United States Patent [19]
Hengstebeck

[11] **3,814,307**
[45] **June 4, 1974**

[54] **CENTRIFUGAL CLARIFIER**

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[73] Assignee: **Standard Oil Company,** Chicago, Ill.

[22] Filed: **Jan. 12, 1973**

[21] Appl. No.: **323,212**

[52] **U.S. Cl.** **233/31,** 233/43, 233/44, 233/15
[51] **Int. Cl.** **B04b 1/00**
[58] **Field of Search** 233/15, 27, 28, 29, 31, 233/37, 43, 46

[56] **References Cited**

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2,619,280	11/1952	Redlich	233/15
3,027,390	3/1962	Thurman	233/15 X
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FOREIGN PATENTS OR APPLICATIONS

129,569	4/1902	Germany	233/31

Primary Examiner—George H. Krizmanich
Attorney, Agent, or Firm—Claron N. White; Arthur G. Gilkes; William T. McClain

[57] **ABSTRACT**

A centrifugal clarifier for removal of contaminants from a liquid by centrifugally separating it into two liquid phases includes a rotor comprising a rotor shaft, a rotor housing mounted on the shaft to enclose an elongated intermediate portion of the shaft so as to provide around the shaft an elongated annular working space, and a set of cylindrical shells mounted in the housing and concentric with the shaft to provide elongated annular chambers of equal radial height within the working space for a set of flows of liquid parallel to the shaft but at different average radial distances from the shaft. Distributor means of the rotor extends radially from the shaft within one end portion of the housing and has openings at different radial distances from the axis of the shaft to furnish liquid separately to the chambers. Collector means of the rotor to receive one of the separated liquid phases extends radially from the shaft within the other end portion of the housing and has openings at different radial distances from the axis of the shaft to communicate with chambers. The total area of openings of the distributor means (or of the collector means when appropriate) communicating with a specific chamber is proportional to the square of the average radius of the chamber to provide a linear flow of liquid through each chamber proportional to the square of that average radius of the chamber. Collector means of the rotor for the other separated liquid phase is located between these end portions of the housing. A feed passageway in the shaft communicates with the distributor means. Outlet passageways in the shaft communicate with the two collection means. The clarifier has outlet pipes communicating with the outlet passageways. The outlet pipe that thereby communicates with one of the collector means to receive that liquid phase containing removed contaminant is valved to control the volume ratio of that liquid to the clarified liquid removed through the other outlet pipe. There may be a valve in that other outlet pipe to adjust overall flow rate through the parallel chambers in the working space when necessitated by a change of concentration of contaminants in the feed liquid.

