United States Patent

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[15] **3,674,206**

[45] **July 4, 1972**

[54] CENTRIFUGAL SEPARATOR WITH MEANS CONTROLLING FLOW

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[22] Filed: **Nov. 20, 1970**

[21] Appl. No.: **91,469**

[52] **U.S. Cl.** .....**233/19 A**, 233/29, 233/33, 233/47 R

[51] **Int. Cl.**.....**B04b 11/00**

[58] **Field of Search** .....233/1 R, 16, 19 R, 19 A, 27, 233/28, 29, 30, 33, 32, 34, 38, 44, 45, 46, 47 R

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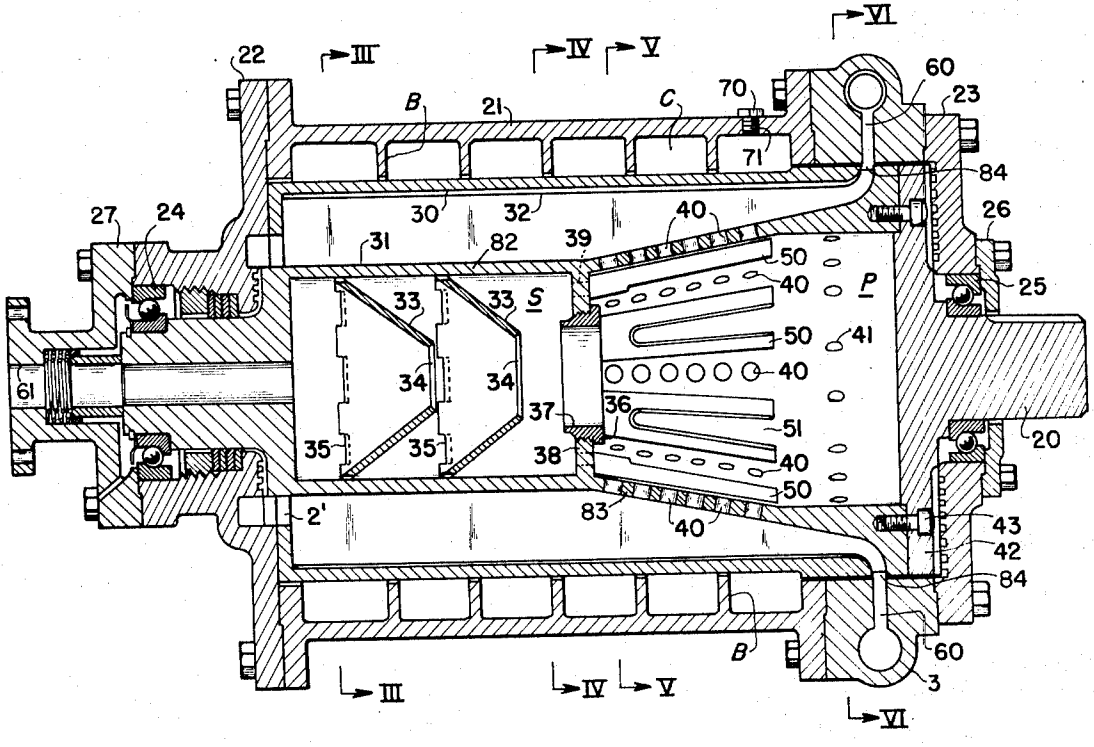
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[57] **ABSTRACT**

A centrifugal separator having a stationary casing and rotating means coaxial with and radially spaced from the casing, the rotating means including an outer shell having an annular inlet passageway, a barrel coaxial with the shell and radially spaced inwardly therefrom to form a primary separation chamber, vanes attaching the barrel to the shell, the barrel having an outwardly flared portion and a cylindrical portion and an end wall closing the large end of the flared portion, a plurality of openings providing communication between the space within the barrel and the space between the barrel and the shell, means within the barrel to enhance the separation of the mixture, first radial outlet means from one end of the barrel and second axial outlet means from the other end of the barrel, and an annular discharge passageway from the primary separation chamber.

