

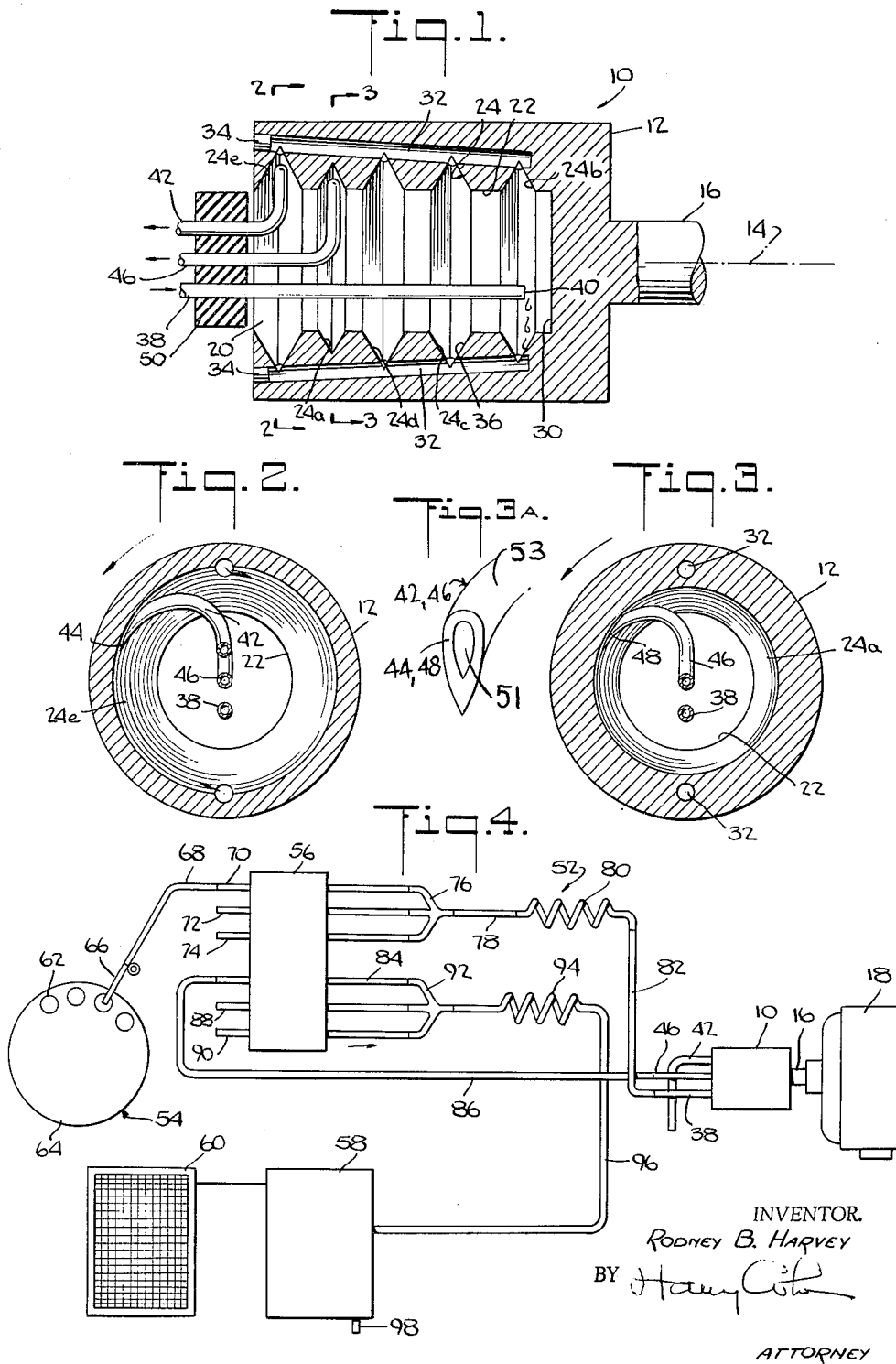
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CENTRIFUGAL SEPARATOR AND ANALYZING MEANS

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CENTRIFUGAL SEPARATOR AND ANALYZING MEANS

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This invention relates to centrifugal separators.