26 Claims, 25 Drawing Figures

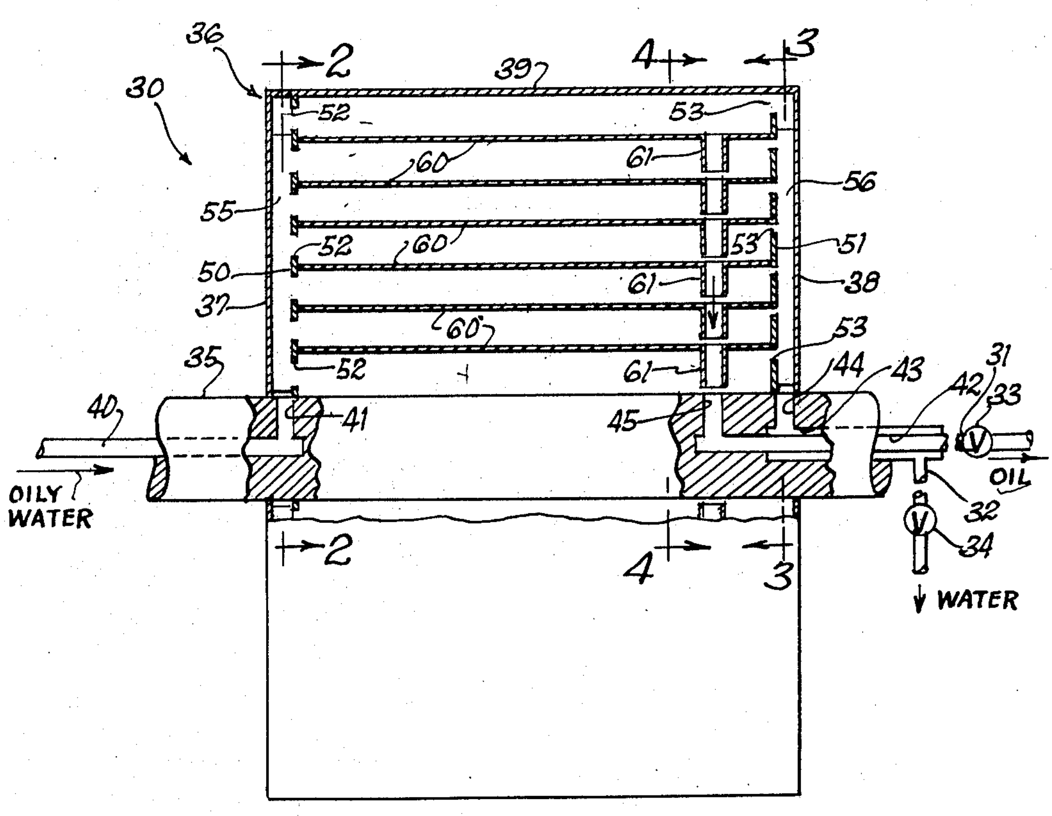


FIG. 1

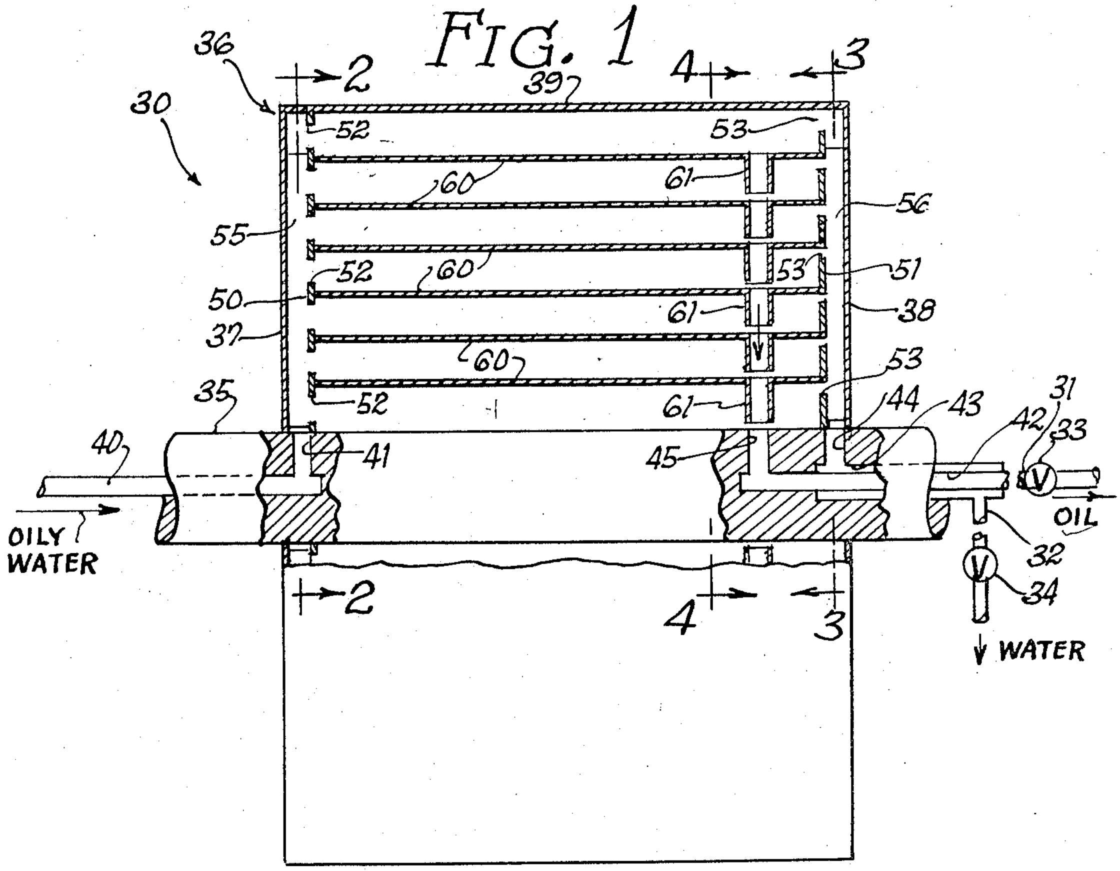


FIG. 2

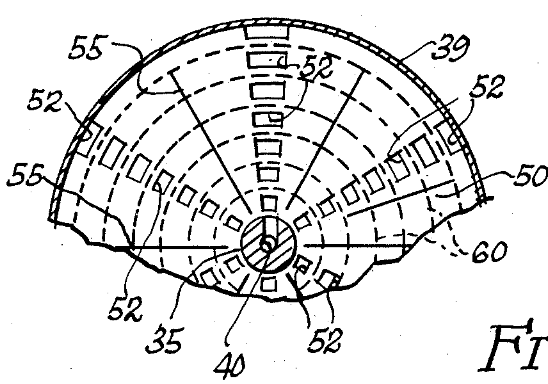


FIG. 3

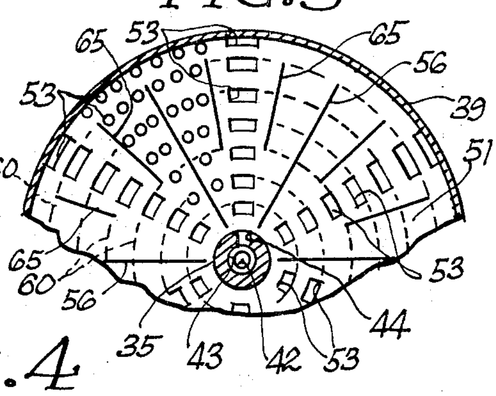


FIG. 4

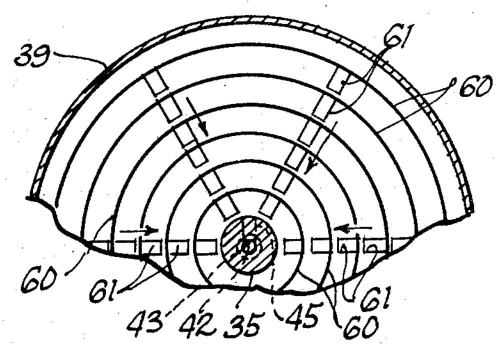


FIG. 5

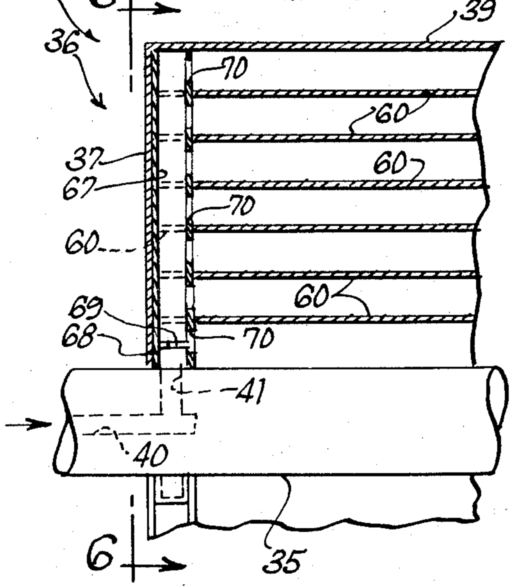


FIG. 6

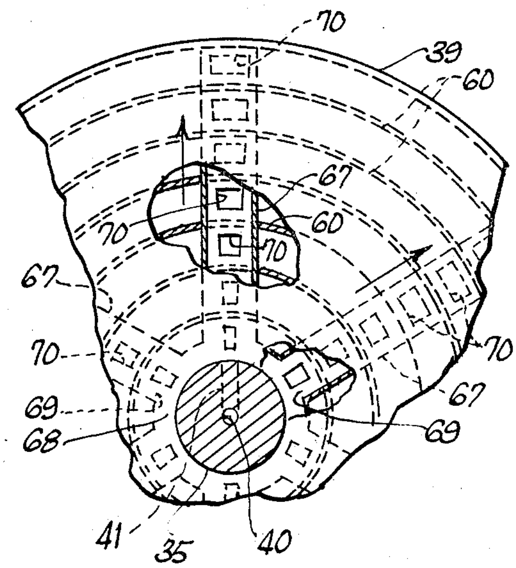


FIG. 7

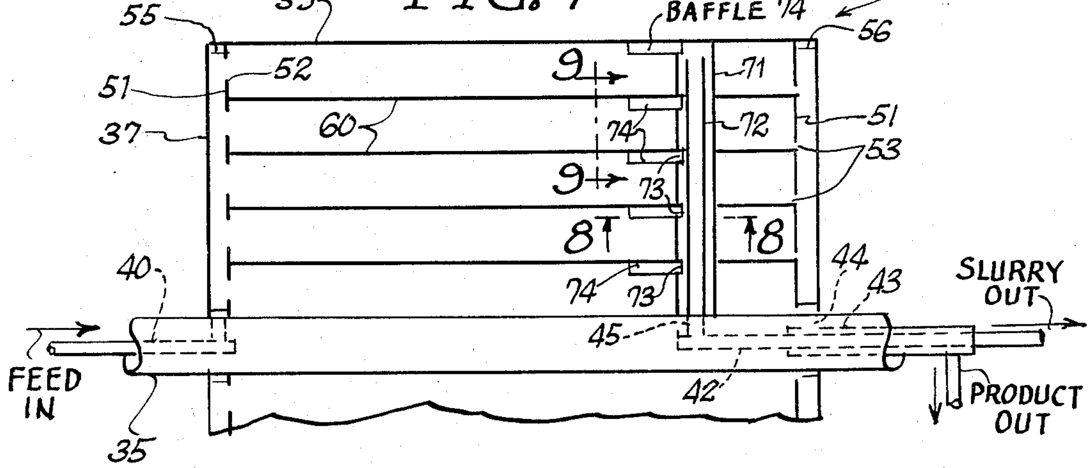


FIG. 8

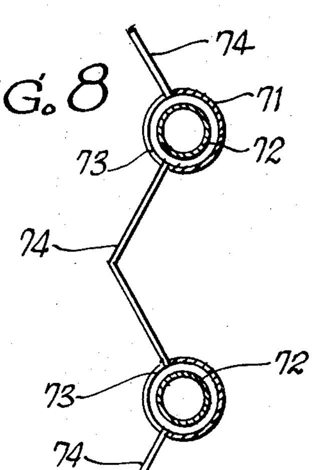


FIG. 9

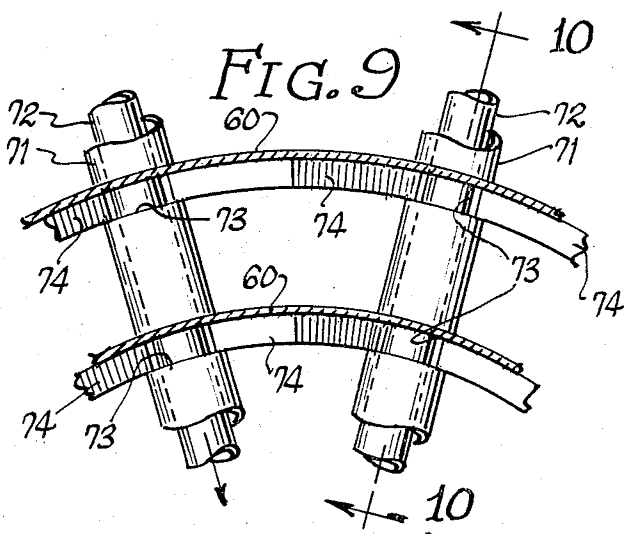


FIG. 10

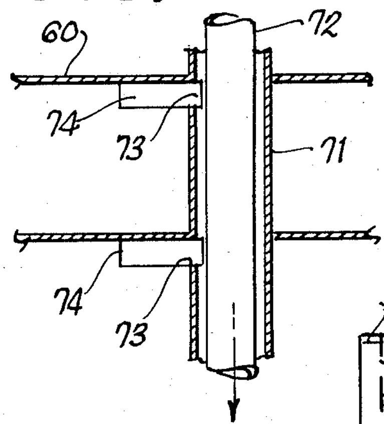


FIG. 11

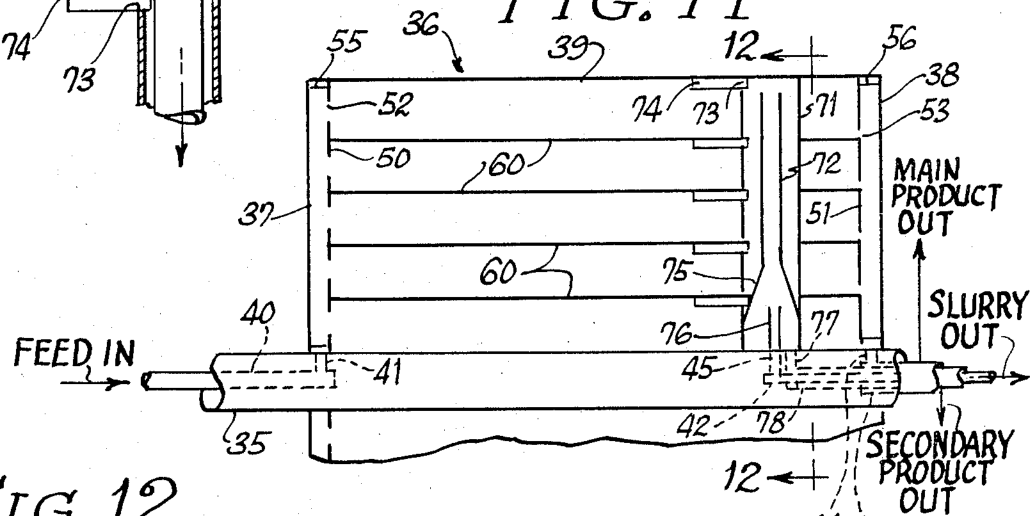


FIG. 12

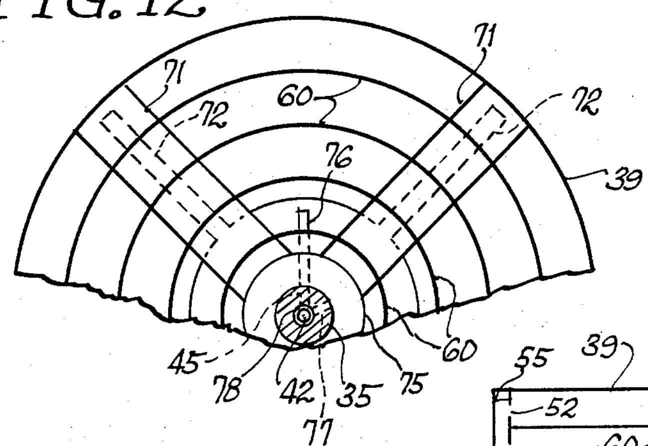


FIG. 13

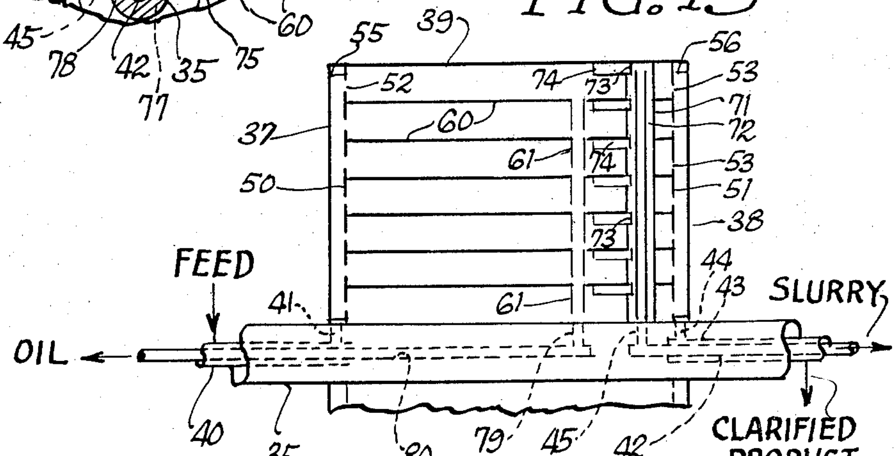


FIG. 14

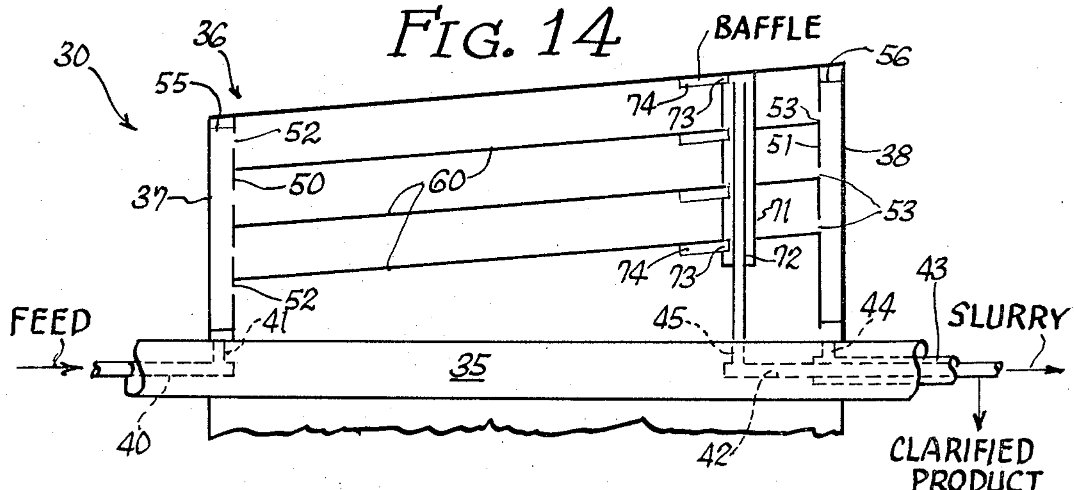


FIG. 15

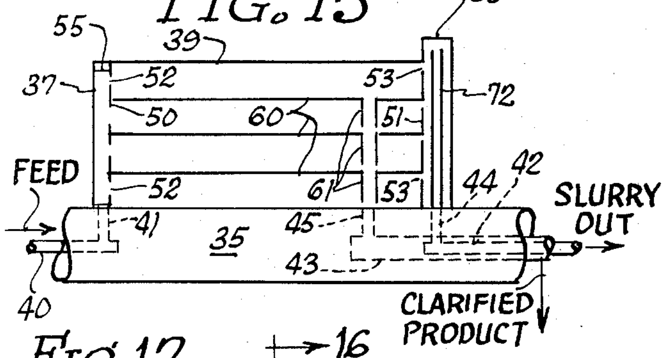


FIG. 16

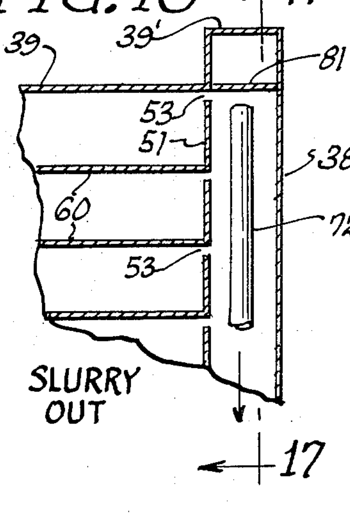


FIG. 17

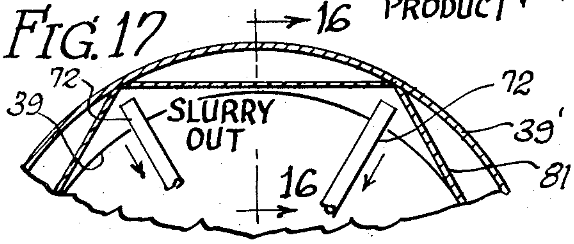


FIG. 18

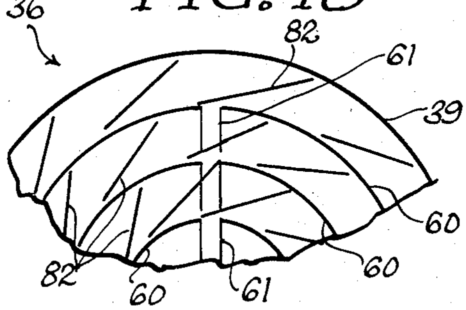


FIG. 19

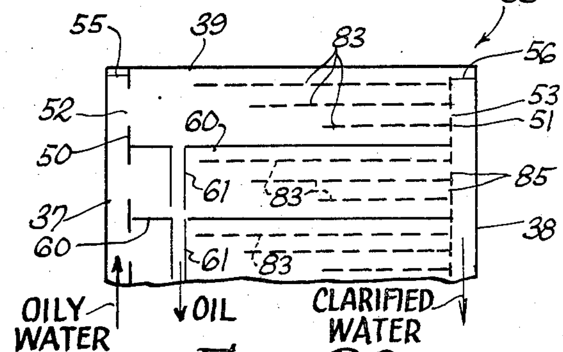


FIG. 21

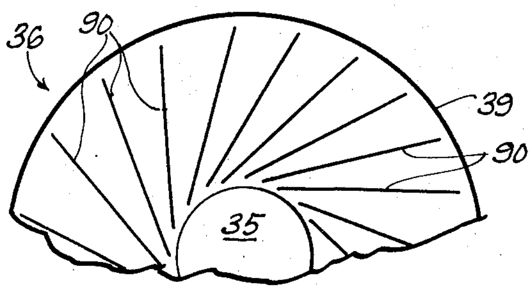


FIG. 20

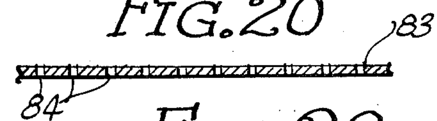


FIG. 22

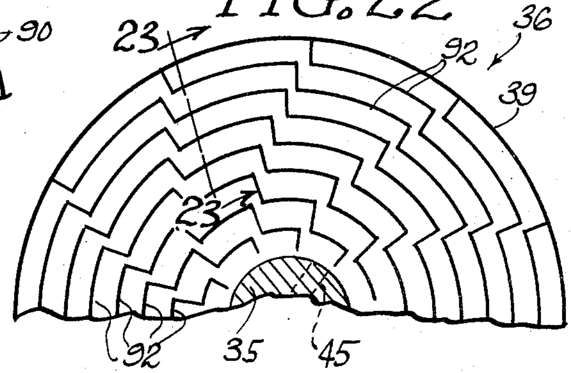


FIG. 23

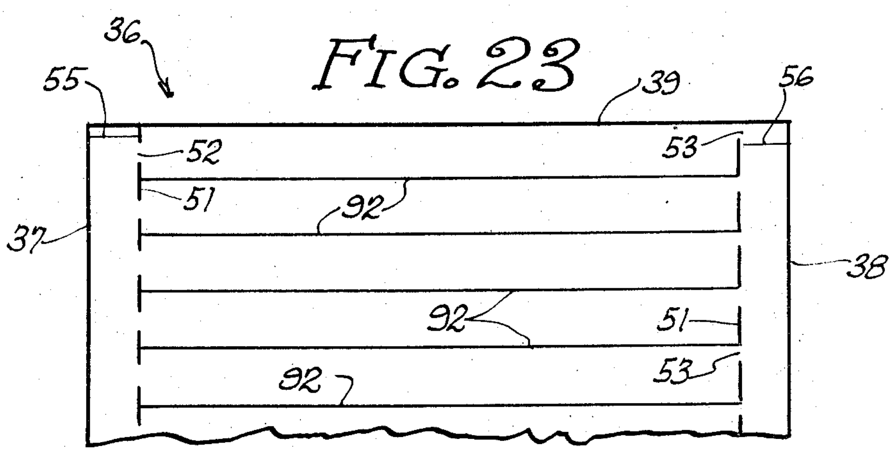
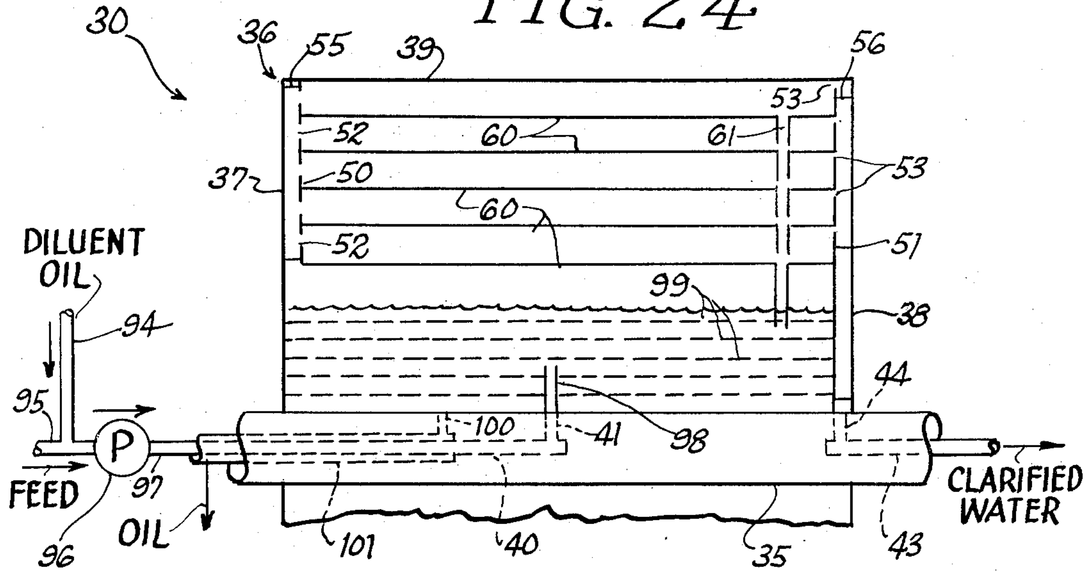


FIG. 24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DILUENT OIL
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FEED
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CLARIFIED WATER
OIL
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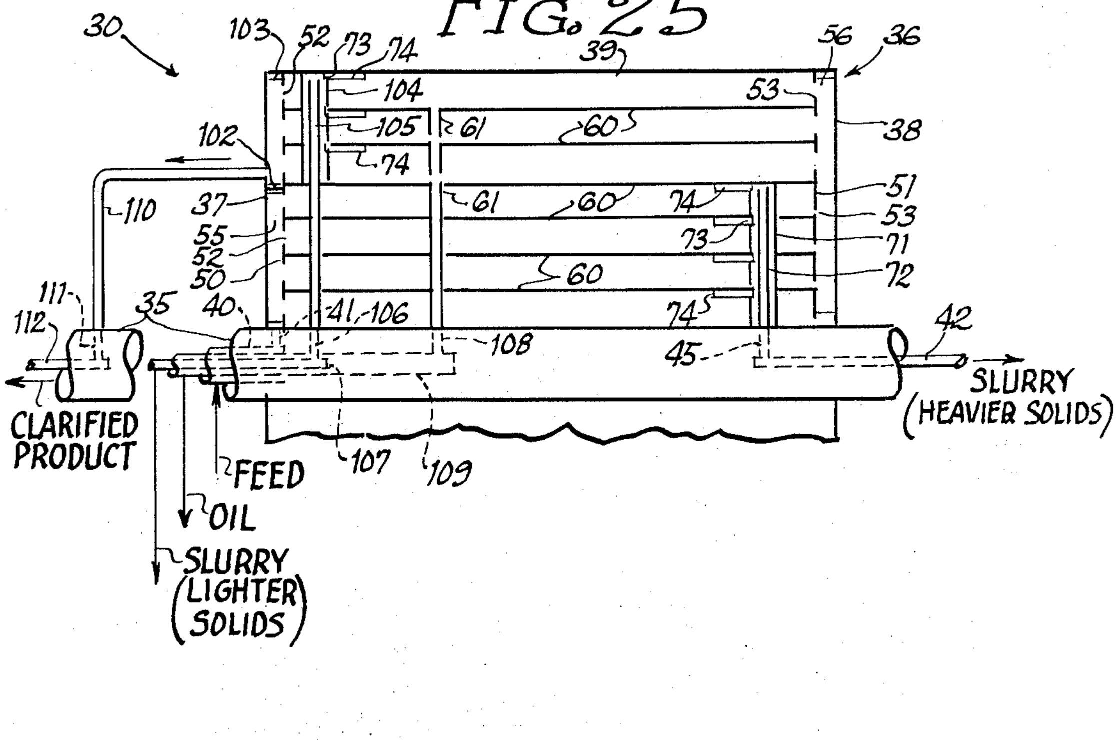
FIG. 25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CLARIFIED PRODUCT
FEED
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SLURRY (HEAVIER SOLIDS)
OIL
SLURRY (LIGHTER SOLIDS)

CENTRIFUGAL CLARIFIER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to centrifugal apparatuses useful to separate solids from liquids and immiscible liquids from each other, e. g., to separate small concentrations of solids or oil suspended in water. It especially relates to drum-type centrigugal clarifiers suitable to clarify liquids containing suspended contaminants, solids or liquid, in a concentration of less than 1 percent, e. g., containing as low as 100 parts or less of contaminant per million parts of liquid to be clarified.