12 Claims, 8 Drawing Figures



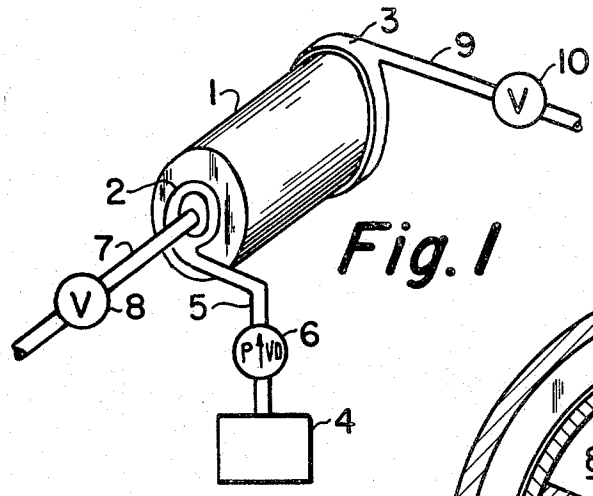


Fig. 1

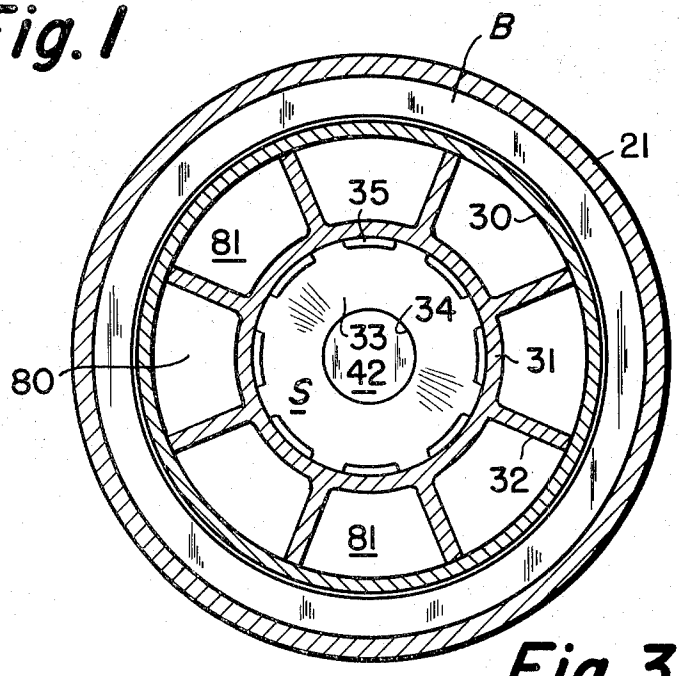


Fig. 3