One of the objects of the invention is to provide an improved centrifuge of relatively simple and inexpensive construction for the separation of at least one substance from a mixture of substances.

Another object is the provision of a continuous centrifuge which is especially well adapted for use in a system for treating and analyzing one or more of the separated substances concurrently with the centrifuging operation in a continuous fashion.

The above and other objects, features and advantages of the invention will be more fully understood from the following description of the invention considered in connection with the accompanying drawings which are to be considered merely illustrative of the invention and not in limitation thereof.

In the drawings:

FIG. 1 is a sectional view of a continuous centrifuge in accordance with the present invention;

FIG. 2 is a cross section taken on line 2—2 of FIG. 1;

FIG. 3 is a cross section taken on line 3—3 of FIG. 1;

FIG. 3A is a detail perspective view of the inlet end of a take-off tube of the centrifuge, and

FIG. 4 is a more or less diagrammatic view illustrating a continuous analysis method and apparatus in accordance with the present invention.

Referring now to FIGS. 1 to 3 of the drawings, the centrifuge 10 comprises a rotary vessel 12 suitably mounted for rotation about its longitudinal axis 14. One end of the vessel is provided with an extending member 16 which is adapted to be connected to a motor 18 (FIG. 4) for rotating the vessel about its longitudinal axis. The opposite end 20 of the vessel is open and its cylindrical internal side wall 22 is provided with a series of parallel circular grooves 24 laterally spaced from each other axially of the vessel in planes normal to the axis of rotation of the vessel.

The grooves are V-shaped and are in communication with the interior of the vessel. With the exception of groove 24a, the grooves 24b, 24c, 24d and 24e increase progressively in diameter from the inner end 30 of the vessel to the open end 20 and are in communication at their respective bottoms with a pair of diametrically opposite passages 32 which extend longitudinally of the vessel and diverge outwardly from the inner end of the vessel to the open end 20. The ends of the passages, adjacent the open end of the vessel, are closed by plugs 34. It is to be noted that the grooves are separated from each other by the walls 36 of the vessel and groove 24a does not communicate with passages 32. The invention is not limited to the indicated number of passages 32.

A stationary inlet tube 38 extends longitudinally through the open end 20 of the vessel into the interior thereof and is positioned in lateral offset relation with respect to the longitudinal axis 14 of the vessel. The outlet end 40 of the tube is positioned with respect to groove 24b so that the incoming mixture is introduced into the vessel in the vicinity of said groove for the separation of the lighter substance in the mixture from the heavier substance as a result of the rotation of the vessel. A stationary take-off tube 42 for the separated heavier substance of the mixture is provided with its inlet end 44 positioned in groove 24e for receiving the separated

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heavier substance which is transmitted to said groove through passages 32. Another stationary take-off tube 46 is provided with its inlet end 48 in position in groove 24a to receive the separated lighter substance from the groove for transmission from the centrifuge. The tubes may be conveniently supported in a stationary apertured plug 50 mounted independently of vessel 10 or by any other suitable means.

As best seen in FIGS. 2 and 3, each inlet end 44 and 48 of the take-off tubes 42 and 46, respectively, are parallel to and confront the adjacent surface of the corresponding groove and the inlet end of the passage 51 (FIG. 3A) of each tube extends perpendicularly from the end of the corresponding tube. The peripheral shape of the inlet end of each tube and the part adjacent thereto is that of an airfoil or hydroplane, as shown in FIG. 3A, with its leading edge 53 confronting the oncoming separated substance, which is moving in a counterclockwise direction as viewed in FIGS. 2 and 3. The airfoil or hydroplane shape minimizes to a tolerable degree or entirely eliminates excessive stirring and splashing of the fluids and the formation of drops of fluid on the ends of the tubes which would periodically fall off resulting in mixing and contamination of the separated substances. It is to be noted that the shape of the inlet ends of the take-off tubes is such that the kinetic energy of the moving substances does not affect the removal of the substances from the centrifuge.

