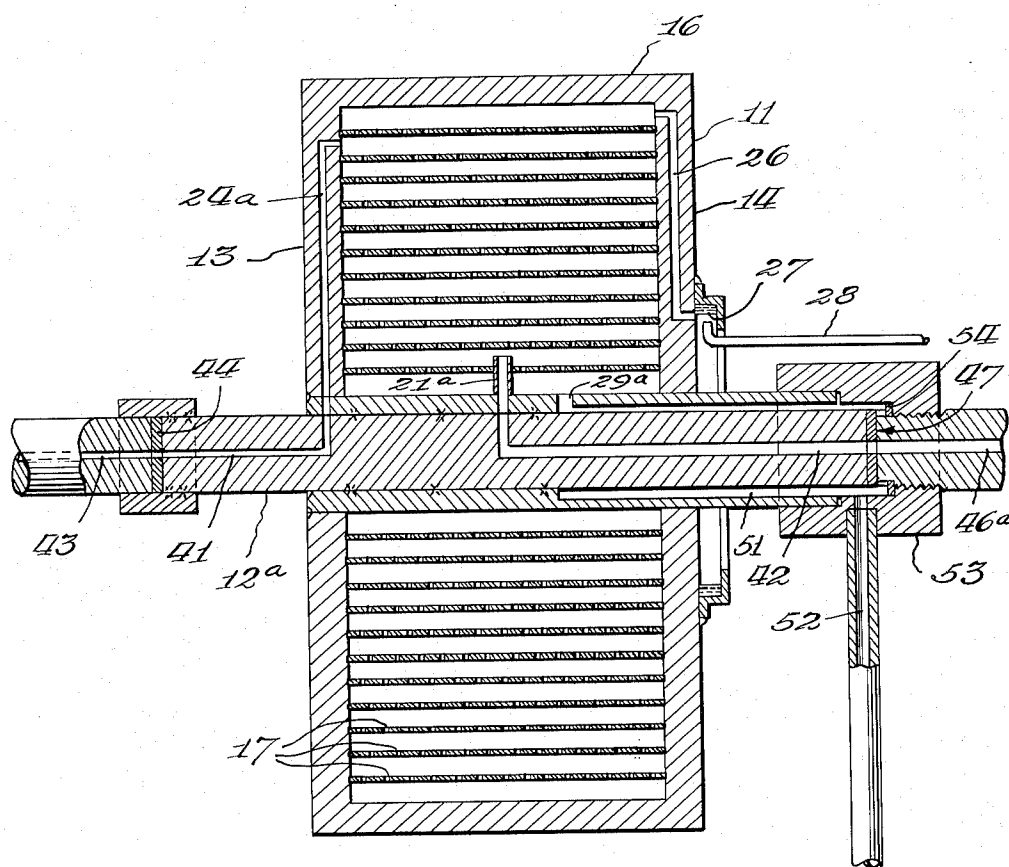
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Fig. 3



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LIQUID CONTACT PROCESS AND APPARATUS
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8 Claims. (Cl. 233—15)

This invention relates to improvements in centrifugal countercurrent liquid contact apparatus and in processes wherein two immiscible liquids of different densities are brought into countercurrent contact with each other in such apparatus.

Countercurrent contact apparatus having an interior working space and having partial barriers to radial flow within the working space are well known in the art. Apparatus wherein the partial barriers are substantially cylindrical perforated walls and particularly concentric perforated rings or a perforated spiral are particularly well suited for countercurrent contact. A typical apparatus utilizing concentric rings is described in my U.S. Patent No. 2,670,132, of February 23, 1954. A typical centrifugal countercurrent contact apparatus using a perforated spiral to provide the barriers is described in my U.S. Patent No. 2,286,157, of June 9, 1942. Centrifugal countercurrent contact apparatus which rotates about a horizontal axis is advantageous in several respects over apparatus which rotates about a vertical axis, particularly in apparatus having substantially cylindrical walls as the partial barriers.