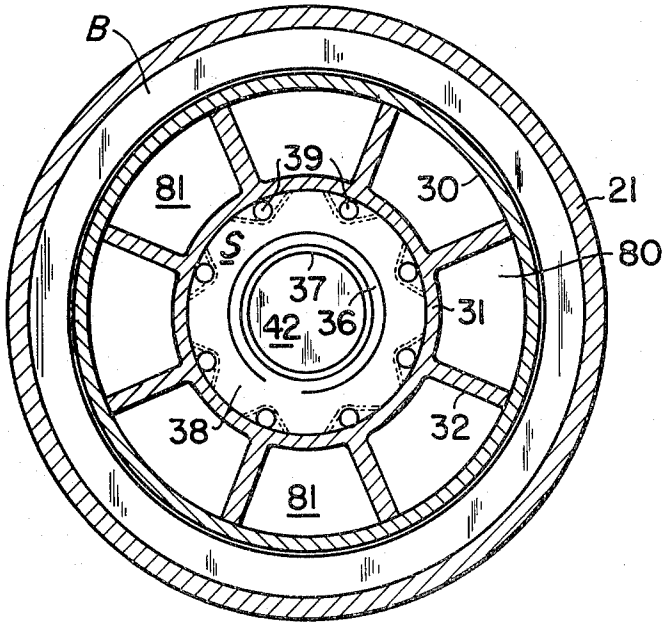


Fig. 4

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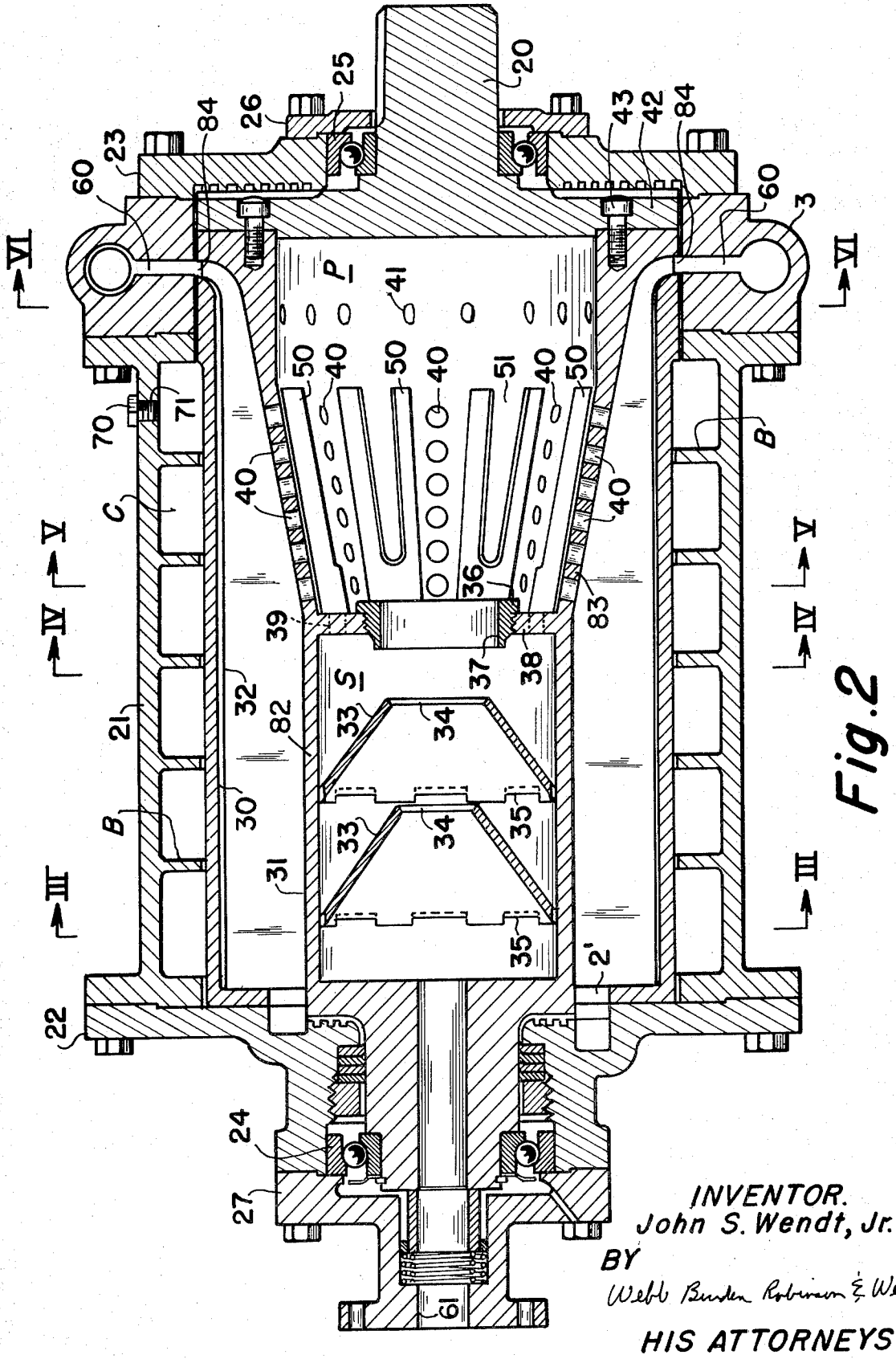