In the operation of the apparatus, the material which is to undergo centrifuging is introduced into groove 24b through the outlet end 40 of inlet tube 38 and due to the centrifugal force created by the rapid rotation of the vessel, the separable heavier constituent of the material moves outwardly from the axis toward the bottom of the groove and the lighter constituent of the material moves axially of the vessel toward the next groove. The separated heavier constituent moves into passage 32 and as additional material is introduced into groove 24b, the lighter constituent of the mixture as well as part of the heavier constituent which has not separated from the mixture flow over the top of groove 24b and flow longitudinally along wall 22 to the adjacent groove 24c. Since this groove has a larger diameter than the previous groove, the material in the groove is subjected to a greater centrifugal force than in the previous groove whereby additional separation of the heavier constituent from the lighter constituent occurs and the separated heavier constituent passes into the passage 32. The remaining material including the separated lighter constituent overflows into the next groove 24d and because of the larger diameter of said groove, the material therein is subjected to a greater centrifugal force than in the previous grooves.

The separated heavier constituent from grooves 24b, 24c and 24d is transmitted by the centrifugal forces resulting from the rotation of the vessel through passage 32 and into groove 24e where it is removed from the centrifuge by the aspirating action of take-off tube 42, which is connected to a suction pump, not shown. The separated lighter constituent of the material is collected in groove 24a, which is out of communication with passage 32, and is transmitted from that groove by take-off tube 46 in a manner similar to the removal action simultaneously occurring in groove 24e.

The centrifuge of this invention is especially useful for separating and removing solid or semi-solid particles or material which may be present in a liquid, for example, separation and removal of proteinaceous material from blood serum or blood plasma in the quantitative analysis thereof in respect to its cholesterol content. For such determination, the serum or plasma may be treated with isopropyl alcohol to precipitate the proteins which are then removed by the centrifuge from the lighter material.

After the protein is separated from the blood by the centrifuging operation, it is collected in groove 24e and removed therefrom by take-off tube 42.

Referring now to FIG. 4, there is shown a liquid analysis or treatment apparatus 52 which may be utilized for treating blood serum or blood plasma to determine its cholesterol content. In addition to the continuous centrifuge 10, the apparatus includes a sample supply device 54, a proportioning pump 56, a colorimeter 58 having a flow cuvette of the continuous flow type and a recorder 60 operable under the control of the colorimeter. The liquid samples which are to be treated for analysis or other processing are provided in open top receptacles 62 which are arranged in a circular row on a rotary support plate 64 which is intermittently rotated to position successive receptacles below the inlet end of an inlet aspirating tube 66. A portion of the sample from each receptacle is aspirated from its respective receptacle by the action of pump 56 and flows as a stream through supply tube 68 and pump tube 70 where it joins a stream of inert gas, for example air, which is supplied through pump tube 72, and a stream of precessing liquid or diluent, which is supplied through pump tube 74. In the treatment of blood serum or blood plasma to determine its cholesterol content, pump tube 74 is supplied with a solution of isopropyl alcohol which is a precipitant for the proteinaceous material in the serum or plasma.

The separate streams merge at fitting 76 and form a segmented stream consisting of a series of liquid segments separated from each other by intervening segments of air. The introduction of air or other inert gas into the tubes or passages through which the sample flows provides a self-cleansing action for said passages as explained in U.S. Patent No. 2,797,149 issued June 25, 1957.

The sample supply device 54 can be of the type shown in U.S. Patent No. 2,946,665 issued July 26, 1960, but is preferably of the type shown and described in the U.S. application of Jack Isreeli, Serial No. 664,403 filed June 18, 1957 and assigned to the assignee of the present application. As explained in said patent and application, the operation of the supply device results in a segment of air being introduced into the intake tube 66 between successive samples so that the samples are separated from each other by air as well as each sample being divided into a series of liquid segments separated from each other by an intervening air segment.