In centrifugal countercurrent contact apparatus rotating about a vertical axis and having cylindrical barrier walls, it is difficult to maintain a uniform liquid layer in contact with such walls because of the effect of gravity, acting in a direction parallel to the walls. A layer of liquid against a vertical cylindrical wall in a contact apparatus which rotates about a vertical axis tends to be thicker at the bottom than at the top. In apparatus rotating about a horizontal axis, there is no such tendency.

In centrifugal countercurrent contact apparatus rotating about a horizontal shaft, it has been the practice to introduce and withdraw the separate liquid streams through paths at or near the axis or shaft. Where two inlet and two outlet streams are to be accommodated, it has been the practice to provide in the shaft an axial passageway extending toward the working space from each end of the shaft and an annular passageway concentric with each axial passageway and also extending inwardly from each end of the shaft.

Seals are required between the stationary and rotating elements of each of the four paths described and such seals, and particularly the seals for the annular paths, represent a problem both in the manufacture of the apparatus and in the maintenance thereof.

In accordance with this invention one or more of the seals described above may be eliminated to simplify the construction and the maintenance of centrifugal countercurrent contact apparatus rotating about a horizontal axis.

In accordance with this invention a concave annulus is provided in at least one of the supplying and discharging means which usually require a seal. The annulus is rotatable on the horizontal axis of the apparatus and communicates with the interior working space. The annulus provides a barrier to liquid flow radially outward and has a continuous circular opening radially inward of the barrier. There is a stationary conduit for liquids which communicates with the interior of the concave annulus through the continuous circular opening.

For convenience, this invention will be described with reference to the figures, of which:

FIGURE 1 is a longitudinal view of the countercurrent contact apparatus, largely in cross section taken through

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the axis thereof in accordance with one embodiment of this invention;

FIG. 2 is a longitudinal cross section similar to FIG. 1 but represents a different embodiment; and

FIG. 3 is a longitudinal cross section similar to FIGS. 1 and 2 and representing still another embodiment.

In the figures similar elements are identified by similar numerals.

Referring to the drawings, rotor 11 includes rotatable shaft 12, mounted and driven to rotate at a high rate of speed, for example, from about 1,000 to 5,000 r.p.m. or even higher. The shaft is maintained in a horizontal direction and serves as axis to the remainder of the rotor structure. The supporting means and mounting means are not shown.

The rotor is formed as a cylindrical casing made up of two side plates 13 and 14 and a peripheral cylindrical member 16 rigidly secured to each other and to the shaft to form a closed chamber.

Within the closed chamber, annular passageways of progressively increasing radius are provided. The passageways are preferably formed by concentric rings or bands 17 which are perforated to permit limited flow of liquid in a radial direction but which provide substantial barriers to such flow. The distance between the bands may vary considerably from about 0.15 inch to about 2 inches depending on the physical properties of the liquids to be contacted. If desired the distance between bands may be varied, for example, by making the distance between bands a function of the radial distance of the axis of rotation, as shown in my U.S. Patent No. 2,670,132, referred to above.

For introduction of heavy liquid within the rotor, there is provided a concave annulus 18 attached to the exterior of side member 14. The concave annulus has a cylindrical wall, outermost with respect to the rotor axis and a lip portion directed radially inward from the cylindrical wall. Conduit 19 communicates with the interior of the concave annulus and permits heavy liquid to be supplied thereto. The annulus has a continuous circular opening facing inwardly so that there is no contact between the annulus and the conduit despite the fact that the latter is stationary while the former is rapidly rotating.

Heavy liquid passed into the annulus through conduit 19 is forced outwardly by centrifugal force to form an annular body of liquid. The liquid passes into the interior of the rotor from annulus 18 through conduit 21.

Light liquid is introduced into the rotor through conduit 22, annulus 23 and conduit 24 in the same manner as the heavy liquid, except that conduit 24 extends to the exterior portion of the rotor so that the light liquid may be introduced near the periphery of the rotor.