Fig. 2

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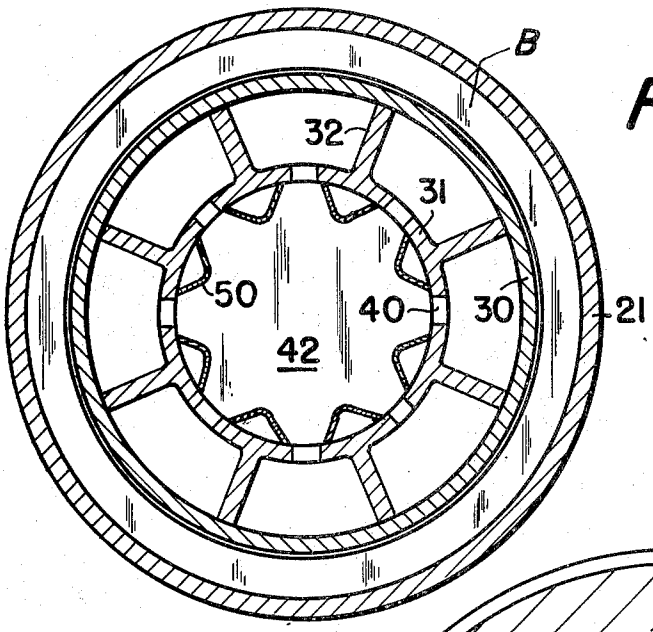
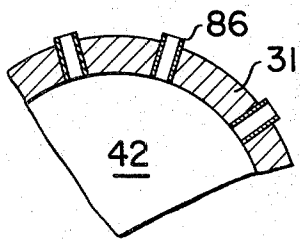


Fig. 5

Fig. 8



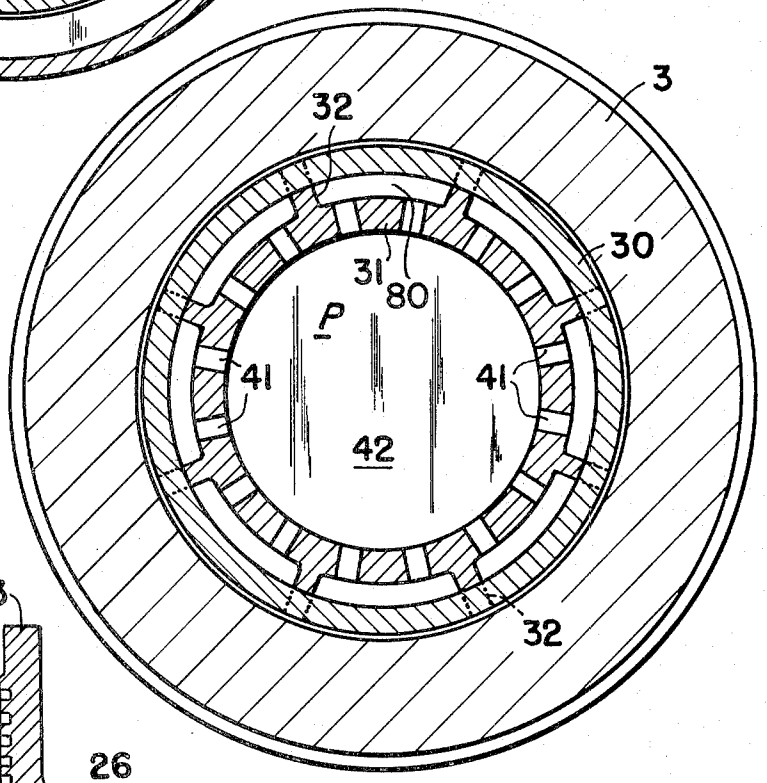


Fig. 6

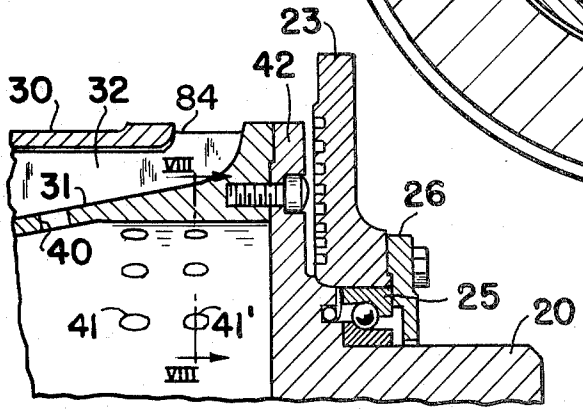


Fig. 7

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CENTRIFUGAL SEPARATOR WITH MEANS CONTROLLING FLOW

This invention relates to the separation of liquids and more particularly to the separation of two immiscible liquids having different densities such as oil and water from a mixture and to apparatus for effecting this separation.

The apparatus of my invention separates two components of a liquid mixture and provides relatively pure individual liquids for subsequent use. The apparatus has ecological value since it may be used to treat waste products to render the individual components suitable for subsequent use or for disposal. For example, an important use of my invention is the separation of oil and water.