Large volumes of water are used daily in petroleum refineries and, of course, thereby large volumes of waste water are obtained from the processing operations in these refineries. The former should be treated to reduce substantially the suspended solids content before use. To avoid environmental pollution the later should be treated to reduce contaminant content, imparted during refinery use of the water, before return of the water to the lakes or streams from which they gave been obtained. Filter plants and plants for clarification by air flotation have been built and used to treat daily tens of millions of gallons of process water containing, for example, 100 to 150 ppm of suspended solids, mostly silt and decayed solids, in river water, and 40 ppm of suspended solids and 80 ppm of oil in process waste water obtained originally from a lake.

2. Description of the Prior Art

Centrifugal devices or apparatuses for separating solids or immiscible liquids from liquids include drum-type centrifugal clarifiers that are modifications of centrifugal contactors, solid bowl centrifuges, basket-type centrifuges, and continuous disc-type centrifuges.

In a solid bowl centrifuge a slurry is thrown out to the walls of a rotating drum equipped with a screw conveyor to move the solids to one end of the drum. The drum and the screw conveyor rotate at different rates.

In basket-type centrifuges solids are retained on a rotating screen through which liquids pass.

Continuous disc-type centrifuges employ a series of rotating cones that divide the input feed liquid into thin layers. Detailed description is presented in the article "Centrifuging and centrifuges" in *Chemistry And Industry*, No. 9, May 6, 1972, published by the Society of Chemical Industry, London, England. Reference is made also to page 265 of the book by Brown entitled *Unit Operations*, published in 1950 by John Wylie & Sons, Inc., New York, N. Y According to Brown, this type of centrifuge was originally designed in 1878 by De Laval and has been widely used to separate cream from milk and for many industrial preparations.

In this type of centrifuge the feed passes radially outward from the bottom of a central tube down which it flows while being accelerate in rotary speed by vertical vanes in the tube to the speed of the bowl. The radial outward movement of the feed is through ports in the bottom portion of the tube. This flow is into the space containing the conical discs. The feed passes upwardly through a series of aligned holes in the cones. These holes are equidistant from the axis of rotation. As the feed moves upwardly through the holes and at the same centrigugal force, the feed passes into an intermediate zone of each working space between two adjacent

closely spaced conical discs. Due to the centrifugal force the heavier liquid or solids of the feed is thrown outward along the underside of the upper disc for each working space and passes downwardly with increasing centrifugal force being applied while the less dense liquid flows upwardly and toward the axis of rotation along the upper surfaces of the discs. As the less dense liquid flows upwardly the centrifugal force being applied to it decreases. Any further separation that occurs in each space between adjacent discs provides separated liquid or solids that must move countercurrent to the main flow on that side of the intermediate zone.

In 1897 E. W. Beach obtained U. S. Pat. No. 587,171 for a centrifugal separator containing a central tube to feed liquid to a bottom chamber of the bowl of the separator. Equidistant concentric cylindrical shells above the bottom chamber are supported by a circular plate defining the top wall of the bottom chamber. The plate has holes located at concentric rings. The holes are of equal area. The holes of each ring are in alignment with a cylindrical compartment of annular cross section defined by two shells. The compartments, of course, have different volumetric capacities. The shells have upper extensions that are directed inwardly toward the central tube. These extensions terminate just short of the central tube to provide an annular channel for upward flow of lighter liquid from these extensions. From this channel the lighter liquid is discharged through an orifice in the narrow top portion of the bowl.

In the Beach separator each shell has a number of outwardly directed shoulders at the juncture with the extension. These shoulders have openings at their outermost portion. The heavier separated liquid flowing upwardly along the inner side of a shell wall passes through these openings to the next outer chamber or compartment, through the openings in the shoulders of the next shell, and similarly through openings of outer shells until ultimately that liquid reaches the wall of the bowl. Then the heavier liquid flows upwardly into tubes that extend inwardly and upwardly to the narrow top portion of the bowl. The tubes extend upwardly in that top portion of the bowl and communicate with other orifices in the top portion of the bowl. The heavier liquid is discharged through those other orifices.

These shoulders of the shells of the Beach separator are of such size as to project radially outward within the adjacent compartment beyond the separated layer of the lighter liquid so that the heavier liquid is delivered from compartment to compartment into the separated layer of heavier liquid.

In the Beach apparatus there is no control of the flow of either separated liquid from the separator.

In 1904 Swedish Pats. Nos. 20754 and 20,757 were granted to G. C. P. De Laval for liquid separators that are constructed with equidistant concentric cylindrical shells to form a number of cylindrical chambers of annular cross section extending parallel to the rotor axis for separate parallel flow of liquid from one end of the chambers to the other end. In each chamber feed liquid is separated into two liquids of different density.

In the separator of Swedish Pat. No. 20,754 the upper margin of each shell has vertical slots to provide a number of flaps positioned around the periphery. The alternate flaps are bent radially inward toward the center of the separator to extend over the space between that shell and the next inner shell. The other flaps are similarly bent but extend radially outward. Vertical plates extend radially in the slots to provide sectoral collection chambers above the chambers provided by the shells as described above. This construction provides alternate sectors in which all flaps that extend radially inward provide passages for separated lighter liquid adjacent the outer sides of the shells and provides the other sectors in which all flaps that extend radially outward provide passages for separated heavier liquid adjacent the inner sides of the shells. From the sectoral chambers above the flaps these liquids flow through holes into concentric chambers. From these two chambers the separated heavier and light liquids flow in an uncontrolled manner through their respective outlet pipes. The total area of the passages provided by the flaps of any particular shell and thus the total flow rate of either separated liquid from a particular cylindrical chamber is proportional to the average radial distance of that chamber from the axis of rotation of the separator.

At the outlet end of each chamber in the separator of Swedish Pat. No. 20,757 there are provided two sets of outlet holes at different radial distances so that the separated lighter liquid passes out one set of holes and the separated heavier liquid passes out the other set of holes. Each set of holes communicates with its own set of collection chambers having radial walls. The separated lighter liquid flows radially inward in one set of collection chambers to and then upward through a central collection pipe. Above, that liquid flows from that pipe out a radial outlet in an uncontrolled manner. The separated heavier liquid flows radially outward in the other set of collection chambers to an annular chamber through which that liquid flows radially inward to and then upwardly through a pipe outside and concentric with the central collection pipe, mentioned above, for the collected lighter liquid. That outer pupe for the separated heavier liquid has an orifice in the upper portion of its wall, so that the separated heavier liquid flows out of that pipe in an uncontrolled manner.

In the separator of Swedish Pat. No. 20,757 the sizes of the two sets of holes as outlets for each cylindrical chamber of annular cross section are fixed, rather than adjustable, due to the nature of the construction of the separator and are such that the total areas of the sets are proportional to the relative volumes of separated liquids to be obtained. For example, to obtain cream and skim milk in a ratio of 1:7, the holes of the set through which the skim milk will flow from a particular cylindrical chamber will have a total area seven times greater than that of the holes through which cream will flow from the same cylindrical chamber. The size of the holes of each of these sets increases with their distances from the axis of rotation, i. e., the size increases with the distance of a cylindrical chamber, with which two sets are associated, from the axis of rotation for the stated reason that the rate of separation increases with that distance. Thus the total area of holes of either set communicating with a particular cylindrical chamber is proportional to the inner radius of that chamber of annular cross section.

As mentioned above, drum-type centrifugal clarifiers of the prior art are modifications of centrifugal contactors. U. S. Pat. Nos. 2,619,280, 3,027,390, 3,053,440, 3,202,407 3,344,983, and 3,519,199 disclose constructions of centrifugal contactors. The modification to provide a clarifier is fundamentally a modification of a contactor such as shown in U. S. Pat. No. 3,344,983. For example, reference is made to U. S. Pat. No. 3,344,982 in which the specific clarifier is constructed with two side-by-side clarifying zones.

The drum-type centrifugal clarifiers, like the contactors, comprise a rotor having a large number of closely-spaced concentric perforated cylindrical shells. Liquid to be clarified is fed into an axial passage in the shaft of the rotor and then out radial passages communicating with radial pipes at a transverse plane intermediate the ends of the working space in the rotor. These pipes extend through some of the perforated shells to introduce all of the feed liquid only to locations between two of the shells, i.e., only to locations in an annular space between those two shells. Those locations are basically at one radial distance.

Except for the flow of feed liquid from the open ends of those radial pipes toward both ends of the working space between those two shells, the liquid flows as separated heavier liquid and separated lighter liquid radially outward and inward, respectively, to the outermost chamber and the innermost chamber. The lighter liquid flows then by radial passageways and another longitudinal passageway in the rotor shaft to an outlet at one end of the shaft. The heavier liquid flows from the outermost chamber through longer radial pipes or via a chamber beyond one end of the shells to radial passageways and still another longitudinal passageway to an outlet at an end of the shaft.

The main flow of liquid within the working space of the rotor, i. e., within the cylindrical chambers between shells, is radial flow. Any lighter liquid separated in the chambers outside the chamber having the outlets of the feed radial pipes and any heavier liquid separated in the chambers between that chamber and the rotor shaft must pass countercurrent to the liquid of the other density in one or more chambers.

British Pat. No. 966,153 discloses a centrifugal apparatus to remove extremely small particles from fluid. The rotor includes a set of concentric shells mounted within the peripheral portion of the rotor housing. Separated solids are deposited on the walls of the shells and periodically the set of shells of the apparatus is cleaned by blowing air or by flushing out the accumulated solids.

To separate liquids of different specific gravities, the rotor of the centrifugal apparatus of U. S. Pat. No. 3,047,215 includes a number of radially-spaced partition walls around the rotor shaft. The adjacent partitions are eccentric to the axis of the shaft in a diametrically opposed relationship so that spaces between them are of increasing width from one side of the axis to the diametrically opposite side and so that the greatest width of one working space is on the opposite side to the greatest width of the next adjacent working space. Radial rods extend through these shells or partition walls and these rods have passageways at various radial distances. These passageways communicate one working chamber or space with the second closest chamber to transfer separated heavier liquid radially without passing in direct contact with lighter liquid in the closest chamber. Each shell has a number of holes through which separated lighter liquid flows radially inward. The feed liquid is admitted to the outer portion of the set of shells, viz., into the second outermost chamber.

In the rotor of the centrifuge of British Pat. No. 1,123,958 there is a set of spaced concentric shells that are conical but almost cylindrical to form a number of generally cylindrical chambers of annular cross section. The rotor includes upper and lower ducts connecting these chambers, on the one hand, at their top ends and, on the other hand, at their bottom ends, The feed liquid is introduced into the bottom end of only one of the chambers. Separated heavier liquid flows out that end of that chamber by a duct to the next outer chamber, while separated lighter liquid flows out of the chamber through a duct at the top end to the next inner chamber.

Partition walls, other than concentric cylindrical shells or concentric conical shells, are disclosed in U. S. Pat. No. 787,950. In the construction of the centrifugal separator of that patent, each of the partition walls extends from the periphery inwardly across a number of radii. These walls provides chambers into which presumably the feed liquid is introduced at one end of each chamber at a common intermediate radial distance. The separated lighter liquid and the separated heavier liquid move radially inward and outward, respectively, in each chamber to inner and outer collection chambers from which they are removed. Summary of the Invention

This invention relates to a centrifugal clarifier that is useful for the removal of contaminants from a liquid. The contaminated liquid as a feed is separated by the clarifier into two liquid phases.

When the feed liquid is water that is contaminated with a small amount of liquid hydrocarbon, such as oil, the two liquid phases are clarified water and liquid hydrocarbon.

When the feed liquid is water that is contaminated with a suspension of solids, the two liquid phases that are obtained are clarified water and a liquid slurry containing a substantially higher content of solids than the feed liquid. In the latter case, there is no sharp line of demarcation or interface between the two liquid phases, but there is a formation of a substantial height of a layer of clarified water that can be removed from the clarifier. Of course, the clarified water may contain a slight content of suspended solids although that content is very substantially less than the content of suspended solids in the feed liquid.

In a specific construction, the centrifugal clarifier of the present invention can provide for a treatment of water containing suspended liquid hydrocarbon and suspended solids to produce a clarified water phase, a liquid hydrocarbon phase and a liquid slurry.

In another construction, the clarifier of the invention can treat a water containing dissolved liquid hydrocarbon with a hydrocarbon of lower solubility, separate these two liquids, and then centrifugally treat the separated aqueous liquid into a liquid hydrocarbon phase and a clarified water phase having a lower content of dissolved hydrocarbon than the feed water.

The centrifugal clarifier of the invention includes a rotor, two outlet pipes and valved means connected to at least one of the outlet pipes. The clarifier is connected, of course, to an inlet pipe that provides feed liquid for the clarifier.

The rotor comprises a rotor shaft, a rotor housing, a set of partition walls within the housing, and distributor means and two collector means within the housing.

The rotor housing encloses an elongated intermediate portion of the rotor shaft so as to provide around that intermediate portion of the shaft an elongated working space of annular cross section. The set of partition walls is mounted in that housing so that these walls are in that working space. These partition walls extend generally parallel to the longitudinal axis of the shaft. Preferably they are parallel to that axis. It is especially preferred that this set of partition walls constitute a set of equally spaced concentric cylindrical shells. It is also especially preferred that these shells be imperforate except for openings at various radial lines about their periphery for mounting of one of the two collector means mentioned above.