During the operation of the countercurrent extraction process the light liquid passes inwardly through the perforated rings from passageway to passageway while the heavy liquid passes outwardly, producing excellent countercurrent contact between the two liquids. Heavy liquid which has worked its way outwardly to the outermost portion of the rotor passes through conduit 26 into concave annulus 27. In annulus 27 an annular body of liquid is maintained by the high rate of rotation with fresh liquid continuously supplied through conduit 26 and with liquid continuously withdrawn through conduit 28. Conduit 28 communicates with the interior of the annulus and serves as a stationary skimmer to maintain the thickness of the annular liquid body at the desired level.

Light liquid which has passed toward the axis of the rotor is withdrawn through conduit 29, concave annulus 31 and conduit 32 in a similar manner.

In addition to the advantage discussed above in the elimination of seals, the above described construction also

permits operation of the centrifugal countercurrent contact apparatus at lower inlet pressures than prior apparatus and also eliminates the necessity for controlling the pressure on the light liquid outlet line.

In the conventional apparatus, where seals are used, all inlets and outlets are located at or near the axis since such locations are the only mechanically practical locations. Of necessity such construction produces pressure differentials which must be overcome to provide the desired liquid flow. One of the pressure differentials in the prior art centrifugal countercurrent contact apparatus is the differential between the pressure at the light liquid inlet and the pressure at the heavy liquid outlet.

In analyzing the pressure requirements of a centrifugal countercurrent contact process, the conduit between the light liquid inlet and the periphery of the interior working space and the conduit between the heavy liquid outlet and the periphery of the interior working space may be considered as the legs of a manometer. In the usual apparatus involving seals these legs are of about equal length. Since the leg leading from the light liquid inlet contains only light liquid, it exerts less pressure than the leg leading to the heavy liquid outlet since the latter leg contains liquid having a higher density. In order to force light liquid into the system, there must be sufficient pressure behind the light liquid stream to overcome the difference in pressure between the two manometer legs. In the usual centrifugal countercurrent contact apparatus the heavy liquid outlet is at about atmospheric pressure while the light liquid is maintained at about 100 p.s.i.g. to overcome pressure differential.

In the seal-less construction described above the heavy liquid outlet passes through a liquid annulus rather than through a seal. The necessity for having the heavy liquid outlet at or near the axis is obviated by this construction. The heavy liquid annulus may be located radially at any desired position and is preferably located at a position outward from the axis to provide a shorter manometer leg from the periphery for the heavy liquid. If the heavy liquid leg is shorter than the light liquid leg in generally inverse proportion to its density the manometer is in balance and the only pressure required at the light liquid inlet is pressure sufficient to overcome internal resistance in the apparatus.

In conventional centrifugal countercurrent contact apparatus there are a series of interfaces between light liquid and heavy liquid, one interface in each space between the concentric rings. All of the interfaces, except one, are maintained in a state of unstable pressure equilibrium and are termed "auxiliary interfaces." In each auxiliary interface, one of the layers of liquid (the layer of the liquid flowing toward the pressure equilibrium position) is a very thin layer.

One interface, called the "principal interface" is in a state of stable pressure equilibrium and has liquid layers of substantial thickness on both sides thereof. The principal interface is in a position which may be varied, as desired, by controlling the pressures in the conduit lines, and particularly the pressure in the light liquid outlet.

A relatively high pressure in the light liquid outlet, approaching the pressure at the light liquid inlet will assure an average density in the extractor approaching that of the light liquid in the light liquid incoming conduit.

The pressure developed in the light liquid incoming conduit must also balance the pressure developed in the working space of the rotor in order for incoming flow to take place. This may be considered as a second manometer with the light liquid in the inlet conduit as one leg and a column of liquid in the working space as the other.

When the pressure in the light liquid outlet necessitates an average liquid density in the working space approaching that of the light liquid, the principal interface is in a

position close to the periphery and the heavy liquid layers at the auxiliary interfaces are thin.

Conversely, when the pressure in the light liquid outlet is relatively low, approaching that of the heavy liquid outlet, then the average density of liquid in the extractor must be close to the density of heavy liquid in the heavy liquid outgoing conduit. In such a case the principal interface is close to the axis and the layers of light liquid at the auxiliary interfaces are thin.