Two uses for my apparatus are removing oil from water (deoiling water) in connection with the disposal of oil tanker ballast in which water is the predominate fluid with oil being present in a relatively small amount, and removing water from oil (dewatering oil) in secondary well recovery or interstage applications in which the major portion of the mixture is a fractional derivative of oil and in which water is present in amounts of less than about 35 percent. It should be understood that complete separation requires that the quantities of oil and water discharged from the separator be in the same ratio as the quantity of each component in the feed mixture. For this reason, it is desirable to control the operation of the separator to approximately proportion the individual discharges to obtain the purity desired. However, one component must be favored to optimize its purity at the expense of the purity of the other component so that the purity of only one component of the mixture is optimized. The less pure component may be recycled or treated in a second stage if desired.

In the accompanying drawings, I have shown preferred embodiments of my invention in which:

FIG. 1 is a schematic diagram of my apparatus;

FIG. 2 is a vertical section through a separator designed to remove water from oil;

FIG. 3 is a section on line III—III of FIG. 2;

FIG. 4 is a section on line IV—IV of FIG. 2;

FIG. 5 is a section on line V—V of FIG. 2;

FIG. 6 is a section on line VI—VI of FIG. 2; and

FIG. 7 is a broken-away section of the discharge portion of the separator modified to remove oil from water.

FIG. 8 is a broken away section on line VIII—VIII of FIG. 7 showing a modification of the discharge portion of the separator.

Referring to FIG. 1 of the drawings, my apparatus consists of a centrifugal separator 1 having an accelerating involute inlet scroll 2 to introduce the feed mixture. The mixture is supplied from a tank 4 through a conduit 5 by a suitable pump 6, but it should be understood that the source of the mixture is not important. After the mixture has been separated into its two components by my novel apparatus, one component flows axially outward to an outlet conduit 7 having a flow control valve 8, and the other component flows tangentially outward through outlet scroll 3 to an outlet conduit 9 having a flow control valve 10. It is essential that the outlet conduits be provided with control valves since the setting of these valves controls the discharge volume which depends upon the proportions of the components in the feed mixture.

The rotary portion of the separator is rotated by a common drive mechanism connected to a splined drive shaft 20. The specific drive mechanism forms no part of my invention.

The details of my novel separator will best be understood with reference to FIGS. 2 – 7 of the drawings. The separator has an outer stationary casing 21 with end pieces 22 and 23 bolted thereto. Standard sealed bearings 24 and 25 are located within the end pieces and are held in place by annular members 26 and 27. Member 26 is bolted to end piece 23 and has an opening for drive shaft 20. At the opposite end of the separator, member 27 is bolted to end piece 22. A well known rotary sealed joint is located within member 27. Suitable seals are provided at both ends of the separator to maintain the fluid in the separator under pressure. In this regard, it is

pointed out that there is no seal between the stationary casing of the separator and the rotary portion. Since there are no seals, a slight leakage of liquid at an exit pressure of about 800 psi flows into a pressure chamber C, and annular baffles B cause the pressure of this liquid to decrease step-by-step to about 180 psi which is slightly higher than the inlet pressure of the feed mixture. Hence, the liquid will flow from pressure chamber C into annular inlet 2'.

The rotary portion of the separator consists of a shell 30 and a coaxial barrel 31 spaced radially inwardly therefrom to form a primary separation chamber 80. Radial vanes 32 extend between shell 30 and barrel 31 in the primary separation chamber and are attached to both the shell and the barrel. These vanes direct the fluid axially throughout the length of the separator, and adjacent blades form gathering troughs 81. The rotary motion of the vanes transmits rotary motion to the feed mixture which creates the initial separating forces in the primary separation chamber.

Barrel 31 is formed with a cylindrical portion 82 and a flared portion 83 can be seen in FIG. 2 of the drawings. The angle between the cylindrical and the flared portions of the barrel will vary from about 5° to about 20° depending upon the application of the separator. The flared portion of barrel 31 has a progressively expanding diameter and defines a primary inner bowl P, and the cylindrical portion of barrel 31 defines a secondary inner bowl S. A pair of spaced coaxial burble cones 33 is mounted within the secondary inner bowl of barrel 31. Each cone has a coaxial opening 34 at its smaller end and a plurality of slots 35 at its larger end located adjacent to the inner surface of barrel 31. While a pair of cones is shown, it should be understood that any number of cones may be used depending upon the application of the separator.