The segmented stream is transmitted by the action of the pump through a conduit 78 to a horizontal helical mixing coil 80 wherein the constituents in each liquid segment are mixed together in the respective segments and the mixed stream is transmitted to the inlet tube 38 of the centrifuge 10 via conduit 82.

The preceipitate resulting from the treatment of the sample with the precipitant is separated from the sample in the centrifuge in the manner described above and the sample, devoid of the precipitate, is aspirated from the centrifuge through take-off tube 46 by the aspirating action of pump 56 due to the connection of tube 46 with pump tube 84 via conduit 86.

Concurrently with the flow of the sample from the centrifuge through pump tube 84, air or other inert fluid and a suitable color producing reagent are transmitted through pump tubes 88 and 90, respectively. The streams merge in fitting 92 and the resulting segmented stream is transmitted by the action of the pump to helical mixing coil 94 and the resulting segmented colored stream is transmitted from the mixing coil to the flow cuvette (not shown) of the colorimeter 58, via conduit 96, wherein the color density or light absorption characteristic of the stream is measured and recorded on the recorder 60 which is operated under the control of the colorimeter and provides a measurement which is indicative of the quantity of the substance present in the sample stream supplied by supply device 54. The stream is discharged from the flow cuvette of the colorimeter through outlet 98.

It will be understood that in the case of blood analysis for cholesterol, the color producing reagent is a solution of ferric chloride in concentrated sulfuric acid. The resulting color density of the treated stream is an indication of the cholesterol content of the sample.

It will be understood that the apparatus may be used for the treatment of many fluids for analysis with respect to an ingredient thereof and the choice of the processing liquids and color reagents used will depend upon the fluid being analyzed. It will be understood that the present invention is independent of any specific method of chemical analysis or treatment but, on the contrary, may be employed in performing any method which necessarily or advantageously makes use of a centrifuge for removing or separating a particular substance or material from another.

Proportioning pump 56, which is schematically illustrated, is preferably of the type shown and described in U.S. Patent No. 2,935,028 issued May 3, 1960. In such pump, the pump tubes are resiliently flexible and are compressed progressively along their lengths by pressure rollers which are moved in engagement with the tubes longitudinally thereof. The quantities of fluids pumped through the various tubes depend upon the internal diameter of the respective tubes since the tubes are simultaneously compressed by the rollers as they move longitudinally along the tubes for the pumping operation. It is within the scope of the present invention to provide pumps other than that indicated and if desired or necessary, separate pumps may be provided for pumping the individual fluids in lieu of the proportioning pump as indicated.

The colorimeter and recorder are well known types and since they do not, per se, form part of the invention, further description of these devices is unnecessary. It is within the scope of the invention to provide measuring means other than a colorimeter, for example and without limitation, a spectral-flame analyzer.

Although the liquid treatment apparatus 52 is shown with a sample supply device 54 for supplying a plurality of individual samples in succession to the treatment apparatus, it is within the scope of this invention to supply a continuous sample stream for treatment as, for example, in a monitoring operation. It is also within the scope of the present invention to treat or analyze either one of the separated substances of the mixture and it is also within the scope of the invention to simultaneously treat and analyze both of the separated substances.

While I have shown and described the preferred embodiment of the invention, it will be understood that the invention may be embodied otherwise than as herein specifically illustrated or described, and that certain changes in the form and arrangement of parts and in the specific manner of practicing the invention may be made without departing from the underlying idea or principles of this invention within the scope of the appended claims.

What is claimed is:

1. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an internal wall surface provided with first, second and third grooves laterally spaced from each other axially along the wall surface, means for introducing the mixture into said first groove for the separation of said substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, means in communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated

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lighter substance from said first groove, and means in communication with said second groove for withdrawing said lighter substance therefrom concurrently with the rotation of said vessel.

2. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an internal wall surface provided with first, second and third grooves laterally spaced from each other axially along the wall surface, said wall surface diverging from said axis in the direction from said first groove to said third groove, means for introducing the mixture into said first groove for the separation of said substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, means in communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and means in communication with said second groove for withdrawing said lighter substance therefrom concurrently with the rotation of said vessel.

3. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an internal wall surface provided with first, second and third grooves laterally spaced from each other axially along the wall surface, said wall surface diverging from said axis in the direction from said first groove to said third groove, means for introducing the mixture into said first groove for the separation of said substances as a result of the rotation of said vessel, passage means diverging from said axis in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, means in communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface out of communication with said passage means between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and means in communication with said second groove for withdrawing said lighter substance therefrom concurrently with the rotation of said vessel.

4. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an internal wall surface provided with first, second and third grooves laterally spaced from each other axially along the wall surface, means for introducing the mixture into said first groove for the separation of said substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, means in communication with said third groove for removing said heavier substances therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, means in communication with said second groove for withdrawing said lighter substance therefrom concurrently with the rotation of said vessel, and a fourth groove in said wall surface be-

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tween said first and second grooves with said passage means being in communication with the bottom thereof, said fourth groove receiving a portion of said mixture from said first groove for the separation thereof into said lighter and heavier substances in like manner.

5. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an internal wall surface provided with first, second and third grooves laterally spaced from each other axially along the wall surface, means for introducing the mixture into said first groove for the separation of said substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, means in communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and means in communication with said second groove for withdrawing said lighter substance therefrom concurrently with the rotation of said vessel, said second groove being of greater diameter than said first groove and said third groove being of greater diameter than said second groove.

6. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an open end and an internal wall surface extending from said open end longitudinally of said axis, first, second and third endless grooves provided in said wall surface laterally spaced from each other axially thereof and in confronting communicating relation with the interior of said vessel, stationary means extending through said open end into said interior of said vessel for introducing said mixture into said first groove for the separation of the substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, stationary outlet means extending through said open end into communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove and stationary outlet means extending through said open end into communication with said second groove for removing said separated lighter substance therefrom concurrently with the rotation of said vessel.

7. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an open end and an internal wall surface extending from said open end longitudinally of said axis, first, second and third endless grooves provided in said wall surface laterally spaced from each other axially thereof and in confronting communicating relation with the interior of said vessel, said wall surface diverging from said axis in the direction from said first groove to said third groove, stationary means extending through said open end into said interior of said vessel for introducing said mixture into said first groove for the separation of the substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the

separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, stationary outlet means extending through said open end into communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and stationary outlet means extending through said open end into communication with said second groove for removing said separated lighter substance therefrom concurrently with the rotation of said vessel.

8. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an open end and an internal wall surface extending from said open end longitudinally of said axis, first, second and third endless grooves provided in said wall surface laterally spaced from each other axially thereof and in confronting communicating relation with the interior of said vessel, said wall surface diverging from said axis in the direction from said first groove to said third groove, stationary means extending through said open end into said interior of said vessel for introducing said mixture into said first groove for the separation of the substances as a result of the rotation of said vessel, passage means diverging from said axis in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, stationary outlet means extending through said open end into communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface out of communication with said passage means between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and stationary outlet means extending through said open end into communication with said second groove for removing said separated lighter substance therefrom concurrently with the rotation of said vessel.

9. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an open end and an internal wall surface extending from said open end longitudinally of said axis, first, second and third endless grooves provided in said wall surface laterally spaced from each other axially thereof and in confronting communicating relation with the interior of said vessel, stationary means extending through said open end into said interior of said vessel for introducing said mixture into said first groove for the separation of the substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, stationary outlet means extending through said open end into communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, stationary outlet means extending through said open end into communication with said second groove for removing said separated lighter substance therefrom concurrently with the rotation of said vessel, and a fourth endless groove in said wall surface between said first and second grooves with said passage means being in communication with the bottom thereof, said fourth groove receiving a

portion of said mixture from said first groove for the separation thereof into said lighter and heavier substances in like manner.