In the apparatus described, the effective pressure at the light liquid outlet can be controlled by the distance of the annulus in the light liquid outlet, obviating the necessity for valve control and for the presence of a valve in the conduit.

Mechanical means for controlling the radial position of the annulus will be apparent to those skilled in the art. Limited adjustment is readily obtained by controlling the radial position of the inlet to conduit 32 which acts as a skimmer and controls the position of the inner free surface of the annulus. Adjustment of the radial position of the light liquid annulus to a greater degree is possible by providing a series of annuluses 31 on one or both side plates at different radial distances from the shaft, each annulus with a conduit 32 to the interior of the rotor with all but one of the conduits plugged up during operation. In general, the mechanisms for radial adjustment of the annulus are not novel per se and are similar to the adjustment mechanisms known in the art in other apparatus utilizing skimming devices.

The embodiment of FIG. 2 is generally similar to that of FIG. 1 except that it uses central passageways in the shaft for liquid inlets and utilizes concave annuluses exterior to the side members of the rotor only in connection with liquid outlets.

In centrifugal countercurrent contact apparatus where in separate liquid streams are introduced and withdrawn at or near the shaft, and in which axial passageways and annular passageways are provided, it is the annular passageways which provide the principal mechanical difficulties with respect to seals. Where only axial passageways are required, as in the construction of the embodiment of FIG. 2, only relatively simple seals are required and the principal benefits of this invention with respect to the elimination of seals are obtained.

In the embodiment of FIG. 2 rotor plates 13 and 14, peripheral cylindrical member 16, and concentric rings 17 are similar to the identically numbered elements of FIG. 1. Rotatable shaft 12a is generally similar to shaft 12 of FIG. 1 except that it contains an axial passageway 41 to provide an inlet for light liquid on the left (as seen in FIG. 2) and a passageway 42 to provide an inlet for heavy liquid on the right (as seen in FIG. 2). Light liquid is introduced through stationary conduit 43 maintained in juxtaposition to the left end of shaft 12a and separated therefrom by seal 44.

Similarly on the right end heavy liquid is introduced through stationary conduit 46 maintained in juxtaposition to the right end of shaft 12a and separated therefrom by seal 47.

The light liquid passageway 41 leads to a radial passageway 24a within side plate 13 so that light liquid may be led to a position near the periphery of the working space of the rotor.

The heavy liquid entering through its annular passageway passes to a short radial conduit 21a leading to the interior of the working space at a position near the axis.

The heavy liquid passes outwardly through the perforated rings countercurrently to light liquid moving toward the shaft. When the heavy liquid approaches the periphery of the rotor it passes through conduit 26 into concave annulus 27, similar to identically numbered elements of FIG. 1. Similarly light liquid is withdrawn through conduit 29 into concave annulus 31. The heavy liquid in annulus 27 is continuously withdrawn through stationary conduit 28 and light liquid in annulus 31 is

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continuously withdrawn through conduit 32 in a similar manner to that described above in connection with FIG. 1.

The embodiment of FIG. 2 not only permits the elimination of the most troublesome seals but also permits operation at lower light liquid inlet pressure since the length of the heavy outlet leg can be made shorter to compensate for its higher density, as described above.

The construction of FIG. 2 is particularly suitable for operations in which the principal interface is maintained close to the axis so that the average density of a column of liquid in the rotor is close to the density of the heavy liquid.

In the construction of FIG. 2 the length of the manometer leg of the heavy liquid outlet conduit can be shortened by moving the heavy liquid annulus outward, away from the shaft. When the heavy liquid outlet conduit leg is shorter than the light liquid inlet conduit leg in inverse proportion to the density of the liquids there is no pressure requirement at the light liquid inlet with respect to overcoming the difference in head in this manometer.

A second manometer may be considered to exist in which a column of liquid within the rotor working space is balanced against the column in the light liquid inlet conduit. When the principal interface is maintained at an inner position, close to the axis, most of the working space is filled with heavy liquid and the manometer leg within the working space has a higher average density than the manometer leg of the light liquid inlet conduit. The construction of FIG. 2 permits adjustment of the length of the manometer leg within the rotor working space by displacement of the light liquid outlet annulus with respect to its radial distance from the shaft. The light liquid outlet annulus may be placed so that the length of the manometer leg within the rotor working space is shorter in the manometer leg in the liquid inlet conduit in inverse proportion to the densities of the liquids in the legs.

Another modification of this invention is shown in FIG. 3 which is generally similar to that of FIG. 2 except that the light liquid outlet annulus of the embodiment of FIG. 2 is replaced by an annular passageway in the shaft which surrounds the axial passageway serving as heavy liquid inlet. In the construction of FIG. 3, elements identical with those of FIGS. 1 and 2 are designed by identical numerals. The flow of liquids through the apparatus of FIG. 3 is substantially similar to that of FIG. 2 except that in place of conduit 29 leading to light liquid outlet annulus 31 and thence to skimmer conduit 32, as in FIG. 2, there is a conduit 29a leading to the annular passageway 51 and through outlet pipe 52. The heavy liquid inlet pipe 46a and the light liquid outlet pipe 52 are located in a stationary cap 53 in which the end of shaft 12a is mounted. Suitable sealing means 54 are provided to prevent leakage of light liquid from the system.

The construction of the apparatus of FIG. 3 eliminates only one of the annular seals of the conventional construction and, in this respect, is not as advantageous as the embodiments of FIGS. 1 and 2 which eliminate both annular seals. However, the embodiment of FIG. 3 permits operation of the centrifugal countercurrent contact apparatus at lower light liquid inlet pressures than prior art centrifugal countercurrent contact apparatus and is particularly suited to operations wherein the principal interface is maintained at a position close to the periphery of the apparatus.

Since the heavy liquid outlet annulus may be located at any desired distance from the axis the manometer system involving the heavy liquid outlet conduit may be balanced readily as discussed above. The second manometer system involving the column of liquid within the rotor working space is also easily balanced since the working space is substantially filled with light liquid when the principal interface is near the periphery. Thus, the only pressure required at the light liquid inlet is pressure

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sufficient to overcome the internal resistance of the system and to overcome whatever back pressure may be maintained on the light liquid outlet by a pressure adjustment valve (not shown) on light liquid outlet conduit 52. In the embodiment of FIG. 3 a pressure adjustment valve on the light liquid outlet conduit is usually required.

While the invention has been described with respect to particularly illustrated embodiments it is to be understood that other embodiments may be employed if desired. The inlet or outlet annuluses may be disposed upon either wall or both walls of the rotor, as desired, and may be modified in size or shape to meet process requirements. Radial conduits 24, 24a, 26, 21a and 29a and conduits 21 and 29 may be pluralized as required, as may the stationary conduits 19, 22, 28 and 32.

In addition, while the invention has been described with particular reference to centrifugal countercurrent contact apparatus in which concentric cylindrical barriers are maintained within the working space, it is to be understood that other types of partial barriers such as a perforated spiral or packing or gauze may be used without departing from the essence of this invention.

The above detailed description of this invention has been given for clearness of understanding only. No unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. In a centrifugal countercurrent contact apparatus for effecting intimate contact between at least partially immiscible liquids of different densities having a rotor rotatable on a horizontal axis with an interior working space, said rotor having a plurality of partial barriers to radial flow within the working space, means for supplying lighter liquid to the interior of the rotor in the proximity of its periphery, means for supplying heavier liquid to the rotor in the proximity of its axis, and separate means for discharging heavier liquid and lighter liquid from said rotor, each of said supplying means and said discharging means including stationary and rotatable elements; the improvement which comprises a concave annulus in at least one of said supplying and discharging means, said annulus being rotatable on said horizontal axis and communicating with said interior working space, said annulus providing a barrier to liquid flow radially outward therefrom and a continuous circular opening radially inward of said barrier, and a stationary conduit for liquids communicating with the interior of said concave annulus through said opening.

2. The centrifugal countercurrent contact apparatus of claim 1 wherein said stationary conduit which communicates with the interior of said concave annulus has a free end which is adjustable in position with respect to its radial distance from said axis.

3. In a centrifugal countercurrent contact apparatus for effecting intimate contact between at least partially immiscible liquids of different densities having a rotor rotatable on a horizontal axis with an interior working space, said rotor having a plurality of partial barriers to radial flow within the working space, means for supplying lighter liquid to the interior of the rotor in the proximity of its periphery, means for supplying heavier liquid to the rotor in the proximity of its axis, and separate means for discharging heavier liquid and lighter liquid from said rotor, each of said supplying means and said discharging means including stationary and rotatable elements, each of said supplying means including a seal between said stationary and said rotatable elements; the improvement which comprises a concave annulus in at least one of said discharging means, said annulus being rotatable on said horizontal axis and communicating with said interior working space, said annulus providing a barrier to liquid flow radially outward therefrom and a continuous circular opening radially inward of said barrier, and a stationary conduit for liquids communi-

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cating with the interior of said concave annulus through said opening.

4. In a centrifugal countercurrent contact apparatus for effecting intimate contact between at least partially immiscible liquids of different densities having a rotor rotatable on a horizontal axis with an interior working space, said rotor having a plurality of partial barriers to radial flow within the working space, means for supplying lighter liquid to the interior of the rotor in the proximity of its periphery, means for supplying heavier liquid to the rotor in the proximity of its axis, and separate means for discharging heavier liquid and lighter liquid from said rotor, each of said supplying means and said discharging means including stationary and rotatable elements, each of said supplying means and said discharge means for light liquid including a seal between said stationary and said rotatable elements; the improvement which comprises a concave annulus in said heavy liquid discharging means, said annulus being rotatable on said horizontal axis and communicating with said interior working space, said annulus providing a barrier to liquid flow radially outward therefrom and a continuous circular opening radially inward of said barrier, and a stationary conduit for liquids communicating with the interior of said concave annulus through said opening.

5. In a method for effecting countercurrent contact between at least partially immiscible liquids of different densities wherein a stream of heavy liquid is introduced into the interior of a centrifugal contacting zone which rotates about a horizontal axis and contains barriers to radial flow, a stream of light liquid is introduced into the interior of said centrifugal contacting zone, a stream of heavy liquid is withdrawn from said centrifugal contacting zone and a stream of light liquid is withdrawn from said centrifugal contacting zone and each of said streams includes a stationary portion and a rotating portion in its path, the improvement which comprises maintaining an annulus of liquid outside of said centrifugal contacting zone, rotating said annulus about the axis of the centrifugal contacting zone at the same rate as said zone, passing liquid between said annulus and said contacting zone and passing liquid between said annulus and a stationary conduit communicating therewith.

6. The method of claim 5 wherein a principal interface between said light liquid and said heavy liquid is maintained at a location near the periphery of said centrifugal contacting zone.

7. In a method for effecting countercurrent contact between at least partially immiscible liquids of different densities wherein a stream of heavy liquid is introduced through a sealed path into the interior of a centrifugal contacting zone which rotates about a horizontal axis and contains barriers to radial flow, a stream of light

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liquid is introduced through a sealed path into the interior of said centrifugal contacting zone near the periphery thereof, a stream of heavy liquid is withdrawn from said centrifugal contacting zone near the periphery thereof, and a stream of light liquid is withdrawn through a sealed path from said centrifugal contacting zone and each of said streams includes a stationary portion and a rotating portion in its path, the improvement which comprises maintaining an annulus of liquid outside of said centrifugal contacting zone, rotating said annulus about the axis of the centrifugal contacting zone at the same rate as said zone, passing heavy liquid to said annulus from said contacting zone and passing said heavy liquid from said annulus to a stationary conduit communicating therewith.

8. The method of claim 7 wherein said heavy liquid annulus is displaced from the axis sufficiently so that the radial length of the heavy liquid stream from the periphery of the centrifugal contacting zone to the annulus is related to the radial length of the rotating portion of the light liquid stream in approximate inverse proportion to the densities of the liquids in each stream.

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