A septum member 38 located at the end of the cylindrical portion of barrel 31 adjacent to the flared portion supports an orifice member 36. The septum member has an internally threaded opening in its center, and the orifice member is threaded on its periphery so that it can be screwed into septum member 38. The reason for the threaded construction is to permit easy adaptation of the separator to different mixtures by the utilization of different size orifice members. A plurality of openings 39 are formed around the periphery of septum member 38.

The wall of the flared portion of barrel 31 is formed with a plurality of openings 40 which are arranged in spaced longitudinally extending rows. In addition to openings 40, a plurality of openings 41 are arranged in a ring at the large end of the flared portion of barrel 31. The thickness of the barrel wall at the portion of the barrel containing openings 41 creates a pumping effect drawing liquid out of the barrel into the end of the primary separation chamber. In this regard, it should be understood that the number of openings 41 (FIG. 7) and 41' in the barrel wall may be varied to change the capacity as required by the application of the separator. Even though the number of openings is varied, the relative head may optionally be maintained by inserting thin walled sleeves 86 (FIG. 8) in the openings 41 and/or 41' and adjusting flow control valves 8 and 10. The relative pumping head must be adjusted in accordance with the hydraulic requirements of the centrate flow. The large end of the flared portion of barrel 31 is closed by end member 42 which is attached to barrel 31 by bolts 43.

A plurality of U-shaped channel members 50 have their bases attached to the inner surface of the flared portion of barrel 31. Each channel member is located between a pair of rows of openings 40 and extends away from septum member 38. Additionally, each channel member is aligned with an opening 39 in septum member 38 and has a longitudinally extending centripetally facing slot 51 formed in its head and opening toward end member 42.

Each member 50 forms a channel which, in water-oil separation, delivers water accumulated on the inner surface of barrel 31 from secondary inner bowl S back to primary inner bowl P so that the water can flow outwardly through outlets 41 into the end of the primary separation chamber, through an

annular discharge passageway **84** formed by the end of shell **30** and a spaced annular extension **85** of the wall of flared portion **83** and into discharge passage **60**. Due to the flared wall of primary inner bowl P, the individual channels act as pumps to effect a refluxing of an oil-water mixture in addition to delivering accumulated water to discharge outlets **41**. The length of slots **51** is proportioned to obtain the desired pumping effect in accordance with the feed mixture being separated.

In operation of the apparatus shown in FIGS. **2 – 6**, the feed mixture is supplied to the gathering troughs in the primary separation chamber through inlet scroll **2** and annular inlet passageway **2'**. The mixture is introduced at a pressure of about 150 psi and at a velocity approaching the peripheral rotary velocity of barrel **31**. The mixture flows axially through the gathering troughs in the primary separation chamber, and a large portion of the more dense component of the mixture is forced outwardly against the inner surface of shell **30** by centrifugal force. This primarily separated liquid then flows out through annular outlet **60** into the stationary outlet scroll **3** from which it flows through conduit **9** to a receiving station. The discharge rate is controlled by the setting of outlet valve **10**.

A mixture of the less dense liquid component and a portion of the more dense component flows centripetally by displacement to the outer surface of barrel **31** and passes axially along the surface toward openings **40**. This mixture passes through openings **40** into primary inner bowl P. The rate of flow is controlled by valve **8** in discharge conduit **7**. The more dense liquid separated from the mixture in the inner bowls is presented by centrifugal action to openings **41** thus augmenting the centripetal flow through openings **40** and ensuring the capture of the less dense liquid in the primary separation chamber. The pumping action of channel members **50** causes an additional portion of the mixture to flow through orifice **37** and orifices **34**. The more dense liquid is forced outwardly to the inner surface of barrel **31** in the secondary inner bowl and passes by induced gravity to slots **35** and openings **39**. The less dense liquid flows toward axial discharge passage **61**. A portion of the more dense liquid which flows through openings **40** is directed toward end wall **42** and flows outwardly through outlets **41** and into discharge passage **60**. Due to the pumping action of channel members **50** and the arrangement of slots **35**, orifice **37** and openings **39**, **40** and **41**, excellent separation is achieved.

