United States Patent [19]
Doyle et al.
[11] 3,770,190
[45] Nov. 6, 1973

# [54] CENTRIFUGAL COUNTERCURRENT SEPARATOR HAVING BANDS COVERED WITH FLUOROCARBON SHEETS

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[22] Filed: **Feb. 25, 1971**

[21] Appl. No.: **118,806**

[52] **U.S. Cl.** .................... **233/15,** 233/31, 233/1 E
[51] **Int. Cl.** .................... **B04b 15/02**
[58] **Field of Search** .................... 233/20 R, 31, 37, 233/39, 41, 43, 46, 1 E, 1 S, 27; 55/435

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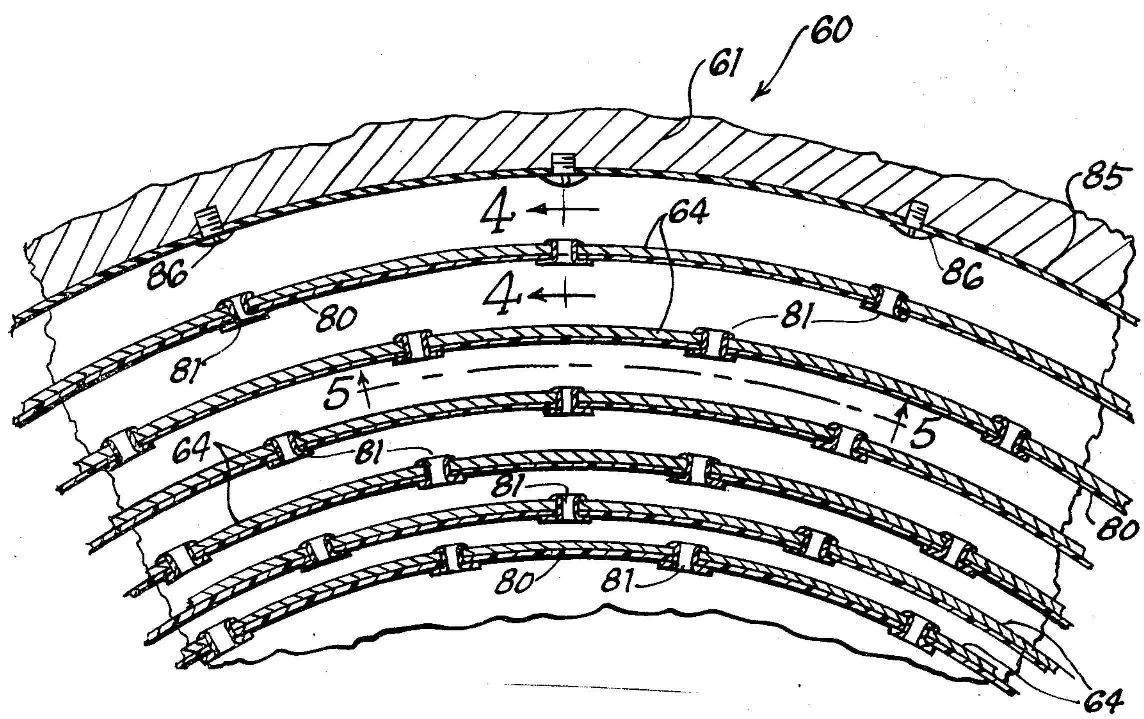
## [57] ABSTRACT

A device which may be a centrifugal countercurrent exchange extractor and/or a centrifugal separator, has a cylindrical rotor within which are mounted concentric, radially spaced, cylindrical, apertured bands. The inwardly facing surface of each band is covered with an apertured fluorocarbon sheet such that the apertures in the sheets are respectively aligned with the apertures in the bands. Rivets pass through the aligned apertures and are deformed to hold the sheets securely against the bands. Orifices are provided either in rivets or through the bands and sheets for the countercurrent flow of liquids.