The partition walls extend from one end part of the intermediate portion of the working space to the other end part of that intermediate portion so as to provide a number of elongated parallel chambers through which the major flow of liquid is across a centrifugal force field and generally parallel to the axis of rotation of the shaft rather than a radial flow. Of course, the centrifugal force field is provided by the rapid movement of the liquid in these chambers aobut the axis of the shaft while the rotor is rotating.

The distributor means of the rotor extends radially outward from the rotor shaft. The distributor means is located within one end part of the housing. The distributor means has concentric sets of openings at different bands of radial distances from the axis of the shaft. Through these openings passes feed liquid separately to one end of the parallel chambers provided by the set of partition walls.

One of the two collector means extends radially outward from the rotor shaft within the other end part of the housing and has concentric sets of openings at different bands of radial distances from the axis of the shaft to receive one of the separated liquid phases produced from the feed liquid in the parallel chambers within the housing. The other collector means is located between these end parts of the housing and thus between the first collector means and the distributor means. This other, or second, collector means is located to receive the other of the separated liquid phases from the parallel chambers.

When the set of partition walls is a set of concentric cylindrical shells, the second collector means in one type of construction comprises a number of downcomers located on the shells at radially aligned openings. The shells have these openings at different radii about the rotor shaft. In that case the separated liquid phase flows radially inward through the openings into downcomers to the next inward chamber. Each downcomer has its bottom opening outwardly spaced from but adjacent the opening of the next inward shell.

In another type of construction of the second collector means, when the partition walls are concentric cylindrical shells, the collector means constitutes a number of radial pipes extending at various radii in a common plane transverse to the axis of the shaft. Each of these pipes extend in a generally fluid-tight manner through openings radially aligned in the shells. Each pipe has an opening adjacent the outer portion of radial height of each chamber to receive separated heavier liquid phase, i.e., the liquid phase that is a slurry of suspended solids in a substantially higher concentration than the content of such solids in the feed liquid. The second collector means in this case preferably includes additional structure within the working spaces to divert this slurry towards these openings. In addition, preferably there is another pipe within each of these radial pipes. The inner pipe has no openings at these different radial distances. Rather, slurry flowing into the outer radial pipe flows radially outward to the open end of the inner pipe. That end is adjacent the housing. The slurry in the inner pipe flows radially inward toward the rotor shaft.

The rotor shaft is constructed with a number of longitudinal passageways. One is an inlet passageway for feed liquid. This passageway extends inwardly to one end part of intermediate portion of that shaft at which the passageway communicates with a radial passageway that communicates with the distributor means. A second longitudinal passageway is an outlet for one of the separated liquid phases and for this purpose extends inwardly to the other end part of that intermediate portion of the rotor shaft. At that location it communicates with a radial passageway that communicates with the collector means at that end part of the rotor housing. The other longitudinal passageway in the rotor shaft extends inwardly to the intermediate portion of the shaft and communicates with a radial passageway that communicates with the other collector means. The latter collector means is at a location within the working space and thus between and spaced from the distributor means and the first-mentioned collector means.

Although all three longitudinal passageways can extend inwardly from the same end of the rotor shaft to the extent described above, it is usually preferred for the simplest construction of the rotor that the two longitudinal passagewaus that serve as outlet passageways extend inwardly from one end, while the other passageway, as an inlet passageway, extends inwardly from the other end of the shaft.

As seen later in the detailed description, there is one embodiment of the centrifugal clarifier in which there are recovered three liquid phases by virtue of two concentric working spaces. In that case there are four longitudinal passageways in the rotor shaft and two of the outlet passageways extend inwardly from the same end of the shaft as the inlet passageway. Other modifications of the location of the passageways are disclosed in the detailed descriptions.

The centrifugal clarifier of the invention includes at least two outlet pipes, as mentioned above. The number of outlet pipes is greater in the case of specific constructions that permit the separation of feed liquid into more than two liquid separated phases. One outlet pipe is connected to the rotor so as to communicate with one of the outlet passageways while the second outlet pipe is connected also to the rotor to communicate with the other of the outlet passageways. The outlet pipe that thereby receives the separated liquid phase containing a major portion of the contaminant has valved means mounted on it to control the rate of removal of that liquid phase from its collector means and thus from the parallel chambers in the working space within the rotor housing. In this case, the other outlet pipe receives the other separated liquid phase, that is, the clarified liquid obtained from those parallel chambers in the working space.

The outlet pipe for the clarified liquid can have valved means mounted on it to control the rate of flow of clarified liquid from the rotor and thereby control the overall flow rate of feed liquid into the working space of the rotor because the major volume of liquid passing through the clarifier is the liquid that becomes clarified liquid.

The valved means mentioned earlier for the first outlet pipe receiving the separated liquid phase, that has the major proportion of contaminant, is an important component of the clarifier because it controls overall the rate of withdrawal of such liquid from the various parallel chambers. That valved means must be changed in its setting as a necessary part of the use of the clarifier in accordance with the changed conditions of separation within the clarifier due to a change in nature and/or concentration of contaminant in liquid feed. Such change can occur when there is a change in waste liquid, as feed liquid, derived, for example, from different processes that use water for one or more purposes.

Another very important limitation present in the construction of the centrifugal clarifier of this invention is the total area of the openings at each band of radial distance from the axis of rotation of the shaft for either the distributor means for feed liquid or the collector means that receives clarified liquid from the working space within the rotor housing. This limitation is that the total area of the openings at each band of radial distance is basically proportional to the square of the radial distances of the band. As will be apparent from the detailed description, it is not feasible for some specific embodiments of the clarifier to construct those embodiments in a manner that this limitation is present in the construction of the collector means for the clarifier liquid. This is the case, e.g., when that liquid is collected by sets of radially aligned downcomers as one collector means at an intermediate transverse plane of the working space, while the other collector means is at an end of the housing to receive the liquid phase containing the enhanced content of contaminant, e.g., for collecting liquid slurry of solids. In such cases, the limitation of construction is necessarily applicable and incorporated in the construction of the distributor means.

When the rotor of the clarifier of the present invention contains a set of equally spaced concentric cylindrical shells in the working space to provide the elongated parallel chambers in the working space of the housing, they provide concentric cylindrical bands of working spaces having different radial distances from the axis of the shaft.

In this construction with cylindrical shells, and with the opneings of the distributor means having total areas at each band to conform to the limitation mentioned above, each ring of openings is preferably located to be in alignment with the average radial height of that band of working space so that flow of feed liquid into a particular elongated chamber is at a radial height or distance approximately intermediate the walls defining that particular cylindrical chamber. This construction permits an interface between the two separated liquids within a chamber to be radially outward or inward of the location of those openings. This construction thereby minimizes any disturbance of the interface of the two separated liquids by the inward flow of feed liquid into the chamber. In another embodiment of this construction with cylindrical shells but in which the limitation of total area of the openings is present as part of the structure of the collector means for the clarified liquid, those openings at each particular elongated chamber are radially offset from the average radial height of that chamber so that flow into that collector means is substantially spaced from the interface between the two separated liquid phases. In the case of the construction of the clarifier for separating oil from water, the offset is radially outward. In this case of the construction of the clarifier for separting suspended solids, as a liquid slurry, from water the offset is radially inward. Description of the Drawings.

In the drawings, the same components that appear in the various embodiments of the centrifugal clarifier of the invention are generally designated by the same numeral.

FIG. **1** is an elevational view, partially broken away as a longitudinal section and partially schematic, showing one of the especially preferred embodiments of the clarifier of the present invention useful for separating contaminant oil from water.

FIG. **2** is a fragmentary cross sectional view taken along line **2—2** of FIG. **1**.

FIG. **3** is a fragmentary cross sectional view taken along line **3—3** of FIG. **1**.

FIG. **4** is a fragmentary cross sectional view taken along line **4—4** of FIG. **1**.

FIG. **5** is a fragmentary longitudinal section of another preferred embodiment of the clarifier of the invention showing a different construction for the distributor means of the rotor.

FIG. **6** is a fragmentary cross sectional view taken along line **6—6** of FIG. **5**.

FIG. **7** is a fragmentary schematic longitudinal section of another especially preferred embodiment of the clarifier that is useful for removing from water a substantial amount of contaminant, in the form of suspended solids, as a liquid slurry.

FIG. **8** is a fragmentary view taken along line **8—8** of FIG. **7**.

FIG. **9** is a fragmentary cross sectional view taken along line **9—9** of FIG. **7**.

FIG. **10** is an enlarged fragmentary view taken along line **10—10** of FIG. **9** to show more clearly the construction of a part of the collector means for aqueous slurry from each chamber in the working space of the rotor housing.

FIG. **11** is a fragmentary schematic longitudinal section of another embodiment of the clarifier showing a modification of the collector means for the aqueous slurry to provide a recovery of some water from the slurry before it passes out of the rotor.

FIG. **12** is an enlarged fragmentary cross sectional view of the rotor of FIG. **11** taken along line **12—12.**

FIG. **13** is a fragmentary longitudinal section of another construction of the clarifier that is useful to separate oil and a slurry of suspended solids from a feed liquid to produce a clarified water.

FIG. **14** is a fragmentary schematic longitudinal section of still another embodiment of the clarifier as a modification of the clarifier of FIG. **7** by using slightly frustoconical concentric shells instead of cylindrical shells to form parallel chambers within the working space of the rotor housing.

FIG. **15** is a fragmentary, schematic longitudinal section of another embodiment of the clarifier that is useful to remove some suspended solids from a feed liquid like the apparatus of FIG. **7**, to produce a slurry and clarified liquid, but differs from FIG. **7** in that the collector means for the slurry is modified and is at the exit end part of the housing while the collector means for the clarified liquid is at an intermediate location within the housing.

FIG. **16** is an enlarged fragmentary view of the apparatus shown in FIG. **15** to show the specific construction of the collector means for the slurry and is a view taken along line **16—16** of FIG. **17.**

FIG. **17** is a cross sectional view taken along line **17—17** of FIG. **16,** to show the diverter plates for the outwardly moving slurry within the collector means at that exit end of the housing where the cylindrical shell of the housing is offset radially outward for a larger diameter.

FIG. **18** is a fragmentary schematic cross section of a modification of the clarifier shown in FIG. **1** in which elongated plates are present in the working chambers to insure adequate rotary movement of liquid in each working chamber.

FIG. **19** is a fragmentary schematic longitudinal section of a clarifier as a modification of the clarifier of FIG. **1,** in which the modification constitutes having within each working chamber a number of perforated cylindrical shells and having the exit downcomers for separated oil relatively close to the feed inlet from the distributor means.

FIG. **20** is an enlarged longitudinal section of one of the perforated shells shown in FIG. **19.**

FIG. **21** is a fragmentary schematic cross section of another embodiment of the clarifier showing, instead of concentric shells in the working space within the rotor housing, a number of elongated plates angularly disposed from radii of the rotor shaft.

FIG. **22** is a fragmentary schematic cross section of another embodiment of the clarifier showing a set of elongated partition walls, transversely curved and stepped, within the working space of the rotor housing, as another alternative to the use of concentric shells to provide elongated parallel chambers.

FIG. **23** is a fragmentary view taken along line **23—23** of FIG. **22.**

FIG. **24** is a fragmentary schematic longitudinal section of still another embodiment of the clarifier of the invention, useful for separating dissolved hydrocarbon from water as well as any hydrocarbon suspended in the water.

FIG. **25** is a fragmentary schematic longitudinal section of another construction of the clarifier that has two concentric working spaces within one rotor housing and that is useful to treat oily aqueous feed containing heavy and light solids suspended in it to obtain from it a separated oil phase, two liquid slurry phases, and clarified water.

Detailed Description

In the following detailed description of various embodiments of the clarifier of the present invention reference is made to their use for the treatment of water as the feed liquid. In that case, the feed water contains a suspension of solids or liquid hydrocarbon, or both, or the feed water contains dissolved liquid hydrocarbon with or without suspended globules of liquid hydrocarbon. Such description of the application of the clarifier for the treatment of water is merely illustrative. The apparatus of this invention is obviously useful for treatment of other liquids containing suspension of solids and/or globules of an immiscible liquid present in a small concentration such as described above for an aqueous system contaminated by solids and/or liquid hydrocarbon, e.g., oil.

The centrifugal clarifier shown in FIG. 1 has a rotor generally indicated at **30**, an outlet pipe **31** to receive one of the separated liquid phases from the clarifier, another outlet pipe **32** to receive the other separated liquid phase from the clarifier, a valve **33** in pipe **31**, and a valve **34** in pipe **32**.

The rotor **30** has a rotor shaft **35**. The elongated intermediate portion of shaft **35** is enclosed by a rotor housing generally indicated at **36**. Within housing **36** is an elongated working space of annular cross section. The housing **36** includes a pair of circular end discs **37** and **38** mounted on shaft **35** at the opposite ends of the intermediate portion of the shaft **35** for rotation with shaft **35**. The housing **36** also includes a cylindrical shell **39** connected at its ends to the peripheral margin of discs **37** and **38** to complete the enclosure of the intermediate portion of shaft **35**.

The shaft **35** has a longitudinal inlet passageway **40** that extends inwardly from one end of shaft **35** to one end of its intermediate portion where it communicates with a radial passageway **41** that communcates with that end of the space within housing **36**. The other end of shaft **35** has a pair of coaxial longitudinal outlet passageways **42** and **43**. The outer passageway **43**, of these coaxial passageways, extends inwardly to the other end of the intermediate portion of the shaft **35** where it communicates with a radial passageway **44** that communicates with the other end of the space within housing **36**. The inner passageway **42**, of the coaxial passageways, extends further inwardly of shaft **35** to a position at which it communicates with a radial passageway **45** that communicates with an intermediate part of the working space in housing **36**.

The outlet pipes **31** and **32** are connected to shaft **35** by a conventional, well-known construction whereby pipes **31** and **32** remain stationary while shaft **35** rotates and during this relative movement pipes **31** and **32** remain in communication with outlet passageways **42** and **43**, respectively. Conventional constructions that provide these communications between outlet pipes and a revolving rotary shaft are disclosed in numerous patents including U.S. Pats. Nos. 3,344,982 and 3,344,983, mentioned above. Similarly, the other or inlet end of shaft **35** is connected to an inlet pipe (not shown) that communicates with inlet passageway **40** to provide feed liquid to the clarifier. Also, the clarifier is constructed in a conventional manner, e.g., as shown in the both patents mentioned above, to include a driven sheave (not shown) to drive shaft **35** at a desired rotational speed. Of course, shaft **35** is rotatably mounted with bearings (not shown). on a suitable supporting structure (not shown).

Within rotor housing **36** and spaced from discs **37** and **38** are circular discs **50** and **51**, respectively. The disc **50** has concentric bands of holes **52**. The chamber defined by disc **37** of housing **36** and disc **50** with its holes **52** provides distributor means at one end of housing **36** whereby feed liquid is distributed through holes **52** to the working space within housing **36** between discs **50** and **51**. The disc **51** also has a number of concentric bands of holes **53**. Through holes **53** flows one of the separated liquid phases. That liquid phase passes thereby into the space between disc **51** and disc **38** of housing **36**. The disc **51** with its holes **53** cooperates with disc **38** to provide collector means for that separated liquid phase from the working space within housing **36**.

Mounted between discs **37** and **50** are radial baffles **55** that extend from adjacent shaft **35** to a position adjacent shell **39**. The baffles **55** are connected to disc **37**, or disc **50**, or both, so that baffles **55** move about the axis of shaft **35** when that shaft and, of course, housing **36**, are rotated. The space between discs **51** and **38** is similarly provided with radial baffles **56**.