Septum member **36** and burble cones **33** provide surfaces and slip planes for refining oil-water separation as a core of separated oil progresses axially toward outlet passage **61**.

The apparatus shown in FIGS. **2 – 6** is designed to dewater oil with oil being the pure product discharged through outlet passage **61**. The modification shown in FIG. **7** is designed to deoil water with water being the pure product discharged from outlet scroll **3**. The basic structural difference between the apparatus for dewatering oil and the apparatus for deoiling water is that in the latter an additional ring of outlet passages **41'** is provided and discharge passages **84** and **60** are substantially larger. These differences will be readily seen from a comparison of FIGS. **2** and **7**. Additionally, slots **51** are shorter when deoiling water, and, therefore, a greater pumping capacity is obtained.

In the operation of the apparatus when dewatering oil, the work in the primary inner bowl is performed on oil, and, hence, a large portion of the oil-water mixture passes into the primary inner bowl. Alternatively, when deoiling water, the percentage of oil and oil-water mixture drawn into primary inner bowl P is only a fraction of the total throughput of the separator since the major portion of the mixture is water which passes through outlet passages **84** and **60**. In this case, the majority of the separating work is performed on water in primary inner bowl P. Eventually the water passes out of the separator through openings **41** and **41'** and outlet passages **84** and **60**, and oil passes through outlet passage **61**.

When dewatering oil, the principal throughput is oil, and only a single ring of outlet passages **41** is used as can be seen in FIG. **2**. The major portion of the throughput passes through openings **40** into primary separation bowl P. The oil-water interface resulting from the separation in the primary separation chamber between shell **30** and barrel **31** represents a smaller quantity of water. The major flow is into the primary inner bowl and consists principally of oil which requires a lower pumping capacity by the discharge openings **41** and a lower reflux rate which is obtained by lengthening slots **51** in channel members **50**. By virtue of the expanding diameter and axial flow of water and oil-water mixture in the direction of expansion, there is rotary acceleration within channel members **50** and against the perforated surface of the flared portion of barrel **31**. This effects a cross flow and slip planes for enhancing the effect of the induced gravity for separating the water from the oil.

In both deoiling water and dewatering oil, the rate of mixture input to the primary inner bowl determines the residence time of the fluid in the separator, and increased residence time permits additional separation of the water from the oil. Additionally, in both instances, as water accumulates centrifugally against the inner surface of barrel **31**, it is discharged through the outlets to passages **84** and **60** due to its greater density, and oil is discharged through outlet passage **61** due to its lesser density.

An additional feature of my invention is the provision of a plug **70** in a threaded opening **71** in stationary casing **21**. This plug may be removed and a service water line attached. Service water is then pumped into pressure chamber C at approximately 800 psi and passes toward the inlet end of the separator gradually losing pressure so that the final pressure is slightly in excess of the inlet pressure in annulus **2'**. Due to the slight excess in pressure, the service water flows into the primary separation chamber, and due to its greater density, it flows along the inner surface of shell **30** and dissolves any soluble salts which have been introduced to the separator with the feed mixture Due to their greater density, these salts will have accumulated centrifugally against the inner surface of shell **30**.

My invention has important features which include the ability to separate two components from a mixture and render one component substantially completely pure for subsequent use. The other component of the mixture may then be recirculated for further separation or secondary treatment. These advantages are especially applicable to oil-water mixtures although my apparatus may be used with equal facility to separate other liquids.

I claim:

1. A centrifugal separator for separating two liquids having different densities from a mixture, said separator including a stationary outer casing and coaxial rotating means within said outer casing, said rotating means including an outer shell having an end wall formed with an annular inlet passageway, a barrel coaxial with and attached to said shell and radially spaced inwardly therefrom to form an annular primary separation chamber, said barrel having an outwardly flared portion with an annular extension at the large end and defining a primary inner bowl and a cylindrical portion defining a secondary inner bowl, an imperforate end wall attached to said barrel at the large end of said flared portion and a drive shaft attached to said end wall, a plurality of openings formed in the wall of the flared portion of said barrel providing communication between said primary separation chamber and said primary inner bowl and means within said barrel providing communication between said primary inner bowl and said secondary inner bowl, means within both of said bowls to assist in separating the mixture, first outlet means from said primary inner bowl to said primary separation chamber and second outlet means from said secondary inner bowl, and an annular discharge passageway formed by said shell and said extension of the flared portion of said barrel, whereby one of said liquids is discharged from the separator through said first outlet

means and said annular discharge passageway and the other of said liquids is discharged from the separator through said second outlet means.