**2 Claims, 5 Drawing Figures**



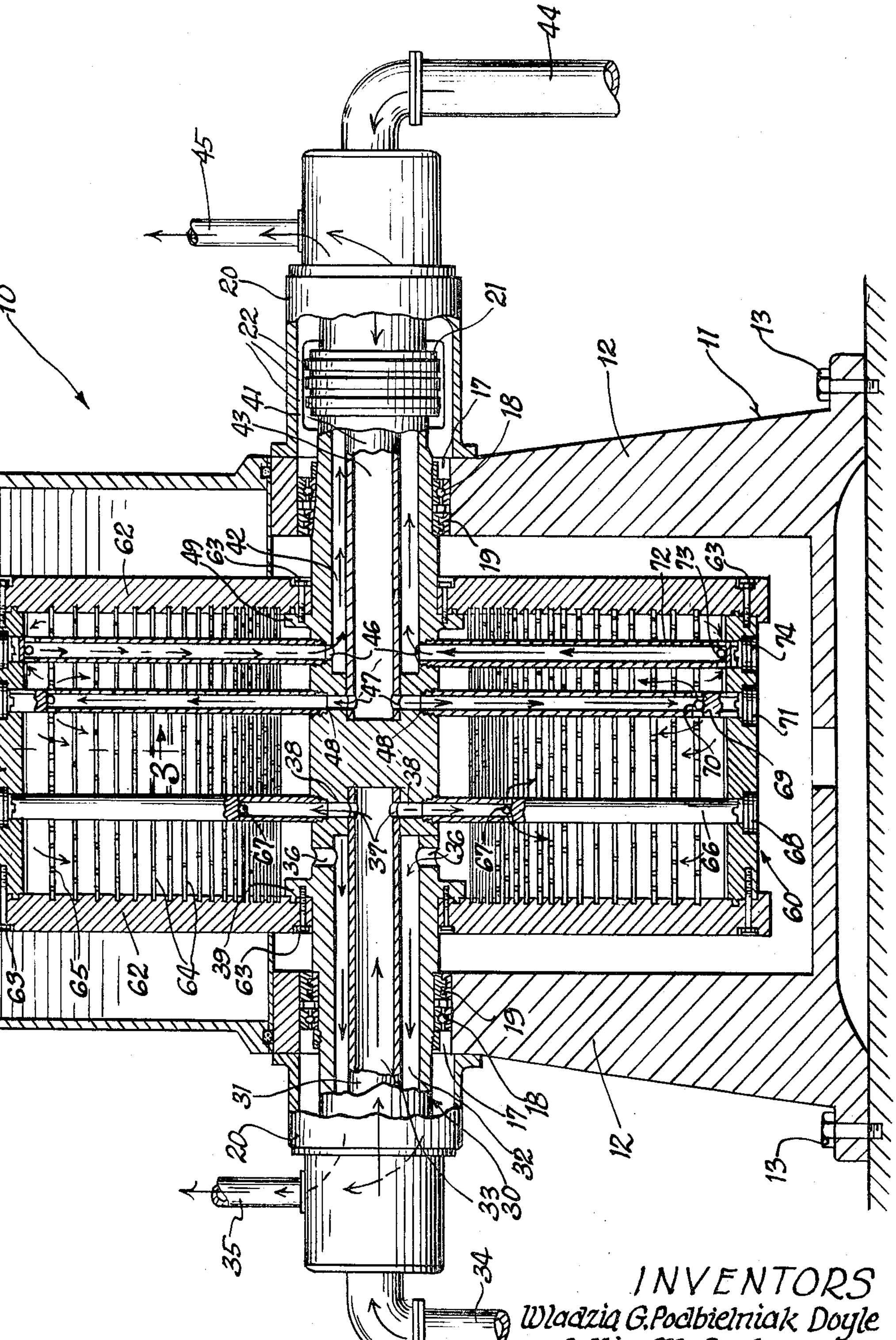


FIG. 1

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FIG. 2