The radial passageway **41** communicates with the space between discs **37** and **50** while radial passageway **44** communicates with space between discs **38** and **51**. The radial baffles **55** impart rotational speed to feed liquid in the space between discs **37** and **50** so that the feed liquid is subjected to increase centrifugal force between passage through holes **52**. Most of the energy used to provide this rotational speed is recovered when separated liquid phase, after passage through holes **53** of disc **51**, passes radially inward in the space between discs **38** and **51**. This recovery of energy is due to the presence of radial baffles **56** of rotor **30** in the space of collector means. Most of the liquid introduced as feed liquid passes to the outlet passageway **42** by passing through that collector means in the clarifier of FIG. **1** because the clarifier is constructed so that the clarified liquid phase passes through that collector means. This is because the feed liquid is oily water in which the major constituent is water and the contaminant is oil. In that case, the major liquid is heavier and thus is collected by that collector means from a number of elongated parallel chambers between discs **50** and **51**.

Those chambers are provided by a number of equally spaced concentric cylindrical shells **60** connected at their ends to discs **50** and **51** so that shells **60** are in the working space mentioned above. Within those chambers, the heavier liquid, i.e., water, of feed oily water is moved radially outward toward the inner surface of each shell **60** for each of the parallel chambers, except the outermost chamber. That chamber is defined by the outermost shell **60** and shell **39** of housing **36**. In that outermost chamber, the water moves toward shell **39**. Of course, shells **60** are mounted so that they are an integral part of rotor **30** to be rotated with shaft **35**.

Each of the concentric shells **60** has openings at two or more radii. At these openings are mounted downcomers **61** to extend radially inward. The inner end of these downcomers **61** except for downcomers **61** mounted on the innermost shell **60** are adjacent but spaced radially outward from the next adjacent radially inward shell **60**. The downcomers **61** constitute the other collector means and taken together they receive the other separated liquid, viz., oil, from the parallel chambers in the working space within housing **36**. The downcomers **61** are preferably, as shown, sets of radially aligned downcomers **61** that are at various radii at a transverse plane at which is located radial passageway **45** that receives this second separated liquid phase. The important control of the rate of withdrawal of this liquid phase from rotor **30** is made possible by the presence of valve **33**. In each parallel chamber an oil layer is formed to provide a thickness that is just sufficient to provide a head for passage through the openings in shell **60** and through downcomers **61** to the innermost parallel chamber. The valve **33** is adjusted to control the rate of removal of oil from the innermost parallel chamber to prevent an accumulation in it such that oil would pass out holes **52** of the inner radial band to be removed undesirably with clarified water from the other chambers. To ensure such control with this design of the clarifier, the flow rate through valve **33** can be such that a small amount of water is withdrawn with the oil. This avoids accumulation of oil in the innermost parallel chamber.

As seen in FIG. **1**, holes **52** are provided in disc **50** at radial distances that are approximately midway between the top and bottom of each of the parallel chambers. As a result, feed liquid is introduced to each chamber at an elevation radially outward of the separated oil layer in each chamber, i.e., outwardly of the interface between separated oil and separated clarified water. This construction minimizes remixing of separated oil. As seen also in FIG. **1**, the holes **53** in disc **51** are at radial distances to communicate separately also with different parallel chambers. For a particular radial height, each hole **53** is located to have its radially outermost part at the inner surface of shell **60** that defines the outermost part of the chamber with which holes **53** communicate. This location of holes **53** ensures that clarified liquid only is withdrawn through holes **53** from the parallel chambers.

It is seen further in FIG. **1** that feed liquid, after having centrifugal energy imparted to it within the distributor means, passes parallel, in separate flows, to the longitudinal axis of shaft **35** and thus normal to the centrifugal force field through the elongated parallel chambers where the major portion of the separation of the feed liquid into two liquid phases occurs. Because the water content constitutes almost all of the feed liquid, the major flow of liquid within the working spaces is from holes **52** of the distributor means to holes **53** of the collector means for clarified water. Within the latter collector means there is radially inward flow just as there is radially outward flow within the distributor means. However, the major separation occurs within the parallel chambers created by the presence of concentric shells **60** within the working space of housing **36**.

As seen in FIG. **2**, holes **52** at each radial height or distance are provided at various radii so that the holes **52** in disc **50** are located at concentric bands of disc **50**. The holes **52** of each band are located to communicate the space between discs **37** and **50** with a specific parallel chamber. It is seen also that the area of openings **52** increases with the distance of the holes from the longitudinal axis of the shaft. The same is true for the areas of holes **53** in disc **51**. In FIG. **2**, holes **52** are depicted as generally rectangular in shape, but this shape is not necessary. As a matter of fact, it is not necessary that they be in radial alignment as seen in FIG. **2**. As seen in FIG. **3**, a number of round holes are shown merely as a convenient way of emphasizing that the total area of holes **53** of a particular band is generally proportional to the square of the average radial distance of the associated working chamber from the axis of rotation. This limitation is depicted in the embodiment shown in FIG. **1** as existing for the collector means including disc **51**. Alternatively, such construction of holes **53** can be the construction of holes **52** of the distributor means, so that the total area of holes **52** at each of the concentric bands of holes in disc **50** is generally proportional to the square of the average radial distance of the associated working chamber from the rotational axis.

In addition to baffles **56**, between discs **38** and **51**, there are present, in that collector means for clarified water, a number of shorter radial baffles **65** and a number of still shorter radial baffles **66**. The baffles **65** and **66** extend radially inwardly generally from a position adjacent shell **39** at radii between baffles **56**. The baffles **56** and **66** provide further recoupment of energy from clarified water as it passes radially inward between discs **38** and **51**.

It is apparent from the foregoing description of the clarifier of FIG. **1** that discs **37** and **50** constitute essentially a hollow circular disc as a distributor means with its holes **52** facing the working space of the rotor and with the hollow chamber in communication with radial inlet passage **41**. Similarly, there is at the other end of housing **36** a hollow circular disc, as the collector means for clarified liquid, comprising discs **38** and **51** with holes **53** facing the working space and the chamber communicating with radial outlet passageway **44**. Of course, for these hollow discs their peripheral walls are the end margins of cylindrical shell **39**.

Referring to FIG. **5**, that clarifier of the invention is the same as the clarifier of FIG. **1**, except for the construction of the distributor means. The collector means for clarified liquid can be modified in the manner described below for the distributor means, except for the location of exit holes for flow of clarified liquid from the parallel chambers.

As will be apparent, concentric shells **60** in the embodiment of FIG. **5** extend to discs **37** and **38**. Instead of circular discs **50** in the construction of FIG. **1** cooperating with disc **37** of housing **36** to provide the distributor means, the clarifier of FIG. **5** has a number of radial pipes **67** adjacent disc **37**. The pipes extend radially inward from shell **39** to a hollow manifold ring **68** mounted on shaft **35** so that the chamber of ring **68** communicates with passageway **41**. The ring **68** has holes **69** in its outer peripheral wall communicating the chamber of ring **68** with pipes **67**. Each of pipes **67** has a number of openings **70**. Each opening **70** of a pipe communicates with one of the annular chambers between a pair of shells **60**, between innermost shell **60** and and shaft **35**, or between outermost shell **60** and shell **39**. The radially innermost opening **70** of each pipe **67** cooperates with an opening in the top portion of one of the sidewalls of ring **68** to provide an opening that permits a smoother flow pattern for feed liquid into the innermost chamber of rotor **30**. The openings **70** of all pipes **67**, taken as a whole, are disposed in concentric circles and the total area of openings **70** at each circle is generally proportional to the square of the average radial distance of the associated elongated chamber to which feed liquid flows from openings **70**. This is schematically, but not precisely, indicated by the different sizes of openings **70** in some of radial pipes **67** shown in FIG. **6**, just as was the case for holes **53** in disc **51** in the construction shown in FIG. **3** for first embodiment of the clarifier.

As in the case of holes **52** in the clarifier of FIG. **1**, openings **70** are located at radial distances approximately midway of the radial height of the corresponding elongated parallel chamber. When the collector means for clarified water is constructed in a similar manner, rather than the construction shown in FIG. **1**, the openings comparable to openings **70** in the radial pipes for that collector means are located at greater radial distances so that they are positioned comparable to the location of holes **53** in the collector means for clarified liquid shown in FIG. **1**.

The embodiment of clarifier of the invention shown in FIG. 7 is constructed like the embodiment of FIG. 1 except as described below. The clarifier of FIG. 7 can be further modified to utilize radial pipes for the distributor means, or for the collector means for clarified water, or for both, in accordance with the description above with respect to FIG. 5.

Instread of openings in shells **60** at which downcomers **61** are mounted, as in the case for the construction of FIG. 1, shells **60** have at various radii a number of radially aligned openings. These openings are closer to the collector means for clarified water than to the distributor means. Through each set of these sets of radially aligned openings is mounted a pipe **71** that extends from shaft **35** to shell **39**. Within each pipe **71** and concentric with it is a smaller diameter pipe **72** that extends essentially from shaft **35** to a position adjacent but spaced from shell **39**. The one end of each pipe **72** communicates with a hollow manifold ring through an opening in the latter and thereby communicates pipes **72** with radial passageway **45** in the same manner as described above in connection with the construction of pipe **67** and hollow manifold ring **68** of the clarifier of FIG. 5. For convenience, in the schematic showing of FIG. 7 this specific construction is not shown.

Each of the pipes **71** has a set of openings **73** at different radial distances. The openings **73** of each pipe **71** are at radial distances comparable to holes **53** of disc **51** so that each opening **73** of any pipe **71** receives separated clarified water from one working chamber. The openings **73** of each pipe **71** can be of the same area because the limitation with respect of total areas of openings **73** in a circle is not applicable. Rather, that limitation is applicable to holes **52** in disc **50** and/or to holes **53** in disc **51**. The clarifier of FIG. 7 also differs from that of FIG. 1 by the location of holes **53** in disc **51**. Through holes **53** flows separated clarified water that is lighter than the other separated liquid phase. Thus holes **53** are located adjacent the outer surface of shells **60** and, in the case of the innermost chamber, adjacent shaft **35**.

As seen in FIG. 9, openings **73** of each pipe **71** have vertical sidewalls. At the underside of each shell **60** and the underside of shell **39**, there are located a set of baffles **74** that are at a plane transverse to the rotor. The baffles **74** have their ends spaced from one another. The baffles **74** are arcuated with a curvature such that they abut the inner surfaces of shells **60** or shell **39** (see FIG. 9). The height of each baffle **74** corresponds with the radial height of openings **73**. The ends of each baffle **74** are positioned so as to abut the vertical sidewalls of opening **73** of adjacent pipes **71**. The baffles **74** in each working chamber prevent liquid slurry separated from feed water containing suspended solids and of a depth less than the height of baffles **74** from passing between pipes **71**. This is because the liquid slurry during the centrifugal separation moves to the outer part of each working chamber. In addition to being arcuate in a plane transverse to the longitudinal axis of shaft **35**, each baffle **74** is V-shaped in a plane normal to the transverse plane with its apex directed upstream, i.e., toward the distributor means, as seen in FIGS. 7 and 8. Because of this V-shaped construction, baffles **74** serve not only as dams for liquid slurry but also serve as diverters to cause liquid slurry to flow towards openings **73**.

In the clarifier of FIG. 7, liquid slurry that passes through openings **73** of each radial pipe **71** flows radially outward, i.e., toward shell **39**, and then flows radially inward through pipe **72** (see arrow in FIG. **10**). This liquid slurry then flows through radial passageway **45** and out longitudinal passageway **42**.

The rate of flow of liquid slurry through passageway **42** is controlled by valve **33** in outlet pipe **31**, as in the clarifier of FIG. **1**. Of course, clarified water flows out holes **53** in disc **51** and then radially inward to flow out passageways **44** and **43**.

The clarifier of FIG. **11** has the same construction as that of clarifier of FIG. 7 except as described below. In the clarifier of FIG. **11**, each of pipes **71** has a larger diameter than each pipe **71** of the clarifier of FIG. 7 and its inner end is spaced from shaft **35**. That inner end is at a location intermediate the radial height of the innermost working chamber that is defined by shaft **35** and innermost shell **60**. Each inner pipe **72** is shorter than in the construction of FIG. 7.

The inner end of each pipe **72** is connected to an outer peripheral opening of a manifold ring **75** that is entirely open at its inner periphery so that the sidewalls of ring **75** engage shaft **35**. The inner portion of the sidewalls of ring **75** are straight and parallel. The distance between these sidewalls corresponds to the diameter of the associated pipe **71**. The outer portions of the sidewalls of ring **75** converge toward the outer peripheral wall of ring **75** so that there is a smaller distance between them. That distance corresponds to the diameter of pipes **72**. As seen in FIG. **11**, each of pipes **71** has its inner end joined to manifold ring **75** at the juncture of the inner parallel sidewall portions and the outer converging sidewall portions. These junctures are, of course, radially inward of the innermost opening **73** of each pipe **71** so that liquid slurry from the innermost working chamber can flow into pipe **71** and then radially outward to shell **39**.

The manifold ring **75** provides a chamber within which a fairly large volume of liquid slurry can accumulate. This liquid slurry cannot flow out of this chamber directly into radial passageway **45**. This is because the clarifier includes, within the chamber provided by manifold ring **75**, a pipe **76** mounted on shaft **35** so that its radially inner end communicates with passageway **45**. As seen in FIG. **12**, passageway **45** and thus pipe **76** are not in radial alignment with any of pipes **72**, whereas in the clarifier of FIG. 7, passageway **45** may or may not be in radial alignment with one of pipes **72**. In the chamber provided by manifold ring **75**, the capacity being much larger than in the case of a manifold ring, like manifold ring **68** of FIG. **5**, there is a further centrifugal separation of water from the liquid slurry. The further separated liquid slurry flows out pipe **76**, while the separated water in that chamber collects adjacent shaft **35** and is withdrawn through a radial passageway **77** that communicates with a longitudinal outlet passageway **78** that is between and concentric with passageways **43** and **44**. The passageway **78** is in communication with an outlet pipe (not shown) that thereby receives, as a secodary product, a water having a higher suspended solids content that clarified water but a smaller solids content than liquid slurry flowing out passageway **42**. The secondary product water may be recycled to the clarifier by admixture with feed water.

The clarifier of FIG. 13 is a modification of the clarifier of FIG. 7 in that each shell 60 has openings that are upstream of pipes 71 and at these openings are mounted downcomers 61 as constructed for the clarifier of FIG. 1. The clarifier of FIG. 13 is useful to treat water containing suspended oil and suspended solids. Because of its construction, the clarifier of FIG. 13 provides a recovery of three separated liquid phases obtained by the centrifugal separation of the oily water containing suspended solids.

As in the case of the construction of the clarifier of FIG. 7, radial passageway 45 receives liquid slurry from tubes 72 through a manifold ring (not shown, but like manifold ring 68 of FIG. 5). The radial passageway 44 receives clarified water from the collector means between discs 38 and 51. The separated oil from each working chamber flows radially inward through the set of radially aligned downcomers 61 and, from the innermost working chamber, separated oil flows into a radial passageway 79 that is in communication with the inner end portion of a longitudinal passageway 80. The separated oil flows out passageway 80 that is inside and concentric with inlet passageway 40. Of course, passageway 70 extends further inwardly of shaft 35 than does passageway 40.

The clarifier of FIG. 14 is identical to clarifier of FIG. 7, except as described below. In the clarifier of FIG. 14, equally spaced shells 60 and shell 39 are slightly frustoconical, i.e., a frustum of a hollow cone with a small included angle instead of being cylindrical. There is only a small difference between the diameters of the ends of shells 60. As seen in FIG. 14 all, except the innermost, of the working chambers are parallel with one another even though slightly inclined from the longitudinal axis of shaft 35. Those chambers are inclined to diverge from the longitudinal axis in a direction away from the distributor means so that, as the parallel flows through the working chambers proceeds, the centrifugal force increases. In the innermost chamber, that is defined by shaft 35 and innermost shell 60, the cross-sectional area increases from the distributor means to the collector means for clarified water. That working chamber has the least centrifugal force applied to liquid in it; however, the residence time of the liquid in that chamber is greater than that in the other chambers. This is primarily because of total area of holes 52 and/or holes 53 of each circle of holes 52 and or holes 53 are in accordance with the limitation mentioned earlier. The residence time is further increased by the increased volumetric capacity of that inner chamber as compared with volumetric capacity it would have if shells 60 (and shell 39) were fully cylindrical as in FIG. 7.