2. Apparatus as set forth in claim 1 including a plurality of elongated radial vanes between said shell and said barrel, said elongated radial vanes extending throughout the length of said shell and being attached to said shell and said barrel, whereby said vanes form a plurality of gathering troughs in said primary separation chamber.

3. Apparatus as set forth in claim 1 wherein said openings formed in the wall of the flared portion of said barrel are arranged in rows extending from the smaller end of said flared portion of said barrel toward said imperforate end wall.

4. Apparatus as set forth in claim 3 including a septum member having a plurality of openings located between said primary inner bowl and said secondary inner bowl, and wherein said means within said primary inner bowl to assist in separating the mixture consists of a plurality of U-shaped channel members extending away from said septum member and positioned between adjacent rows of openings, each channel member being aligned with an opening in said septum member, and an axially opening slot formed in the head of each channel member, whereby said channel members form pump means to pump liquid through the openings in said septum member into said primary inner bowl, the degree of pumping action being determined by the length of said slots.

5. Apparatus as set forth in claim 1 including a septum member having a plurality of openings located between said primary inner bowl and said secondary inner bowl, and wherein said means in said primary inner bowl to assist in separating the mixture consists of a plurality of channel members extending away from said septum member and aligned with an opening in said septum member, each of said channel members having an axially opening slot formed in its head, whereby said channel members form pump means to pump liquid through the openings in said septum member into said primary inner bowl, the degree of pumping action being determined by the length of said slots.

6. Apparatus as set forth in claim 1 wherein said means within said barrel providing communication between said primary and secondary inner bowls consists of an orifice member defining an orifice coaxial with said barrel and a septum member supporting said orifice member and having a plurality of spaced openings formed therein.

7. Apparatus as set forth in claim 1 wherein the means in said secondary inner bowl to assist in separating the mixture consists of a plurality of burble cones coaxial with said barrel, each of said cones having its larger end opening toward said second outlet means and attached to the inner surface of said barrel and a coaxial opening at its smaller end, and a plurality of slots formed in each cone adjacent to said barrel, whereby surfaces and slip planes for separating said mixture are formed by said cones and said slots.

8. Apparatus as set forth in claim 1 including a pair of outlet conduits, an outlet scroll connected to one of said conduits and having an annular passage formed therein, said second outlet means from said secondary inner bowl being coaxial with said barrel and said annular discharge passageway communicates with said annular passage formed in said outlet scroll, each of said second outlet means and said annular passage in said outlet scroll communicating with one of said outlet conduits, and each of said conduits having a flow control valve therein to control the rate of discharge therethrough.

9. Apparatus as set forth in claim 1 wherein said first outlet means from said primary inner bowl to said primary separation chamber constitutes a plurality of rings of openings in said flared portion of said barrel adjacent to said imperforate end wall, whereby the number of rings of openings determines the relative pumping capacity from said primary inner bowl to said primary separation chamber.

10. Apparatus as set forth in claim 9 including a thin walled insert in each opening of said plurality of rings of openings, whereby the length of said inserts determines the relative head between the centrate flow through said plurality of openings formed in the wall of the flared portion of said barrel and the centrifugal flow through the openings of said plurality of rings of openings.

11. Apparatus as set forth in claim 1 wherein said outer casing is radially spaced from said shell to form an annular pressure chamber around said rotating means, and a plurality of radially inwardly directed annular baffles are attached to the inner surface of said casing to form a plurality of individual pressure chambers around said rotating means extending from adjacent said annular discharge passageway to adjacent said annular inlet passageway, whereby high pressure discharge liquid leakage passes through said individual pressure chambers and into said annular inlet passageway.

12. Apparatus as set forth in claim 11 wherein an inlet passageway is provided in said casing adjacent to the end of said casing near said annular discharge passageway, whereby high pressure service water may be supplied to said pressure chamber through said inlet opening to pass into said annular inlet passageway.

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