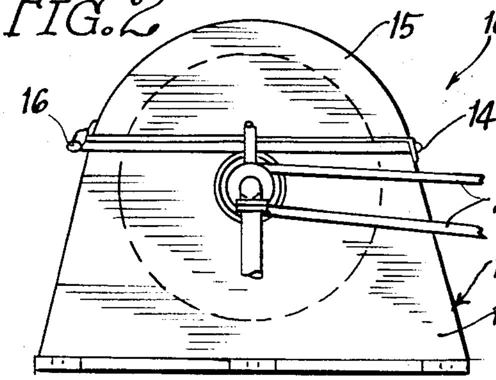



FIG. 4

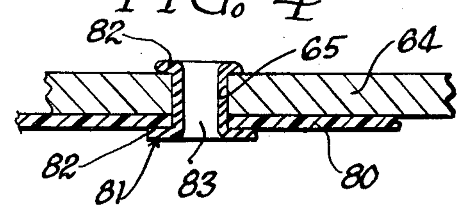



FIG. 3

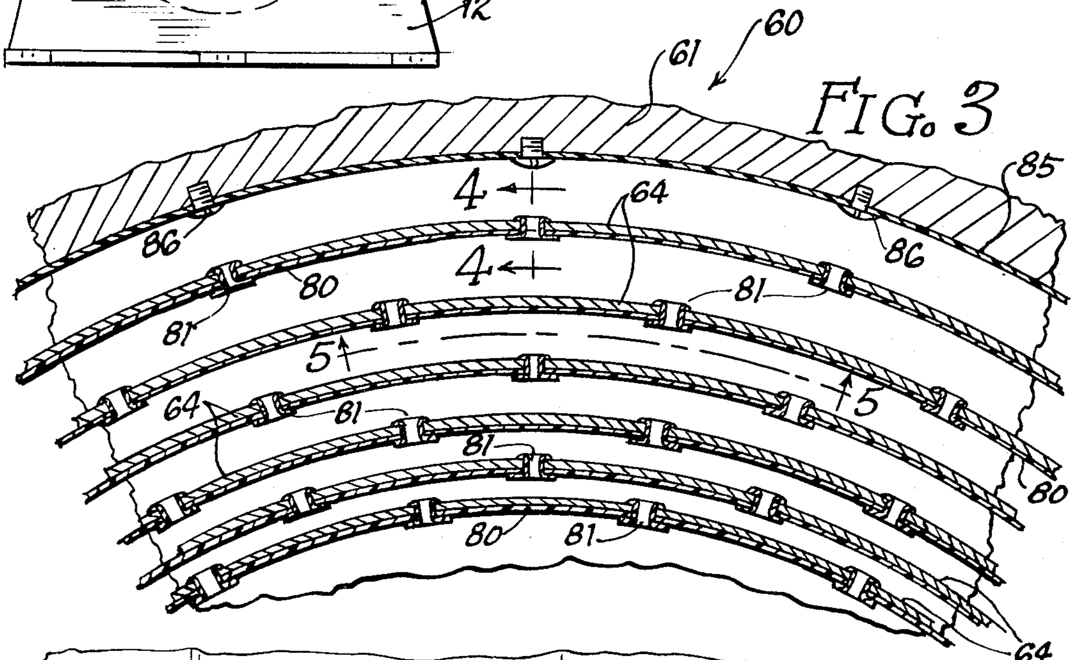
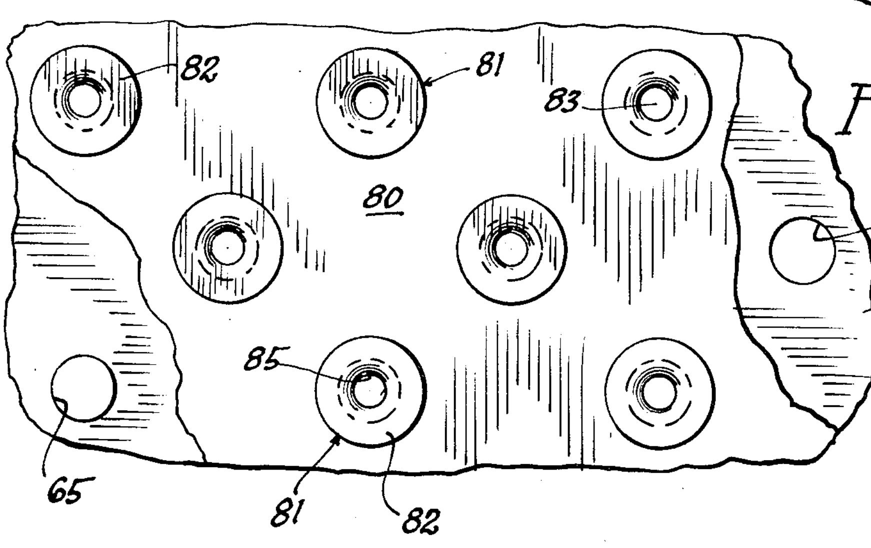