Each of pipes 71 in the clarifier of FIG. 14 has its radially inner end closed. The pipe 72 passes through that closed end that is spaced a substantial distance from shaft 35, but is still below opening 73 in the innermost working chamber. This is a modification from that shown in FIG. 7 but the constructions are interchangeable.

The clarifier shown in FIGS. 15, 16, and 17 differs in construction from the clarifier of FIG. 7 in the following manner. Instead of the collector means for clarified water being at the downstream end of rotor housing 36, that collector means is at an intermediate location and is constructed like the collector means for oil at such intermediate location in the clarifier of FIG. 1. This is possible because the clarifier is used to separate clarified water from the other separated heavier liquid phase, that is, liquid slurry. This collector means for clarified water comprises sets of radially aligned downcomers 61 mounted on shells 60 in alignment with openings in those shells. In this construction, the other collector means, namely, the collector means for liquid slurry, is at the downstream end of housing 36. In this construction, pipes 71 are absent. Instead, there is present a disc 51 with openings 53 spaced from disc 38.

As seen in FIG. 15, disc 38 is of larger diameter than disc 37 to enclose the downstream end of the housing provided with the modified shell 39 that is in this construction provided with a radially outward offset end portion 39'. The end chamber containing offset portion 39' and enclosed by discs 38 and 51, has within it a number of radial pipes 72 that extend beyond the diameter of the normal part of shell 39 at different radii. Within this chamber, provided in part by the offset portion 39', are located a number of diverted plates 81 arranged to form a polygonal construction with each juncture of adjacent sides being in alignment with the longitudinal axis of a radial pipe 72 (as seen in FIG. 17). The liquid slurry passes from the working chambers through holes 53 to this end chamber and then radially outward toward the outermost portion of the that chamber that serves as a collector trough where the slurry is diverted to radial pipes 72 through which it passes inwardly to passageway 44. Of course, as in other constructions mentioned above, pipes 72 have their inner ends connected to openings in a manifold ring (not shown) that communicates with passageway 44.

In view of the construction described above for clarifier of FIG. 15, in that the collector means for liquid slurry is downstream of the collector means for clarified water, it is unnecessary to have baffles, such as baffle 74, adjacent openings 73 of pipes 71 of the collector means to receive liquid slurry. There is no place for slurry to go except through openings 53 of disc 51.

The clarifier of FIG. 18 is a modification of one of more of the clarifiers mentioned above. It is illustratied as a modification of the clarifier of FIG. 1. The modification comprises including within each parallel working chamber a larger number of closely spaced elongated plates 82 that extend from one end of the working space to the other and are angularly disposed with respect to radii of the rotor. The principal purposes of the baffles of this construction are to reduce the radial distance of travel before a particle of contaminant contacts a solid surface and to provide "inclined" surfaces along which the contaminant travels radially.

The clarifier shown in FIG. 19 is a modification of clarifier of FIG. 1. Such modification can be suitably incorporated in other clarifiers described above. In each working space of the clarifier of FIG. 19 there are mounted concentric perforated shells 83 that extend from the downstream end collector means, that is from disc 51. Within each working chamber, perforated shells 83 having increasing length, with the longest shell 83 being the outermost of the set. FIG. 20 shows one of shells 83 with its perforations 84.

The purpose of the set of perforated shells 83 in each working chamber is to permit separate globules of oil at several annular strata to accumulate more readily. They accumulate on the outer surface of these shells and then, as larger globules, pass downwardly through perforations 84 to the outer surface of shells 60 (or shaft 35 in the case of the innermost chamber). This minimizes remixing of separated oil with water. To eliminate the necessity of separated clarified water to flow from the downstream end of the chamber entirely to openings 53 at their normal location, there are additional holes 85 between adjacent shells 83 and between the innermost shell 83 and adjacent shell 60. The downcomers 61 are located upstream of the location of the longest perforated shell 83.

For each working chamber, the total area of holes 52 is generally proportional to the square root of the distance is mentioned above. Alternatively, this limitation can be applicable to the total area of holes 53 and holes 85 for each chamber or the limitation could be applicable to both the distributor means and that collector means.

The clarifier shown in FIG. 21 is the same construction as the clarifier of FIG. 1, except concentric shells 60 are absent and downcomers 61 are absent. Instead, between discs 50 and 51 there are located a number of elongated plates 90 that are disposed about the working space within housing 36. These plates 90 extend from disc 50 to disc 51. The plates 90 are angularly disposed with respect to the radii of shaft 35, as seen in FIG. 21. Of course, shaft 35 has radial passageways 41, 44, and 45, and longitudinal passageways 40, 42, and 43. The plates 90 are present for the purposes described above for plates 82 in the clarifier of FIG. 18. The shaft 35 rotates clockwise, as the clarifier is viewed in FIG. 21. The plates 90 define a number of parallel chambers through which liquid flows in parallel paths while being subjected to centrifugal force in the working space within housing 36. Within each of these elongated chambers, a fluid is introduced by one set of holes 52 at many radial distances. Those holes 52 for a specific chamber are generally at a plane midway between the two plates 90 that define the chamber. Oil separates from oily water introduced in each chamber and flows radially inward until it meets the trailing surface of the leading plate 90 defining part of that chamber. As a result, a layer of oil accumulates about shaft 35 and flows out radial passageway 45. In each chamber, water remains essentially at the same radial level and passes out holes 53 in disc 51. The holes 53 are at concentric bands are described for holes 52.

This construction of a clarifier of the present invention, of course, has the limitation of total area, vis-a-vis square of radial distance with respect to openings at annular bands, each of which passes through all parallel chambers. This construction does not have a number of working chambers that are concentrically disposed but does provide for separate parallel flow and for each chamber longitudinal flow rate increasing radially outward.

In the clarifier of FIGS. 22 and 23, there is instead of a set of concentric cylindrical shells 60 and downcomers 61 a set of elongated partition walls 92 that are transversely curved and stepped. As seen in FIG. 21, this set of partition walls 92 provides a number of parallel chambers that extend from disc 50 to disc 51 for separate parallel flow of liquid from the distributor means to the collector means for clarified water. These chambers are not concentric, but each chamber has a series of stepped arcuate bands in which the stepping of each from housing shell 39 to shaft 35 is such that there is a space at the start of each step between partition wall 92 and the next adjacent partition wall 92. Through this space flows separated oil that by a step flow moves radially inward to shaft 35 and then to outlet radial passageway 45. The water flows from the distributor means to the collector means for clarified water essentially at the same radial level as introduced. At each band of radial height, holes 52 have total area corresponding to limitation mentioned above for other embodiments of the clarifier of the invention.

The clarifier of the invention that is shown in FIG. 24 differs from the clarifier of FIG. 1 in a number of respects as described below. The clarifier of FIG. 24 is directed to the centrifugal separation of an aqueous feed that contains a small amount of dissolved hydrocarbon oil, with or without suspended oil. The dissolved hydrocarbon is primarily, if not entirely, one or more aromatic hydrocarbons that have a greater solubility in water than do aliphatic hydrocarbons and naphthenic hydrocarbons. The clarifier of FIG. 24 reduces dissolved hydrocarbon content of the aqueous feed and, of course, reduces content of suspended oil, if present, in the aqueous feed.

The apparatus of FIG. 24 includes means to mix the aqueous feed with a diluent oil, illustratively of an aliphatic hydrocarbon type, with the aqueous feed before introducing the aqueous feed into longitudinal passageway 40 of shaft 35. To accomplish this, a pipe 94 communicates with an aqueous feed inlet pipe 95 that is connected to the inlet of a pump 96 having its outlet connected to a pipe 97 that communicates with inlet passageway 40. The aliphatic hydrocarbon diluent oil is mixed with aqueous feed in pump 96 and extracts a substantial part of the aromatic hydrocarbon content dissolved in the aqueous feed. The admixture flows from passageway 40 through radial passageway 41 into the chamber defined by rotor housing 36. This introduction is through short radial pipes 98 at different radii within that chamber and communicating with radial passageway 41 by a manifold ring (not shown). The pipes 98 have the same length to discharge the admixed feed at the same radial distance.

In the clarifier of FIG. 24, passageway 40 extends further inwardly of shaft 35 than in the case of passageway 40 in the clarifier of FIG. 1. The inner end of passageway 41 is approximately midway of the intermediate portion of shaft 35 enclosed by housing 36. The particular location of passageway 41 and radial pipes 98 along the longitudinal axis is such that the outlets of pipes 91 are located at a transverse plane that is a substantial longitudinal distance from the distributor means defined by discs 37 and 50.

As seen in FIG. 24, the inner annular portion of the chamber enclosed by housing 36 does not have any of the set of equally spaced concentric cylindrical shells 60. Instead, the inner portion has a set of spaced concentric perforated cylindrical shells 99. Each of the pipes 98 extends radially outward through radially aligned openings in the innermost shells 99 of the set to introduce this admixture of aqueous feed and diluent oil at a radial distance less than that of some of shells 99. Thus there are perforated shells 99 radially outward of the outlets of pipes 98 and some shells 99 radially inward of the outlets.

The shaft 35 contains a radial passageway 100 between passageway 41 and the transverse plane containing housing disc 37. The passageway 100 communicates with a longitudinal passageway 101 that is concentric with and outside inlet passageway 40. Separated diluent oil flows out passageway 100 and then out passageway 101 to a valved outlet pipe (not shown). The clarifier of FIG. 24 differs also from FIG. 1 in that there is no radial outlet passageway 45 and no longitudinal outlet passageway 43. This is because passageways 100 and 11 are used to remove separated oil.

In the operation of the clarifier of FIG. 24, sufficient diluent oil is accumulated in the chamber of housing 35 to provide an interface between it and the heavier aqueous liquid located between the outermost perforated shell 99 and the innermost shell 60. The admixture of diluent oil and aqueous feed passing out of pipe 98 is separated by centrifugal action within the body of accumulated diluent oil. The aqueous liquid flows radially outward to the body of aqueous liquid between the interface and innermost shell 60. Aqueous liquid from that body of aqueous liquid flows toward disc 37. The disc 50 extends radially inward from housing shell 39 only to the end of innermost shell 60, so that aqueous liquid from the body of liquid mentioned above can flow radially outward between disc 37 and disc 50. The flow of aqueous liquid from that body of liquid to disc 39 is prevented by disc 51 that extends from housing shell 39 to shaft 35. Thus, there is only one outlet for aqueous liquid from the body of aqueous liquid. That outlet is the distributor means located only at the outer annular portion of the one end of the rotor housing.

The distributor means includes disc 50 with its holes 52 that are disposed at concentric bands corresponding to the parallel chambers provided between shells 60 or shell 60 and shell 39 for the outer chamber. There are similar bands of holes 53 in disc 51. The limitation of total area of holes 52 of a band of those holes and/or the total area of holes 53 of a corresponding band of those holes with respect to the square of the radius is applicable in the manner described for the other embodiments.

As in the case of clarifier of FIG. 1, each shell 60 has about its periphery a number of openings at which are mounted downcomers 61 to provide sets of radially aligned downcomers 61. The downcomers 61, that extend radially inward from innermost shell 60, are sufficiently long to extend through the interface between diluent oil and aqueous liquid in the inner annular portion of the chamber of housing 36. Those longer downcomers 61 can extend through some of the set of perforated shells 99.

The radial distances of holes 52 and 53 associated with each chamber, in the clarifier of FIG. 24, are the same as described above with respect to the clarifier of FIG. 1.

It was mentioned above that separated oil flows out passageway 101 to a valved outlet pipe. The rate of withdrawal of oil from rotor 30 is determined by the setting of the valve. That valve is controlled to prevent an accumulation of separated oil between outermost perforated shell 99 and innermost shell 60 such that the interface would shift radially outwardly until there would no longer be a body of aqueous liquid radially inward of innermost shell 60 to provide aqueous feed only to the inlet chamber between discs 50 and 37. Of course, the setting of that valve is made in light of the fact that diluent oil is being added at a predetermined rate by pipe 94.

The solubility in water of hydrocarbons of a particular class decreases with increase of molecular weight. Thus the diluent oil may be an aromatic hydrocarbon, instead of aliphatic and/or naphthenic hydrocarbon, provided the diluent oil has a substantially higher molecular weight than the aromatic hydrocarbon in the aqueous feed.

The clarifier of FIG. 25 is a clarifier with an integral construction that provides two concentric working spaces within one rotor. That clarifier is useful to separate an aqueous feed containing oil and suspended solids of two different densities into clarified water, two aqueous slurries and oil. Because of its construction, it may also be called a two-stage multipass clarifier for removing suspended oil and solids from aqueous feed.

As in the case of clarifier of FIG. 1, shaft 35 in FIG. 25 has longitudinal passageways 40 and 42 extending inwardly from opposite ends to the intermediate portion of shaft 35 that is enclosed by housing 36. The passageway 40 communicates with radial passageway 41 to introduce aqueous feed to the distributor means. The passageway 41 has the same location as passageway 41 in the clarifier of FIG. 1, that is, in alignment with the distributor means at the one end of the chamber of housing 36. The passageway 42 communicates with radial passageway 45 that is spaced inwardly of the other end of the chamber provided by housing 36, as is the case for passageway 45 of FIG. 1 to receive separated oil and as is the case for passageway of FIG. 7 to receive separated aqueous slurry. In the case of the construction of clarifier of FIG. 25, passageway 45 receives aqueous slurry from the collector means constructed in the inner annular working space of the clarifier. That distributor means is a construction like that shown in FIG. 7. Thus, it includes about shaft 35 a set of outer radial pipes 71 at various radii in a common plane and inner concentric radial pipes 72 in pipes 71.

As in the construction of the clarifiers of FIGS. 1 and 7, there is a number of equally spaced concentric cylindrical shells 60 that can be referred to as an inner set and an outer set. Thus, there are two sets of parallel chambers through which liquid flows parallel to the longitudinal axis of shaft 35 and normal to the centrifugal force created by rotor 30. In the inner set of parallel working chambers, the flow is from left to right, as viewed in FIG. 25, whereas the major flow of liquid in the outer set of parallel chambers is from right to left. The two sets of parallel chambers ar separated by a shell 60 that provides a common wall for the outermost chamber of the inner set and the innermost chamber of the outer set. At the radial distance of that common shell 60 is mounted a short cylindrical shell 102 between discs 37 and 50 to separate the chamber defined by the annular chamber between discs 37 and 50 into an outer annular chamber and an inner annular chamber. Thus, the distributor means defined by discs 37 and 50 extends radially outward from shaft 35 only to shell 102. That chamber contains radial baffles 55 as in previously described constructions for FIGS. 1 and 5. The outer annular chamber has similar radial baffles 103. That chamber is a collector means for clarified water and comprises the outer annular portion of disc 37 and disc 50 with its holes 52.

In the inner annular working space having pipes 71 and 72, the former have openings 73 at which are located baffles 74 with a construction as shown in FIGS. 8 and 9. Aqueous feed, introduced through the inner annular set of concentric rings of holes 52, to the inner annular set of parallel chambers, is separated in those chambers into an aqueous slurry containing heavier solids that collect as a slurry at the outer portion of those chambers. That slurry flows through openings 73 of pipes 71. It flows radially outward and then radially inward through pipes 72 and finally out passageways 45 and 42 to a valved outlet pipe (not shown). The valve of that pipe is controlled to set the rate of removal of that slurry from the parallel chambers of the rotor as described in earlier embodiments.