10. A centrifuge for separating substances of different specific gravities, respectively, present in the form of a mixture of said substances, said centrifuge comprising, a rotary vessel mounted for rotation about its longitudinal axis and having an open end and an internal wall surface extending from said open end longitudinally of said axis, first, second and third endless grooves provided in said wall surface laterally spaced from each other axially thereof and in confronting communicating relation with the interior of said vessel, stationary means extending through said open end into said interior of said vessel for introducing said mixture into said first groove for the separation of the substances as a result of the rotation of said vessel, passage means in communication with the bottoms of said first and third grooves for receiving the separated heavier substance from said first groove and transmitting it to said third groove during rotation of said vessel, stationary outlet means extending through said open end into communication with said third groove for removing said heavier substance therefrom concurrently with the rotation of said vessel, said second groove being located in said wall surface between said first and third grooves in position to receive and collect the separated lighter substance from said first groove, and stationary outlet means extending through said open end into communication with said second groove for removing said separated lighter substance therefrom concurrently with the rotation of said vessel, said second groove being of greater diameter than said first groove and said third groove being of greater diameter than said second groove.

11. Apparatus for continuously processing a liquid having two constituents of different specific gravities, comprising: source means for continuously supplying the liquid; a rotary vessel mounted for rotation about its longitudinal axis having a wall defining a conical central cavity, three grooves in said wall longitudinally spaced apart, and a passageway through said wall interconnecting the apex proximal groove with the apex remote groove; motive means coupled to said rotary vessel for rotating said vessel about said longitudinal axis; first conduit means having an inlet coupled to said source means and an outlet in fluid flow communication with said apex proximal groove, for conveying the liquid to said apex proximal groove as a stream; said vessel serving as a centrifuge whereby the heavier constituent of the liquid passes through said passageway from said apex proximal groove to said apex remote groove, and the lighter constituent of the liquid passes along said wall from said apex proximal groove to the medial groove; analysis means; second conduit means having an outlet coupled to said analysis means and an inlet in fluid flow communication with one groove of the group of grooves consisting of said apex remote groove and said medial groove, for conveying the constituent therein to said analysis means; and third conduit means having an inlet in fluid flow communication with the other groove of said group of grooves, for conveying the constituent therein from said other groove.

12. Apparatus for continuously processing a liquid having two constituents of different specific gravities, comprising: source means for continuously supplying the liquid; a rotary vessel mounted for rotation about its longitudinal axis having a wall defining a conical central cavity, three grooves in said wall longitudinally spaced apart, and a passageway through said wall interconnecting the apex proximal groove with the apex remote groove; motive means coupled to said rotary vessel for rotating said vessel about said longitudinal axis; first conduit means having an inlet coupled to said source means and an outlet in fluid flow communication with said apex proximal groove, for conveying the liquid to

said apex proximal groove as a stream; said vessel serves as a centrifuge whereby the heavier constituent of the liquid passes through said passageway from said apex proximal groove to said apex remote groove, and the lighter constituent of the liquid passes along said wall from said apex proximal groove to the bedial groove; analysis means; pump means; second conduit means having an inlet coupled to the outlet of said pump means, and an outlet coupled to the inlet of said analysis means; third conduit means having an inlet end of hydroplane shape with its leading edge confronting the oncoming separated constituent as said vessel is rotated, and closely spaced from the surface of and in fluid flow communication with one groove of the group of grooves consisting of said apex remote groove and said medial groove, and an outlet coupled to the inlet of said pump means, for conveying the constituent in said one groove to said analysis means; and fourth conduit means having an inlet end of hydroplane shape with its leading edge confronting the oncoming separated constituent as said vessel is rotated, and closely spaced from the surface of and in

fluid flow communication with the other groove of said group of grooves, for conveying the constituent therein from said other groove.

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