FIG. 5



# CENTRIFUGAL COUNTERCURRENT SEPARATOR HAVING BANDS COVERED WITH FLUOROCARBON SHEETS

## BACKGROUND OF THE INVENTION

This invention relates to a device which may be a centrifugal countercurrent exchange extractor or a centrifugal phase separator, or a device convertable from one form to the other. Both devices are characterized by a cylindrical rotor containing a plurality of apertured cylindrical bands. When such a device is used as a countercurrent exchange device, the heavy liquid is introduced into the rotor near the axis thereof and the light liquid is introduced near the periphery of the rotor. As the rotor spins, the light liquid flows inwardly toward the axis while the heavy liquid flows outwardly toward the periphery with intimate mixing taking place in the apertures. Precipitous solids which may be present either in the heavy liquid or in the light liquid tend undesirably to collect and adhere to the inwardly facing surfaces of the bands. Thus the bands must be periodically cleaned to remove the solids adhered thereto. Similar difficulties occur when the device is constructed to be a centrifugal separator. In that egent, liquid containing the two phases to be separated is introduced at a point along the radius of the rotor determined by the ratio of the light phase to the heavy phase. The centrifugal force operates on the liquid to separate the two phases, with the bands serving as coalescent areas which assist in the separation process. Any solids present in the liquid undesirably tend to adhere to the inwardly facing surface of the bands.

There has been a previous proposal to reduce the amount of solids which collects on the inwardly facing surfaces of the bands. Such a proposal is shown in a patent issued to D. B. Todd for Solids Handling Centrifugal Extractor, U.S. Pat. No. 3,519,199. The patent discloses a process of spraying a thin film of Teflon (Du Pont trademark) on the bands (referred to in the patent as "contacting elements.") The bands are the heated to a temperature of about 725° to 800° F. to bake or fuse the coating. The Teflon repels the solids, thereby preventing them from accumulating on the bands.

It is desirable that the material used to construct the bands have optimum corrosion resistance so as not to be damaged by the highly caustic materials which are often processed in centrifugal devices. Stainless steel type 316 is perhaps one of the most corrosion resistant materials presently available, due to the physical properties imparted to it during heat treatment. The chemical constituents of type 316 stainless steel are chromium, nickel, iron, molybdenum and carbon. When these elements are properly proportioned, alloyed into steel and subjected to an elevated temperature, carbides are formed. The steel is then quenched rapidly so that the carbides are retained. These carbides provide the excellent corrosion resistant capability of type 316 stainless steel.

It type 316 stainless steel is heated to temperatures exceeding 500° F., the carbon in the carbide precipitates to the grain boundaries, thereby diminishing the corrosion resistance of the steel. Since the process and construction disclosed in the Todd patent require heating to temperatures between 725° and 800°it would not be usable with type 316 stainless steel.



## SUMMARY OF THE INVENTION

It is, therefore, an important object of the present invention to provide a device which may be a centrifugal countercurrent exchange extractor and/or a centrifugal separator wherein soldis moving with the heavy phase do not tend to collect on the concentric bands of the device.

Another object is to apply a fluorocarbon sheet to the bands in such a device without the use of heat.

Still another object is to provide a fluorocarbon sheet on the inwardly facing surface of each band in such a device, secured with rivets.

In connection with the foregoing object, it is yet another object to provide rivets with orifices for passage of the liquids.

In summary, there is provided a centrifugal device comprising a shaft, a rotor carried by the shaft and having a cylindrical shell, a plurality of radially spaced cylindrical apertured bands mounted in the rotor, a plurality of cylindrical fluorocarbon sheets respectively against the inwardly facing surfaces of at least some of the bands, each of the sheets having apertures therethrough which are respectively aligned with the apertures on the adjacent one of the bands, and a plurality of rivets respectively passing through some of the aligned apertures on the bands and the sheets, each of said rivets being deformed at the ends thereof to hold the sheets respectively in intimate contact with the bands.

Further features of the invention pertain to the particular arrangement of the parts of the centrifugal device and the fluorocarbon covered bands used therein whereby the above outlined and additional features are attained.