The balance of the aqueous feed flows from the inner annular set of parallel chambers through holes 53 that are located at radial distances as described for holes 53 of the clarifier of FIG. 7. That liquid flows radially outward in the chamber between discs 38 and 51 with increased rotational motion due to radial baffles 56 that extend in that chamber from adjacent shaft 35 and housing shell 39. This aqueous liquid then flows through the outer annular set of concentric rings of holes 53 that are located with respect to the associated parallel chambers in the same manner as described above with respect to holes 52 in disc 50 of the distributor means of clarifier of FIG. 1.

The outer annular portion of the chamber within housing 36 has a number of radial pipes 104 at various radii in a common transverse plane. The pipes 104 extend from housing shell 39 to common shell 60 that closes the inner end of pipes 104. These pipes 104 are adjacent but spaced from disc 50. Extending adjacent but spaced from shell 39 within pipes 104 are concentric pipes 105 that extend radially inward through common shell 60 and the other shells 60 of the inner annular portion of the chamber within housing 39. The inner ends of pipes 105 are connected to a manifold ring (not shown, but like ring 68) and thereby communicate with a radial passageway 106 that communicates with a longitudinal passageway 107 that extends along the inlet end of shaft 35 where it is concentric with and inside passageway 40. In this outer annular set of parallel chambers containing pipes 104 the liquid flowing from right to left (as viewed in FIG. 25) is subjected to a greater centrifugal force than in the inner annular set of parallel chambers. This results in that outer set of parallel chambers in a further separation to provide another aqueous slurry. Some of that slurry flows toward openings 73 in pipes 104. Most flow is in a direction between pipes 104. That flow is diverted to openings 73 by baffles 74 associated with pipes 71.

At an intermediate location within this outer annular set of parallel chambers, that is, at a location between pipes 104 and disc 51, shells 60 of the outer set have about their periphery a number of holes in which are mounted downcomers 61 to provide sets of radially aligned downcomers at various radii. Each of the downcomers 61 for shell 60, that is common to both portions of the chamber, extends radially inward to communicate with another manifold ring (not shown) that receives from these downcomers 61 oil separated in each parallel chamber of the outer annular set. That manifold ring is constructed like ring 68 in FIG. 5. The oil from that ring flows into a radial passageway 108 and from it through a longitudinal passageway 109 that extends inwardly from the inlet end portion of shaft 35 where it is coaxial with and between passageways 40 and 104.

In the outer annular set of parallel chambers slurry of lighter solids separates along with the separation of oil as described above. Intermediate of these two separated layers is clarified water that flows out concentric rings of holes 52 into its collection chamber mentioned above as defined by the outer annular portion of disc 37 and that of disc 50. These outlet holes 52 are located with respect to their associated parallel chambers approximately midway of the height of those chambers as in the case of inlet holes 52 in the inner annular portion of disc 50, even though these outlet holes 52 are similar in function to outlet holes 53 for the collection chamber of clarified water in the clarifier of FIG. 1. These holes 52 of the outer annular set are at this different location because there are essentially three layers and because clarified water is being removed as an intermediate layer. In that chamber, clarified water passes radially inward to an outlet pipe 110 connected to a hole in disc 37 radially outside but adjacent shell 102. That pipe 110 communicates with a radial passageway 111 in an outer portion of shaft 35. From there the clarified water flows out a longitudinal passageway 112.

There are valved outlet pipes communicating with passageways 42, 107, and 109. These valves are present, as in the case of valve 33, in the clarifier of FIG. 1, as an important part of the clarifier of the invention. Of course, the outlet pipe communicating with passageway 112 can be similarly valved to control the overall flow rate as described earlier.

Instead of the construction shown in FIG. 25 for removing clarified water from its collector means, i.e., from between discs 37 and 50 radially outward of shell 102, by pipe 110, obviously the clarifier can contain one or more radial pipes at different radii extending from a manifold ring about shaft 35 through shell 102 to communicate the collector means for clarified water with a longitudinal passageway that would replace passageway 112.

The foregoing embodiments of the clarifier that are useful to separate oil from water containing suspended globules of oil, having a substantially lower specific gravity than that of water, can be modified to provide, with comparable effectiveness, a clarified water from feed water containing suspended globules of hydrocarbon oil or other immiscible liquid lighter than water but having a specific gravity almost that of water. For such treatment, the feed water is intimately mixed with a small amount of hydrocarbon diluent that is substantially lighter than water and that is miscible with the liquid of the suspended globules in the feed water. The two types of globules contact each other to provide globules with a specific gravity lower than those in the initial aqueous feed. This mixture may be obtained by the use of pipes 94 and 95 and pump 96 in the clarifier of FIG. 24, the resultant mixture is them pumped to a clarifier such as those in FIGS. 1 and 5.

Although the preferred aspect of the present invention requires the construction that includes the limitation of valved outlet means for the separated liquid phase containing substantially greater contaminant content than that of feed liquid and the limitation of total area of openings at each band of radial distance being basically proportional to the square of the radial distance, some of the abovedescribed embodiments of the clarifier of the invention also in other respects have structure that is not obvious from the prior art. Thus, the invention includes those clarifiers without the two limitations mentioned in this paragraph and earlier.

Preferably those clarifiers have such total areas proportional to a radial distance taken to a power substantially greater than one and especially preferred they are proportional to that distance taken basically to a power of two, as described earlier.

Many modifications of the clarifier of the present invention will be apparent from this detailed description and the summary of the invention. The foregoing description of preferred embodiments has been presented for purpose of illustration only. The invention is limited only by the claims that follow.

I claim:

1. A centrifugal clarifier for removal of contaminants from a liquid by separating the liquid into two liquid phases, which includes:

a rotor comprising:

a rotor shaft;

a rotor housing to enclose an elongated intermediate portion of said shaft so as to provide around said intermediate portion of said shaft an elongated working space of annular cross section;

a set of partition wall means in said working space of said housing and extending generally parallel to the longitudinal axis of said shaft from one end part of said intermediate portion to the other end part of said intermediate portion providing a number of elongated parallel annular chambers about said axis for major flow of liquid in said working space across a centrifugal force field and generally parallel to said axis;

distributor means extending radially outward from said shaft within one end part of said housing and having concentric sets of openings at different bands of radial distances from said axis to furnish feed liquid separately to said chambers;

first collector means extending radially outward from said shaft within the other end part of said housing and having concentric sets of openings at different bands of radial distances from said axis to receive one of the separated liquid phases from said chambers; and

second collector means located between said end parts of said housing to receive the other of the separated liquid phases from said chambers,

said rotor shaft having:

a longitudinal inlet passageway extending inwardly to said one end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said inlet passageway with said distributor means;

a first longitudinal outlet passageway for one of the separated liquid phases extending inwardly to said other end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said first outlet passageway with said first collector means;

a second longitudinal outlet passageway for the other of the separated liquid phases extending inwardly to said intermediate portion of the shaft; and

a radial passageway communicating said inner end of said second outlet passageway with said second collector means;

a first outlet pipe connected to said rotor to receive from one of said first and second outlet passageways the separated liquid phase having a major proportion of contaminant from the feed liquid;

a second outlet pipe connected to said rotor to receive from the other outlet passageway the other separated liquid phase as a clarified liquid; and

valved means mounted on first outlet pipe to control the rate of removal of the separated liquid phase by said first outlet pipe,

the total area of said openings at each band of radial distance from said axis for one of said distributor means for feed liquid and said collector means to receive the clarified liquid being basically proportional to the square of the radial distance.

2. The clarifier of claim **1** wherein:

said rotor housing comprises a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

said distributor means within said one end part of said housing comprises:

radial inlet pipes adjacent one of said circular discs and having holes in said inlet pipes to constitute said concentric sets of openings at different bands of radial distances from said axis; and

means communicating the radially inner end of said inlet pipes with said radial passageway communicating with longitudinal inlet passageway; and

said first collector means within said other end part of said housing comprises:

radial outlet pipes adjacent the other of said circular discs and having holes in said outlet pipes to constitute said concentric sets of openings at different bands of radial distances from said axis; and

means communicating radially the inner end of said outlet pipes with said radial passageway communicating with said first longitudinal outlet passageway.

3. The clarifier of claim **2** wherein:

said set of partition wall means comprises a set of equally spaced concentric generally cylindrical shells spaced from said shaft and said housing shell in said working space;

said holes in said inlet pipes at each of said bands of radial distances communicating only with one of said elongated parallel chambers and said holes being in alignment with the intermediate portion of the radial height of the associated parallel chamber; and

said holes in said outlet pipes at each of said bands of radial distances communicating only with one of said elongated parallel chambers and said holes being adjacent one of the outer and inner peripheral portions of the associated parallel chamber.

4. The clarifier of claim **3** wherein:

each of said concentric shells has holes about its periphery at a transverse plane that is between the said radial inlet pipes and said radial outlet pipes;

said second collector means comprises:

downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said downcomers providing sets of radially aligned downcomers at different radii;

said radial passageway communicating with said second outlet passageway being at the transverse plane containing said sets of downcomers; and

said holes in said outlet pipes communicating with the outer peripheral portion of the associated parallel chamber.

5. The clarifier of claim 4 wherein said housing shell and said concentric shells are cylindrical.

6. The clarifier of claim 3 wherein:

said second collector means is located at a transverse plane between said radial inlet pipes and said radial outlet pipes and comprises:

radial outlet pipes extending radially inward from said housing shell through said concentric shells at different radii and having said holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber;

baffles extending between adjacent outlet pipes of said collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said first collector means;

inner radial pipes concentric with said radial outlet pipes of said second collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said radial outlet pipes to flow radially inward in said inner radial pipes; and

means communicating said inner pipes with said radial passageway communicating with said second longitudinal outlet passageway.

7. The clarifier of claim 6 where said housing shell and said concentric shells are cylindrical.

8. The clarifier of claim 1 wherein:

said rotor housing comprises a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

said set of partition wall means comprises a set of equally spaced concentric generally cylindrical shells spaced from said shaft and said housing shell in said working space;

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis; and

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with one of the outer and inner peripheral portions of the associated parallel chamber provided by said concentric shells,

said concentric shells extending from said inlet disc to said outlet disc.

9. The clarifier of claim 8 wherein each set of said concentric sets of openings in said circular inlet disc is in alignment with an intermediate annular portion of that parallel chamber provided by said concentric shells in said working space.

10. The clarifier of claim 9 wherein:

said housing shell and said concentric shells are cylindrical;

each of said concentric shells has holes about its periphery at a transverse plane spaced from said inlet disc and said outlet disc;

said second collector means comprises:

downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said downcomers providing sets of radially aligned downcomers at different radii;

said radial passageway communicating with said second outlet passageway being at the transverse plane containing said sets of downcomers; and

said holes in said outlet disc communicating with the outer peripheral portion of the associated parallel chamber.

11. The clarifier of claim 10 wherein said cylindrical inlet chamber and said cylindrical outlet chamber contain radial baffles mounted to rotate with said shaft.

12. The clarifier of claim 9 wherein:

said housing shell and said concentric shells are cylindrical; and

said second collector means is located at a transverse plane between said inlet disc and said outlet disc and comprises:

radial outlet pipes extending radially inward from said housing shell through said concentric shells at different radii and having said holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber;

baffles extending between adjacent outlet pipes of said collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said first collector means;

inner radial pipes concentric with said radial outlet pipes of said second collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said radial outlet pipes to flow radially inward in said inner radial pipes; and

means communicating said inner pipes with said radial passageway communicating with said second longitudinal outlet passageway.

13. The clarifier of claim 12 wherein:

said means communicating said inner pipes of said second collector means with said radial passageway comprises:

a manifold hollow ring that is mounted on said shaft and having at its inner periphery an opening to communicate with said radial passageway, that has sidewalls that for their inner portion are straight and parallel and for their outer portion are converging outwardly to an outer periphery of lesser width than that of the inner periphery, and that at its outer peripheral wall has openings communicating with said inner ends of said radial outlet pipes of said second collector means; and

a radial pipe communicating with said radial passageway, that communicates with said second collector means, and extending outwardly within said manifold ring at a radius other than the radii of said inner radial pipes within said radial outlet pipes, whereby liquid slurry passing through said inner radial pipes can be further centrifugally separated in said hollow ring to a slurry, with a higher solids content than that of said slurry received by said ring, and to additional clarified water; and

said shaft further includes:

a third longitudinal passageway extending inwardly to a transverse plane containing said ring; and

a radial passageway communicating said third longitudinal passageway with said hollow ring to receive said additional clarified water.

14. The clarifier of claim **12** wherein:

each of said concentric shells has holes about its periphery at a transverse plane between and spaced from said inlet disc and said transverse plane containing said radial outlet pipes of said second collector means; and

said cylindrical inlet chamber and said cylindrical outlet chamber contain radial baffles mounted to rotate with said shaft,

said clarifier further including:

third collector means which comprises: downcomers mounted on said concentric shells at said holes of said shells and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said downcomers providing sets of radially aligned downcomers at different radii; and

a third longitudinal passageway extending inwardly to said transverse plane containing said downcomers; and

a radial passageway communicating said third longitudinal passageway with the innermost of said parallel chambers at said transverse plane containing said downcomers.

15. The clarifier of claim **9** wherein:

said housing shell and said concentric shells are slightly frustoconical, based on a cone with a small included angle;

said inlet disc and adjacent housing disc have smaller diameters than those of said outlet disc and adjacent housing disc; and

said second collector means is located at a transverse plane spaced from and between said inlet disc and said outlet disc and comprises:

radial outlet pipes extending radially inward from said housing shell through said concentric shells at different radii and having said holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber;

baffles extending between adjacent outlet pipes of said collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said first collector means;

inner radial pipes concentric with said radial outlet pipes of said second collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said radial outlet pipes to flow radially inward in said inner radial pipes; and

means communicating said inner pipes with said radial passageway communicating with said second longitudinal outlet passageway.

16. The clarifier of claim **1** wherein:

said rotor housing comprises a cylindrical housing shell having one end portion that is offset radially outward and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell:

said set of partition wall means comprises a set of equally spaced concentric generally cylindrical shells spaced from said shaft and said housing shell in said working space;

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis;

said first collector means within said other end part of said housing comprises:

a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell at the juncture of the main cylindrical portion of the rotor housing shell and the offset portion of that housing shell, and spaced from said other end part of said housing to provide, with said housing disc at that other end and with the offset end portion of said housing shell, a cylindrical outlet chamber having a larger diameter than that of the main portion of said housing shell, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with the outer peripheral portion of the associated parallel chamber provided by said concentric shells;

radial pipes extending into the outer peripheral portion of said cylindrical outlet chamber provided by said offset portion of said housing shell and spaced from said offset portion of said housing shell to permit liquid flowing radially outward in said cylindrical outlet chamber to flow radially inward in said radial pipes toward said shaft; and

means communicating said radial pipes with said radial passageway communicating with said first longitudinal outlet passageway;

each of said concentric shells has holes about its periphery at a transverse plane between and spaced from said inlet disc and said outlet disc;

said cylindrical inlet chamber contains radial baffles mounted to rotate with said shaft;

said second collector means comprises:

downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said downcomers providing sets of radially aligned downcomers at different radii;

said radial passageway, that communicates with said second outlet passageway, is at the transverse plane containing said sets of downcomers,

said concentric shells extending from said inlet disc to said outlet disc.