The invention both as to its organization and method of operation, together with further objects and advantages thereof, will best be understood by reference to the following specification when taken in connection with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a veiw in vertical section of a centrifugal countercurrent exchange device embodying the invention, with portions thereof being cut away and other portions being shown in elevation;

FIG. 2 is an end view on a smaller scale of the device of FIG. 1;

FIG. 3 is a view in vertical section on a greatly enlarged scale along 3—3 of FIG. 1;

FIG. 4 is a view in vertical section along 4—4 of FIG. 3; and

FIG. 5 is a fragmentary view taken along 5—5 of FIG. 3.

Referring now to the drawings, and more particularly to FIGS. 1 and 2 thereof, there is shown a centrifugal countercurrent exchange device **10**. The device **10** comprises a base **11** which may be secured to the floor by means of bolts **13**. Attached to the base **11** by means of hinges **14** is a part-cylindrical cover **15** which, in turn, carries a handle **16**. Formed respectively in the side walls **12** of the base **11** are axially-aligned openings **17** within which is mounted the outer race of a pair of bearing units **18**. The inner race of each of the bearing units **18** is affixed to a shaft **30** which passes through the openings **17**. The shaft **30** is maintained in a fixed axial position by means of a pair of key members **19**.

Encircling the shaft 30 adjacent the ends thereof and aligned respectively with the openings 17 are caps 20. One side of the shaft 30 is provided with a sleeve 21 upon which is mounted a plurality of drive belts 22. Each of the drive belts 22 may be connected to a motor of different operational speed, so that the speed of rotation of the shaft 30 may be selected, depending upon the particular use of the device 10.

The shaft 30 is provided with a longitudinal bore on the left, as viewed in FIG. 1, within which is mounted a tube 31. The annular space between the tube 31 and the shaft 30 defines a passageway 32 for the flow of light liquid out of the device 10. The space within the tube 31 defines a passageway 33 for the flow of heavy liquid into the device 10. The tube 31 communicates with an inlet pipe 34 which is, in turn, coupled to a source of heavy liquid. An outlet pipe 35 communicates with the passageway 32 and is coupled to a container or the like to collect the light liquid effluent discharged from the device 10. The passageway 32 communicates, adjacent its inner end, with a set of openings 36, and the passageway 33 communicates, at its inner end, with a set of openings 37 formed in he tube 31. The openings 37, in turn, communicate respectively with threaded bores 38 in the side wall of the shaft 30. The shaft 30 further includes an annular, radially-extending flange 39 disposed outwardly (to the left, as viewed in FIG. 1) of the openings 36.

Similarly, formed in the right side of the shaft 30 is a longitudinally-extending bore within which is mounted a tube 41. Tha annualr space between the tube 41 and the shaft 30 defines a passageway 42 for the heavy liquid to flow out of the device 10. The space within the tube 41 defines a passageway 43 for the flow of light liquid into the device 10. The tube 41 communicates with an inlet pipe 44 which is, in turn, coupled to a source of light liquid. An outlet pipe 45 communicates with the passageway 42 and is coupled to a container or the like to collect the heavy liquid effluent discharged from the device 10. The passageway 42 communicates, adjacent its inner end, with a set of threaded openings 46; and the passageway 43 communicates, at its inner end, with a set of openings 47 formed in the tube 41. The openings 47, in turn, communicate respectively with threaded bores 48 in the side wall of the shaft 30. The shaft 30 further includes an annular, radially-extending flange 49 disposed outwardly (to the right, as viewed in FIG. 1) of the openings 46.

The countercurrent exchange device 10 also includes a rotor 60, which rotor 60 is defined by a cylindrical outer shell 61 and a pair of annular end plates 62 secured at the outer ends thereof to the outer shell 61 by means of bolts 63. Formed centrally in each of the end plates 62 is an opening through which passes the shaft 30. The annular outer regions of the end plates 62 near the shaft 30 are secured respectively to the outwardly-facing surfaces of the flanges 39 and 49 by means of bolts 63.

A plurality of concentric cylindrical bands 64 is positioned in annular grooves formed in the end plates 62 in a manner presently described, each band 64 being formed with a plurality of apertures 65. In the form illustrated, the bands 64 are arranged with the spacing between any pair thereof increasing as the radius increases. Although this is the preferred form of construction, it is not necessary to the invention hereinafter described.

Positioned in radially-aligned openings in the bands 64 is a supply tube 66, which is threaded at one end thereof to mate with a threaded opening 38 in the shaft 30. Additional sets of radially-aligned openings in the bands 64 accommodate additional supply tubes 66, all of which are, in the form shown, in axial alignment. Each of the tubes 66 has an opening 67 nearer the end thereof that is adjacent to the shaft 30. The outer end of each of the supply tubes 66 is located within a suitable opening in the shell 61, each of which openings has an enlarged, threaded portion to receive a plug 68. The plug 68 may be unscrewed to enable removal of the tube 66, for cleaning or replacement. A supply tube 69 passes through a second set of radially-aligned openings in the bands 64. Additional sets of openings in the bands 64 accommodate further tubes 69. Each supply tube 69 is threaded at one end thereof to mate with a threaded opening 48 in the shaft 30. Each tube 69 has an opening 70 near the outer end thereof. The outer end of each of the supply tubes 69 is located within a suitable opening in the shell 61, each of which has an enlarged threaded portion to receive a plug 71. A discharge tube 72 passes through a third set of radially-aligned openings in the bands 64. Other discharge tubes are provided, each of which is threaded at one end thereof to mate with the threaded openings 46 in the shaft 30. Each of the tubes 72 has an opening 73 at its outer end, that is, adjacent to the shell 61. The outer end of each of the tubes 72 is located within a suitable opening in the shell 61, which is enlarged and threaded to receive a plug 74. Although two of each of the tubes 66, 69 and 72 are shown, it is to be understood that any number of such tubes may be provided.

Referring now to FIGS. 3, 4 and 5 of the drawings, the details and construction of the bands 64 and the fluorocarbon sheeting applied thereto will be described. Applied to the inwardly facing surface (that surface of each band 64 in FIG. 3 facing the bottom of the drawing) is a sheet 80 composed of a fluorocarbon material. Each of the sheets 80 has a multiplicity of apertures respcetively aligned with the apertures 65 in the band 64. Passing through each pair of aligned apertures respectively in a band 64 and the adjacent fluorocarbon sheet 80 is a rivet 81 having the ends thereof deformed, as is best shown in FIG. 4, into flanges 82, thereby securely to retain the fluorocarbon sheet 80 against its associated band 64. Each rivet 81 has passing therethrough an orifice 83 for purposes to be explained hereinafter. A sheet 85 of fluorocarbon is also applied to the inwardly facing surface of the shell 61 of the rotor 60. The sheet 85 may be held securely in position by means of screws 86 of the like.

In operation, heavy liquid from the source thereof is supplied through the inlet pipe 34, through the passageway 33, through the openings 37 and 38 into the liquid supply tubes 66. The rotation of the rotor 60 causes the heavy liquid to flow outwardly through the tubes 66 and through the openings 67 into the interior of the rotor 60. The heavy liquid flows outwardly through the orifices 83 in the rivets 81 by centrifugal force. Similarly, light liquid from a source thereof flows through the inlet pipe 44 and is supplied through the passageway 43, the openings 47 and 48, and into the supply tube 69, all as indicated by the arrows. The centrifugal force of the spinning rotor 60 causes the light liquid to flow outwardly through the tubes 69, as indicated by the arrows, and into the space between the two outer-most bands **64**. The pressurized light liquid flows inwardly through the orifices **83** in the rivets **81** and mixes with the heavy liquid in countercurrent fashion. As the liquids pass through the band **64**, they are broken up into droplets by the orifices **83**. A violent and intimate mixing of both droplet-dispersed liquids then takes place in the areas between each pair of bands **64**, causing the solute in one liquid to be transferred to the solvent which is the other liquid. After both liquids have passed through all of the mixing stages, the same continue on through the present nonmixing or clarification areas. The heavy liquid which arrives in the space near the outer shell **61** flows into the discharge tubes **72** by means of the openings **73**. The heavy liquid flows back down the tubes **72**, as indicated by the arrows, through the openings **46**, the passageway **42**, through the outlet pipe **45** to a container for the effluent. The light liquid which reaches the shaft **30** flows through the openings **36**, through the passageway **32**, through the outlet pipe **35**, as indicated by the arrows, and to a container for the light liquid effluent.

Generally, both liquids travel concurrently or in the same direction as they pass through the rotor **60**. This direction of travel is of course the same as the direction of rotation of the rotor itself. However, as a liquid passes from one band **64** to the next, this liquid is either accelerated or decelerated as above described. Since the passage of a liquid from one band **64** to the next takes but a short moment of time, the described acceleration or deceleration thus imports a violent or jolting action to that liquid. In the case of the decelerating lighter liquid, the jolting action is in a direction opposed to the general direction of the liquid's travel. On the other hand, the jolting action of the accelerating heavy liquid is in the same direction as the general direction of the liquid's travel. There thus occurs a violent cross collision between the two liquids in the area between any two bands **64**.

The heavy liquid is thrown outwardly by the centrifugal force of the spinning rotor **60**, against the inwardly facing surfaces of the bands **64**. There may be solids in either the light liquid or the heavy liquid, which solids move outwardly with the heavy liquid and tend to adhere to these inwardly facing surfaces of the bands **64**. However, the presence of a fluorocarbon sheet **80** on the inwardly facing surface of each band **64** substantially reduces the quantity of such solids adhering to the bands. Because the solids are impelled outwardly by the centrifugal force, they rarely have more than passing contact with the outwardly facing surfaces of the bands **64**. Accordingly, the solids do not tend to adhere to these outwardly facing surfaces and there is no need for any fluorocarbon sheets to be attached thereon.

The size of the orifices **83** are selected to maximize the efficiency of the device **10** for the particular liquids being used. The size of each orfice may be anywhere from one-sixteenth inch to five-eighths of an inch in diameter. The orifices **83** may be constant in size or gradate either radially outwardly or radially inwardly. Whatever small amounts of solutes do adhere to the fluorocarbon sheets are loosely held thereby and can be readily removed by a simple washing operation. The fluorocarbon sheets **80** may be any desired thickness, preferably in the range of about 7 to 35 mils.

The number of rivets **81** required is determined almost exclusively by the number of passageways desired between successive mixing zones. As far as serving the purpose of holding the sheets **80** tightly against the bands **64**, only a few rivets **81** are required. The centrifugal force created by the spinning rotor **60** will operate to press tightly the sheets **80** against their associated bands **64**. A preferable form of fluorocarbon is polytetrafluoroethylene, since it has great strength and ability to withstand the corrosive tendency of certain liquids which may be used.

This construction can be used with the very best corrosion-resistant stainless steel such as type 316 previously referred to. This, by virtue of the fact that the fluorocarbon sheets **80** are applied to the bands **64** and secured thereto by rivets rather than applying by way of a spray and then heating the bands to solidify the spray.

Although the specific embodiment shown in the drawings is a centrifugal countercurrent exchange extractor, it is to be understood that the invention is equally useful in a centrifugal separator. In such a case, only one set of distribution tubes is needed, to admit the liquid containing two phases which are to be separated. The point along the radial extent of each distribution tube which the liquid is to be admitted into the rotor, would be dependent upon the ratio of the heavy phase to the light phase. A plurality of cylindrical, concentric, apertured separator bands are provided, which bands function as coalescent areas to assist in the separation process. It should further be noted that the centrifugal countercurrent device **10**, illustrated in the drawings can be converted into a separator, by blocking one set of distribution tubes.

While a preferred embodiment of the invention has been shown and described for illustrative purposes, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

We claim:

**1.** A centrifugal device comprising a shaft, a rotor carried by said shaft and having a cylindrical shell, a plurality of radially spaced cylindrical apertured bands mounted in said rotor, a plurality of cylindrical fluorocarbon sheets respectively against the inwardly facing surfaces of as least some of said bands, each of said sheets having apertures therethrough which are respectively aligned with the apertures on the adjacent one of said bands, and a plurality of rivets respectively passing through at least some aligned apertures on said bands and said sheets and deformed to secure firmly said sheets to said bands, and rivets each having an orifice for the countercurrent flow of liquids therethrough.

**2.** The centrifugal device of claim **1**, wherein said rivets pass through all of said aligned apertures.

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