17. The clarifier of claim 16 and further including in the outer peripheral portion of said cylindrical outlet chamber a number of plates arranged in a polygonal manner with each juncture of the adjacent ends of said plates that form two sides of the polygon being at the radius of one of said radial pipes within said cylindrical outlet chamber to divert liquid flowing radially outward in said outlet chamber toward said radial pipes.

18. The clarifier of claim 1 wherein:

said rotor housing comprises a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

said set of partition wall means comprises a number of elongated plates that are disposed about said working space within said housing so that they are angularly disposed with respect to the radii of said shaft;

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis; and

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis,

said elongated plates extending from said inlet disc to said outlet disc to provide said elongated parallel chambers and the inner ends of said elongated plates being spaced from said shaft to provide said second collector means at said space around and adjacent said shaft.

19. The clarifier of claim 1 wherein:

said rotor housing comprises a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the end of said shell;

said set of partition wall means comprises a set of elongated partition walls that are transversely curved and stepped with a space between each step of said partition wall and the next adjacent partition wall for radially inward flow of lighter liquid separating from feed liquid in which it is a contaminant, said set of curved and stepped partition walls providing a number of parallel chambers that are transversely curved and stepped;

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis; and

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis,

said curved and stepped partition walls extending from said inlet disc to said outlet disc.

20. The clarifier of claim 1 wherein:

said rotor housing comprises a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

said set of partition wall means are located at an outer annular portion of said working space within said housing and comprises a set of equally spaced concentric generally cylindrical shells spaced from said shaft by an inner annular portion of said working space and spaced from said housing shell in said working space;

said distributor means within said one end part of said housing comprises a circular inlet disc at said outer annular portion of said working space, extending from said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber at that end of said outer annular portion to receive heavier liquid from said inner annular portion of said working space, said inlet disc having concentric sets of openings at different bands of radial discs from said axis;

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft through said inner and outer annular portions of said working space to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with the outer peripheral portion of the associated parallel chamber provided by said concentric shells in said outer annular portion of said working space;

each of said concentric shells extends from said inlet disc to said outlet disc and has holes about its periphery at a transverse plane spaced from and between said inlet disc and said outlet disc;

said second collector means comprises:

downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer, except those downcomers for the innermost concentric shell, being spaced from the inner periphery of the parallel chamber in which it extends;

said inlet passageway extending inwardly beyond said one end part of said intermediate portion of the shaft;

said radial passageway communicating with said inlet passageway being located to communicate with it at that end of said inlet passageway;

said radial passageway communicating with said second outlet passageway being located at a transverse plane intermediate the transverse plane containing said downcomers and the transverse plane containing said inlet chamber; and

said first outlet pipe is connected to receive liquid from said radial passageway communicating with said second outlet passageway,

said clarifier further including:

means to introduce liquid to be treated into said inlet passageway;

means to mix another liquid with said feed liquid in said feed introduction means;

a set of equally spaced concentric perforated hollow cylinders in said inner annular portion of said working space, said perforated cylinders extending from said housing disc adjacent said inlet disc to said outlet disc, and the outermost of said perforated cylinders being spaced from said innermost shell of said set of concentric shells that are in the outer annular portion of said working space; and

radial pipes of equal length and at different radii communicating with said radial passageway communicating with said inlet passageway and extending through some of said perforated cylinders to discharge feed liquid at the same radial distance in said inner annular chamber,

said downcomers extending from said innermost concentric shell passing through at least the outermost one of said concentric perforated hollow cylinders in said inner annular portion of said working space.

21. The clairifer of claim **1** wherein:

said set of partition wall means comprises a set of equally spaced concentric cylindrical shells spaced from said shaft and said housing shell, said shells being partly at an inner annular portion and partly at an outer annular portion of said working space and one of the intermediate shells defining a common wall between said inner annular portion and said outer annular portion of said working space;

said distributor means within one said end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell and spaced from one said end part of said housing, to provide a cylindrical inlet chamber for the parallel chambers defined by said cylindrical shells for the inner annular portion of said working space and to provide a cylindrical outlet chamber for said parallel chambers defined by said cylindrical shells for the outer annular portion of said working space, said inlet disc having said concentric sets of openings at different bands of radial distance from said axis in alignment with said parallel chambers in said inner annular portion of said working space and having concentric sets of openings at different bands of longer radial distances from said axis in alignment with the intermediate portion of said parallel chambers in said outer annular portion of said working space;

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with the inner peripheral portion of the associated parallel chamber provided by said concentric shells in the inner annular portion of said working space and having concentric sets of openings at different bands of longer radial distances from said axis with each set being in alignment with an associated parallel chamber in the outer annular portion provided by said concentric shells;

said second collector means is located at a transverse plane spaced from and between said inlet disc and said outlet disc and comprises:

radial outlet pipes extending radially inward from said housing shell through said concentric shells in said inner annular portion of said working space at different radii to said shell providing said common wall and having said holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber;

baffles extending between adjacent outlet pipes of said collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said first collector means;

inner radial pipes concentric with said radial outlet pipes of said second collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said radial outlet pipes to flow radially inward in said inner radial pipes; and

means communicating said inner pipes with said radial passageway communicating with said second longitudinal outlet passageway,

said shaft has third and fourth longitudinal outlet passageways and third and fourth radial passageways communicating with said inner end of said third and fourth outlet passageways,

said set of concentric shells extending from said inlet disc to said outlet disc, and said rotor of said clarifier further including:

radial baffles in said cylindrical inlet chamber and mounted to rotate with said shaft, said radial baffles extending outwardly to a radial distance less than the radial distance of said shell providing said common wall;

radial baffles in said chamber between said inlet disc and said one end part of said housing and spaced from said housing shell, said baffles being in alignment with the outer annular portion of said working space;

third collector means located primarily within said outer annular portion of said working space and comprising:

second radial outlet pipes extending radially inward from said housing shell through said concentric shells in said outer annular portion of said working space at different radii and having holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber in said outer annular portion of said working space;

baffles extending between adjacent second outlet pipes of said third collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said outer annular portion of said inlet disc;

second inner radial pipes concentric with said radial outlet pipes of said third collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said second radial outlet pipes to flow radially inward in said second inner radial pipes; and

means communicating said inner pipes with said third radial passageway communicating with said third longitudinal outlet passageway;

fourth collector means comprising:

holes in each of said shells in the outer annular portion of said working space and said shell providing the common wall, between that annular portion and said inner annular portion, said holes being about the periphery of each shell at a transverse plane spaced from and between said radial outlet pipes in said outer annular portion of said working space and said outlet disc;

downcomers mounted on said concentric shells in said outer annular portion at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the next parallel chamber in said outer annular portion, while said downcomers mounted on said shell providing said common wall extends through said shells in said inner annular chamber to the innermost parallel chamber of said inner annular portion of said working space; and

means communicating said downcomers, extending from said shell providing said common wall, communicating with said fourth radial passageway at the transverse plane containing said downcomers;

a short cylindrical shell between said one end of said housing and said inlet disc to separate the chamber therebetween into an inner annular chamber and an outer annular chamber having radial dimensions corresponding generally to those of said inner and outer annular portions of said working space; and

means for communicating said outer annular chamber between one end of said housing and said inner disc with said radial passageway communicating with said first longitudinal passageway and thereby communicating said outlet chamber with that longitudinal passageway through said parallel chambers in said outer annular portion of said working space.

22. A centrifugal clarifier for removal of contaminants from a liquid by separating the liquid into two liquid phases, which includes:

a rotor comprising:

a rotor shaft;

a rotor housing to enclose an elongated intermediate portion of said shaft so as to provide around said intermediate portion of said shaft an elongated working space of annular cross section, said rotor housing comprising a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

a set of equally spaced concentric generally cylindrical shells spaced from said shaft and said housing shell in said working space defining a plurality of chambers;

distributor means extending radially outward from said shaft within one end part of said housing and having concentric sets of openings at different bands of radial distances from said axis to furnish feed liquid separately to said chambers;

first collector means extending radially outward from said shaft within the other end part of said housing and having concentric sets of openings at different bands of radial distances from said axis to receive one of the separated liquid phases from said chambers; and

second collector means located between said end parts of said housing to receive the other of the separated liquid phases from said chambers,

said rotor shaft having:

a longitudinal inlet passageway extending inwardly to said one end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said inlet passageway with said distributor means;

a first longitudinal outlet passageway for one of the separated liquid phases extending inwardly to said other end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said first outlet passageway with said first collector means;

a second longitudinal outlet passageway for the other of the separated liquid phases extending inwardly to said intermediate portion of the shaft; and

a radial passageway communicating said inner end of said second outlet passageway with said second collector means;

a first outlet pipe connected to said rotor to receive from one of said first and second outlet passageways the separated liquid phase having a major proportion of contaminant from the feed liquid;

a second outlet pipe connected to said rotor to receive from the other outlet passageway the other separated liquid phase as a clarified liquid; and

valved means mounted on first outlet pipe to control the rate of removal of the separated liquid phase by said first outlet pipe.

23. The clarifier of claim **22** wherein:

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis;

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with one of the outer and inner peripheral portions of the associated parallel chamber provided by said concentric shells;

each set of said concentric sets of openings in said circular inlet disc is in alignment with an intermediate annular portion of that parallel chamber provided by said concentric shells in said working space;

said housing shell and said concentric shells are cylindrical;

each of said concentric shells has holes about its periphery at a transverse plane spaced from said inlet disc and said outlet disc;

said second collector means comprises:

downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said downcomers providing sets of radially aligned downcomers at different radii;

said radial passageway communicating with said second outlet passageway being at the transverse plane containing said sets of downcomers; and

said holes in said outlet disc communicating with the outer peripheral portion of the associated parallel chamber.

24. The clarifier of claim **22** wherein:

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis;

said first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with one of the outer and inner peripheral portions of the associated parallel chamber provided by said concentric shells;

said housing shell and said concentric shells are cylindrical; and

said second collector means is located at a transverse plane between said inlet disc and said outlet disc and comprises:

radial outlet pipes extending radially inward from said housing shell through said concentric shells at different radii and having said holes at each of said bands of radial distances that are in alignment with the outer peripheral portion of the associated parallel chamber;

baffles extending between adjacent outlet pipes of said collector means at the radial distance of said holes and constructed to divert to said holes liquid at that radial distance that would otherwise flow between those pipes toward said first collector means;

inner radial pipes concentric with said radial outlet pipes of said second collector means and having their outer ends spaced from said housing shell to permit liquid flowing radially outward in said radial outlet pipes to flow radially inward in said inner radial pipes; and

means communicating said inner pipes with said radial passageway communicating with said second longitudinal outlet passageway.

25. The clarifier of claim **22** wherein:

said distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having said concentric sets of openings at different bands of radial distances from said axis;

said first collector means within said other end part of said housing comprises:

a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide, with said housing disc at that other end, a cylindrical outlet chamber, said outlet disc having said concentric sets of openings at different bands of radial distances from said axis with each set being in alignment with the outer peripheral portion of the associated parallel chamber provided by said concentric shells;

radial pipes extending into the outer peripheral portion of said cylindrical outlet chamber provided by said offset portion of said housing shell and spaced from said offset portion of said housing shell to permit liquid flowing radially outward in said cylindrical outlet chamber to flow radially inward in said radial pipes toward said shaft; and

means communicating said radial pipes with said radial passageway communicating with said first longitudinal outlet passageway;

each of said concentric shells has holes about its periphery at a transverse plane between and spaced from said inlet disc and said outlet disc;

said cylindrical inlet chamber contains radial baffles mounted to rotate with said shaft;

said second collector means comprises: downcomers mounted on said concentric shells at said holes and extending radially inward with the inner end of each downcomer being spaced from the inner periphery of the parallel chamber in which it extends, said down comers providing sets of radially aligned downcomers at different radii;

said radial passageway, that communicates with said second outlet passageway, is at the transverse plane containing said sets of downcomers,

said concentric shells extending from said inlet disc to said outlet disc.

26. A centrifugal clarifier for removal of contaminants from a liquid by separating the liquid into two liquid phases, which includes:

a rotor comprising:

a rotor shaft;

a rotor housing to enclose an elongated intermediate portion of said shaft so as to provide around said intermediate portion of said shaft an elongated working space of annular cross section, said rotor housing comprising a generally cylindrical housing shell and two circular discs mounted on said shaft and connected at their periphery to the ends of said shell;

a set of partition walls comprises a set of elongated partition walls that are transversely curved and stepped with a space between each step of said partition wall and the next adjacent partition wall for radially inward flow of lighter liquid separating from feed liquid in which it is a contaminant, said set of curved and stepped partition walls providing a number of generally parallel chambers that are transversely curved and stepped;

distributor means within said one end part of said housing comprises a circular inlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said one end part of said housing to provide a cylindrical inlet chamber, said inlet disc having concentric sets of openings at different bands of radial distances from said axis providing inlets to said chambers;

first collector means within said other end part of said housing comprises a circular outlet disc mounted on said rotor shaft, extending from said shaft to said housing shell, and spaced from said other end part of said housing to provide a cylindrical outlet chamber said outlet disc having said concentric sets of openings at different bands of radial distances from said axis,

said curved and stepped partition walls extending from said

inlet disc to said outlet disc;

second collector means located between said end parts of said housing to receive the other of the separated liquid phases from said chambers,

said rotor shaft having:

a longitudinal inlet passageway extending in-

wardly to said one end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said inlet passageway with said distributor means;

a first longitudinal outlet passageway for one of the separated liquid phases extending inwardly to said other end part of said intermediate portion of the shaft;

a radial passageway communicating said inner end of said first outlet passageway with said first collector means;

a second longitudinal outlet passageway for the other of the separated liquid phases extending inwardly to said intermediate portion of the shaft; and

a radial passageway communicating said inner end of said second outlet passageway with said second collector means;

a first outlet pipe connected to said rotor to receive from one of said first and second outlet passageways the separated liquid phase having a major proportion of contaminant from the feed liquid;

a second outlet pipe connected to said rotor to receive from the other outlet passageway the other separated liquid phase as a clarified liquid; and

valved means mounted on first outlet pipe to control the rate of removal of the separated liquid phase by said first outlet pipe.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,814,307 Dated June 4, 1974

Inventor(s) Robert J. Hengstebeck

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 24, "gave" should read --have--.
Column 3, line 35, "pupe" should read --pipe--.
Column 6, line 20, "aobut" should read --about--.
Column 12, lines 15-16, "between" should read --before--.
line 21, "the space" should read --that space--.
Column 14, line 5, "56 and 66" should read --65 and 66-- .
line 41, "and and" should read --and--.
Column 15, line 8, "Instread" should read --Instead--.
line 33, "of total areas" should read --to total areas--.
Column 16, line 63, "secodary" should read --secondary--.
line 64, "that clarified" should read --than clarified--.
Column 17, line 24, "70" should read --79--.
Column 18, line 19, "diverted" should read --diverter--.
line 25, "the that" should read --that--.
line 40, "one of" should read --one or--.
line 41, "illustratied" should read --illustrated--.
line 44, "larger" should read --large--.
Column 19, line 12, "tance is" should read --tance as--.
line 58, "21" should read --22--.
Column 21, line 6, "11" should read --101--.
line 8, "35" should read --36--.
line 22, "to disc" should read --to shell--.
line 47, "ar" should read --are--.
Column 32, line 35, "discs" should read --distances--.
Column 35, line 44, "one end" should read --said one end--; "inner" should read --inlet--.
line 46, "longitudinal" should read --longitudinal outlet--.
line 47, "outlet chamber" should read --first collector means--.
line 48, "gitudinal" should read --gitudinal outlet--.

Signed and sealed this 3rd day of December 1974.

(SEAL)
Attest:

McCOY M. GIBSON JR.
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents