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Javet

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[54] **CENTRIFUGAL SEPARATOR FOR SEPARATING EMULSIONS**

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[51] **Int. Cl.**..**B04b 1/00**

[58] **Field of Search**..........233/31, 32, 27, 39, 41, 46, 233/47 R, 20 R, 21, 29, 28, 30; 210/380

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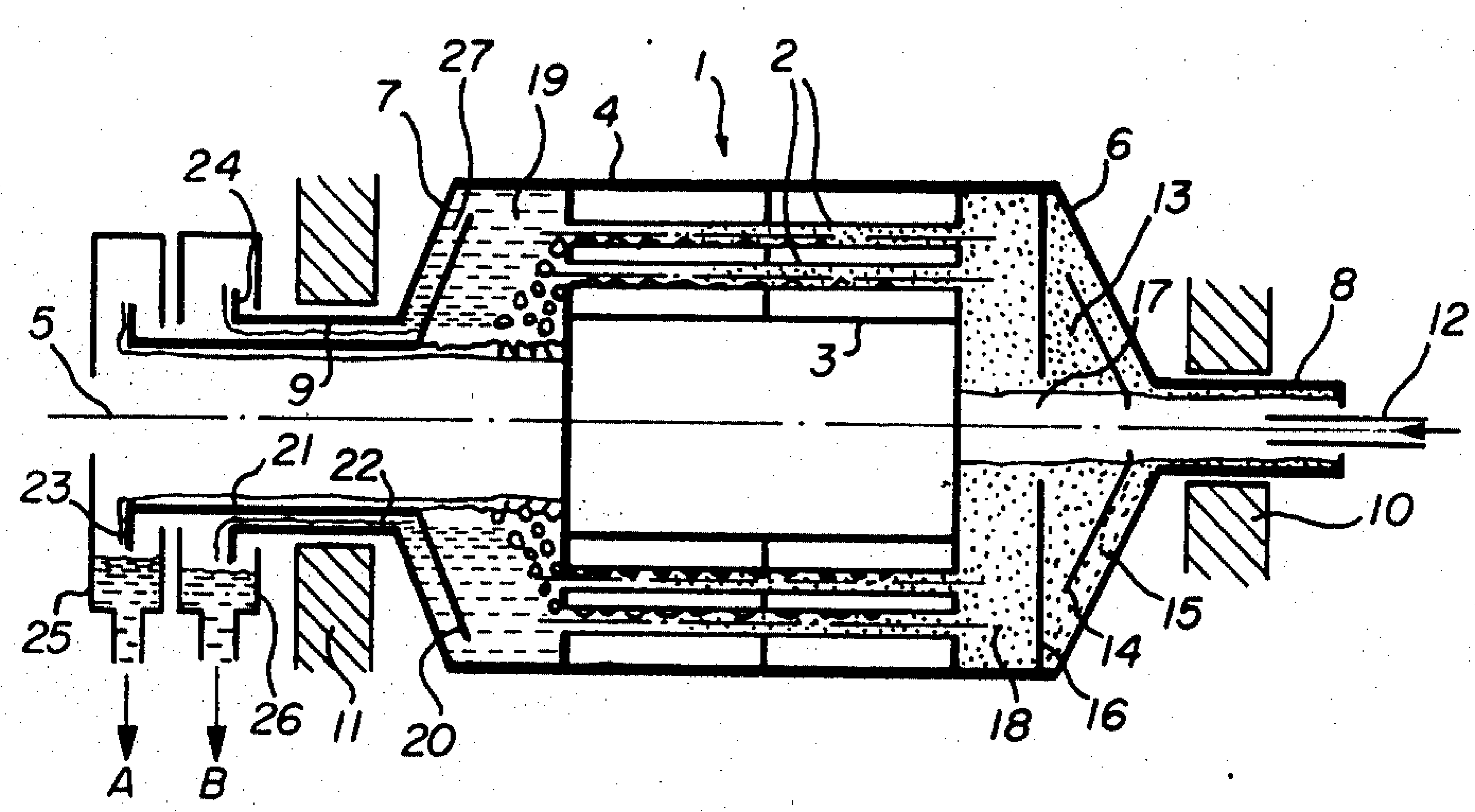
[57] **ABSTRACT**

A centrifugal separator for emulsions comprises a rotating drum with an admission chamber at one end thereof, connected to atmosphere via an axial supply inlet, and a multitude of separating tubes arranged around an axial hub to extend longitudinally from the common admission chamber to a common outlet chamber at the other end of the drum. One or more outlets connected to atmosphere are arranged to discharge the lighter constituent of the emulsion from the discharge chamber at a radial distance lying between the radius of the supply inlet and that of the hub. An outlet duct connected to atmosphere extends from the periphery of the outlet chamber towards the drum axis so as to discharge the heavier constituent at a radial distance slightly greater than that of the discharge outlet for the lighter constituent of the emulsion. Liquid movement through the separator is provided through centrifugal force only. Emulsion supplied to the admission chamber is driven radially outward and forms therein a coaxial liquid level at atmospheric pressure. The lighter constituent forms in the outlet chamber a coaxial overflow level at atmospheric pressure at the discharge outlet. The heavier constituent forms a further coaxial overflow level at atmosphere pressure, at the discharge end of the outlet duct.

6 Claims, 3 Drawing Figures



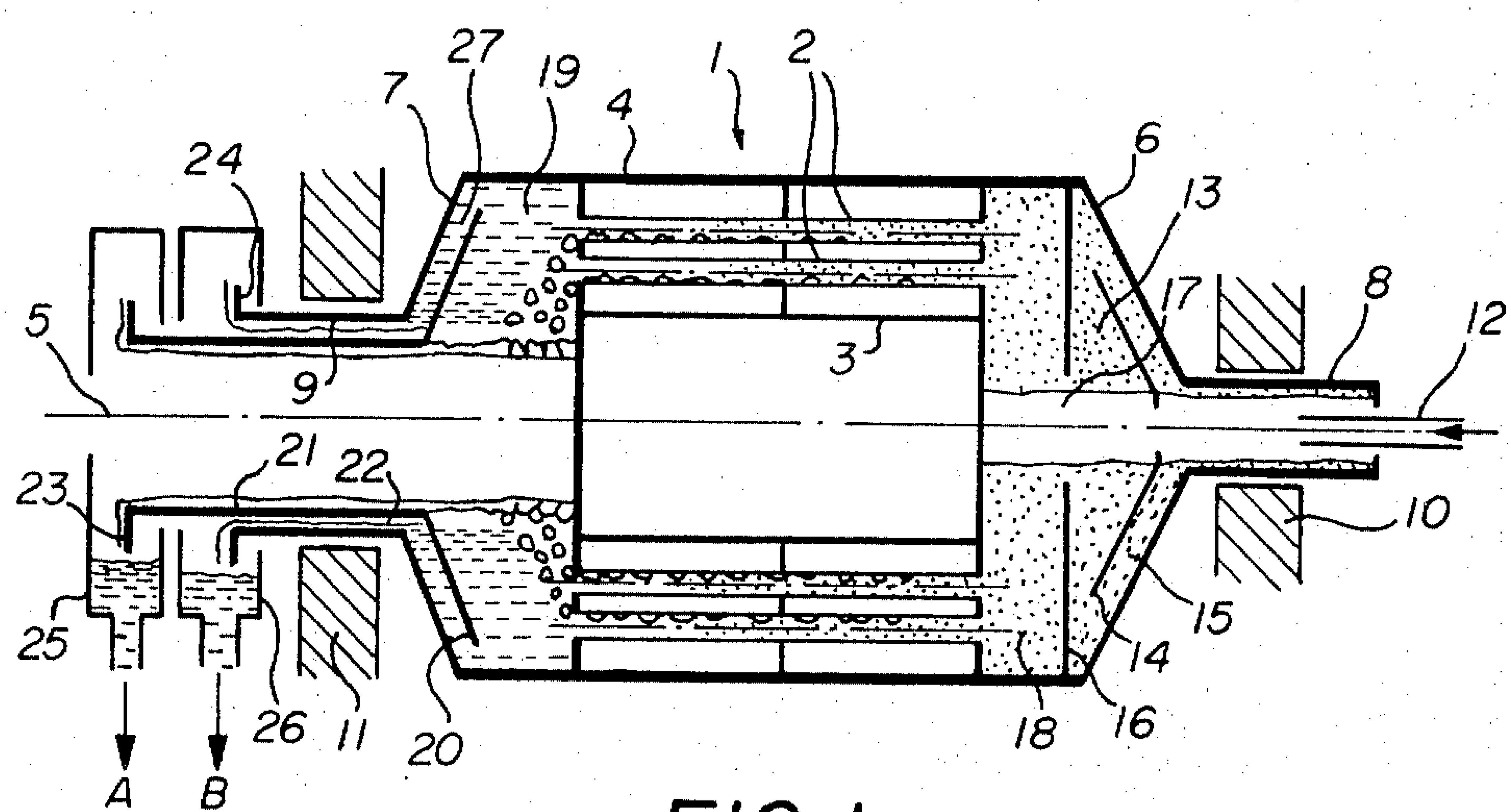


FIG. 1

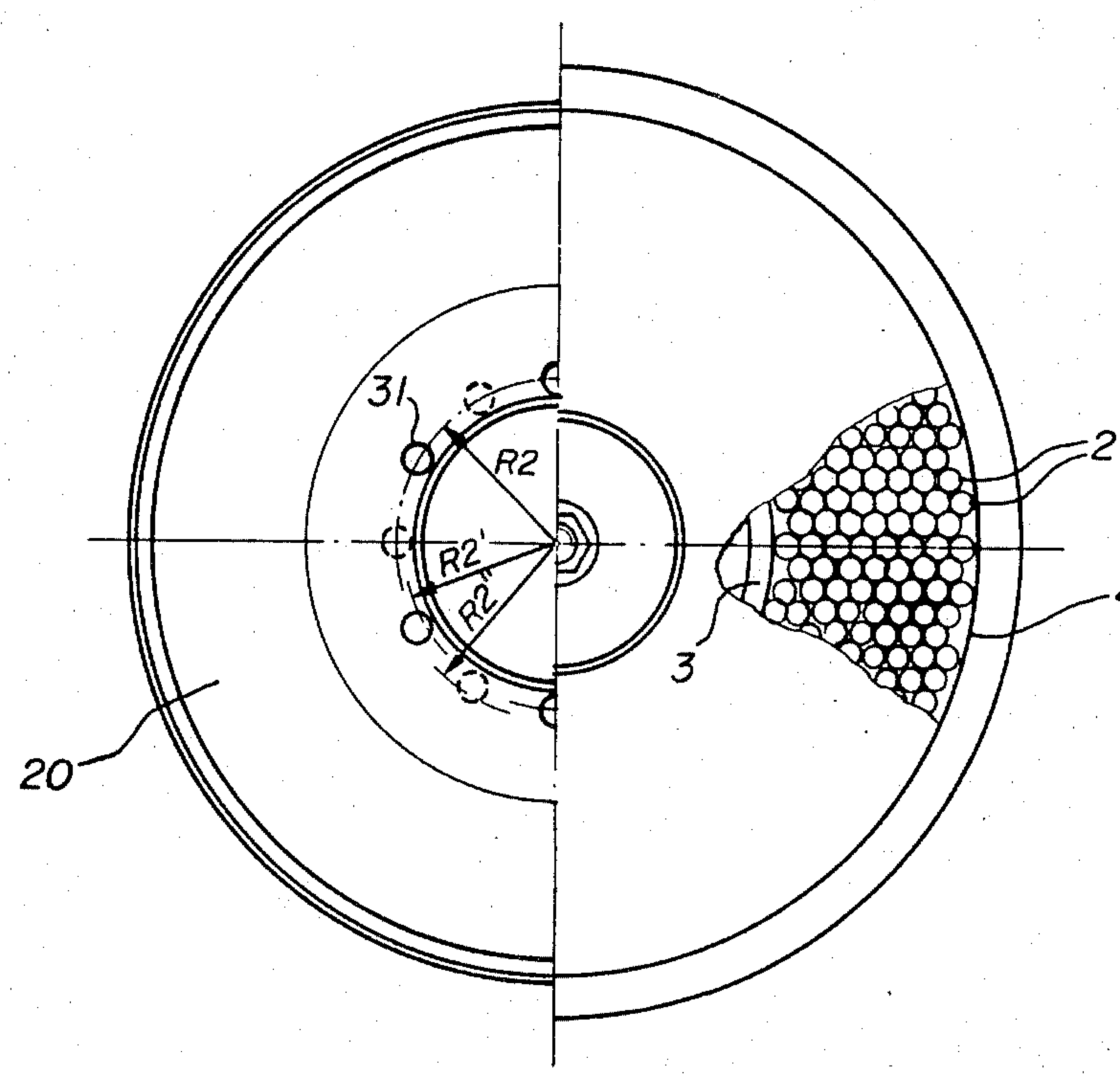


FIG. 3

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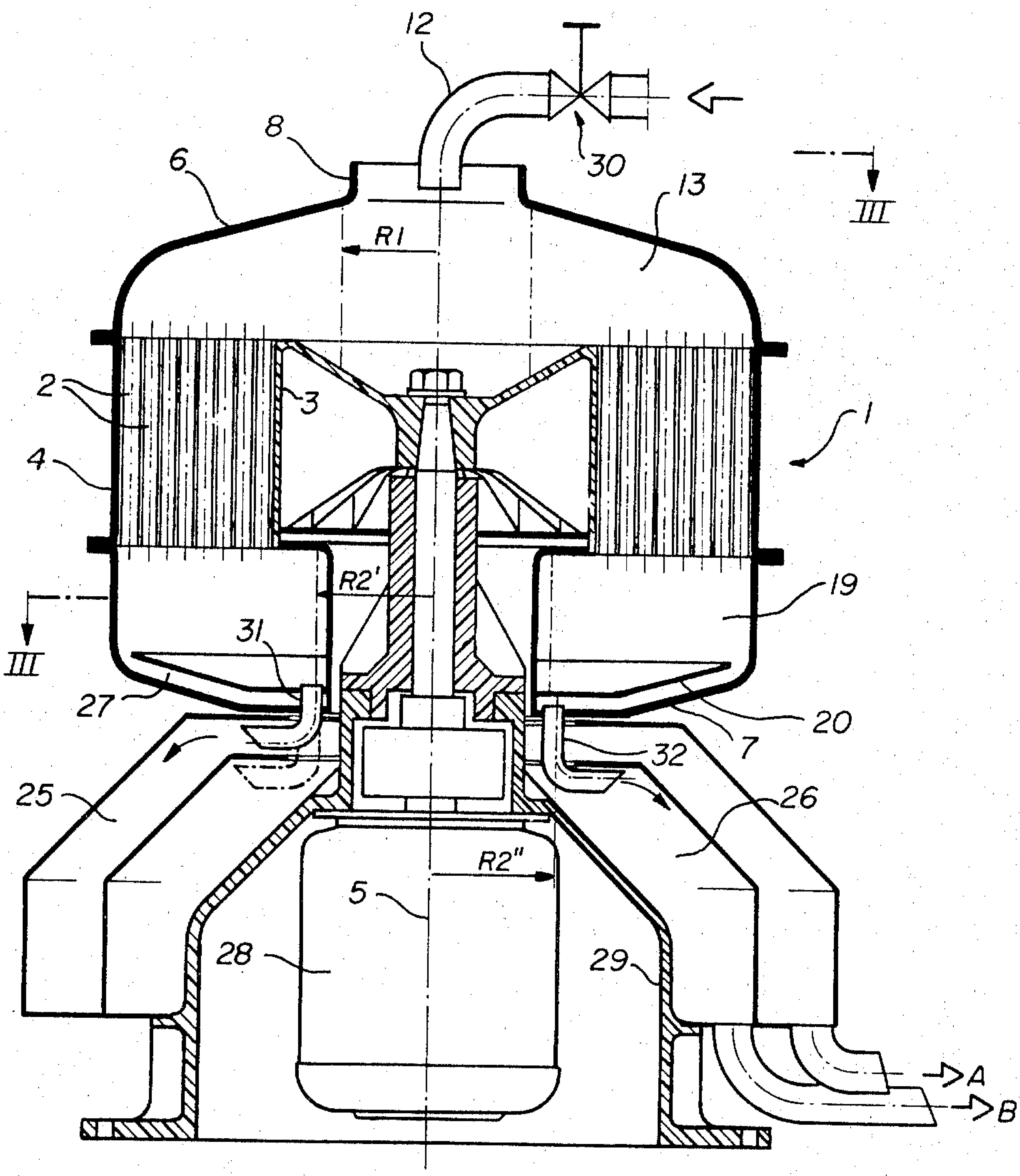

FIG. 2

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CENTRIFUGAL SEPARATOR FOR SEPARATING EMULSIONS

This invention relates generally to the separation of liquid mixtures and particularly to the separation of the two constituents or fractions of different density of an emulsion.

It is known that when two non miscible liquids are brought together, an emulsion may be formed in which the liquid having higher surface tension is more or less uniformly divided in the mass of the liquid with lower surface tension. The formation of emulsions is by no means desirable in many cases but is an inevitable consequence of various industrial operations and may also occur when handling liquids and in particular during their transport. Consequently, separation of emulsions into their constituents is of great interest in various technical fields. Thus, for example, the treatment of certain industrial waters and of the water used for washing the tanks of oil tankers requires such a separation in an effective and economical manner. Known static separators are generally very cumbersome since they comprise decanting tanks having dimensions which may readily become prohibitive when it is required to treat large amounts of liquid on an industrial scale. In addition, their effectiveness often does not meet the now prevailing requirements provided for by the water-pollution laws.

The known dynamic separators, although more effective, are, however, relatively complicated and have a price which is too high for many applications. There is thus a definite need for a simple and sturdy separator with slight bulk which allows an effective liquid/liquid separation with low energy consumption at a cost which is well below that of conventional dynamic separators.

The separating means now existing require, for each application contemplated, that a compromise be made between the quality of the separation and the flow rate of the treated liquid mixture. As a matter of fact, when it is desired to separate as completely as possible liquids which are difficult to separate, one is faced with a choice of equipment (e.g., supercentrifuges) whose cost which is high in relation to the volume of liquid mixture treated. If, on the other hand, it is desired to treat liquids of low value which are easy to separate, one has a choice of relatively inexpensive equipment which is, however, cumbersome and much less effective.

The main object of the present invention is to provide a centrifugal separator which is simple, compact and inexpensive in design and allows the above-mentioned disadvantages to be obviated. According to the invention, a centrifugal separator for separating emulsions into two liquid constituents of different density comprises a rotating drum forming an admission chamber for the emulsion to be separated, arranged at one end of the drum, an outlet chamber for the separated constituents, arranged at the other end thereof, and an intermediate portion including a separating zone consisting of a multitude of longitudinally extending separating passages arranged around an axial hub and interconnecting these chambers. The admission chamber has an axial inlet communicating with the ambient atmosphere, the outlet chamber being equipped with at least one outlet for the constituent of lower density; this outlet communicates with the ambient atmosphere and serves to discharge the lower-density constituent at a distance from the drum axis greater than the radius of the inlet and smaller than the radius of the hub, the outlet chamber being further equipped with at least one outlet duct for the constituent of higher density, which extends from a peripheral zone of the outlet chamber toward the axis of rotation, up to a radial distance equal to or slighter greater than that of the outlet for the constituent of lower density, and communicates with the ambient atmosphere.

In the accompanying drawing, in which I have illustrated two embodiments of the separator according to the invention:

FIG. 1 is a diagrammatic sectional view showing a first embodiment of the separator;

FIG. 2 shows a second embodiment of the separator, in axial section; and

FIG. 3 is a cross-sectional view taken on line III—III of FIG. 2.

The separator shown in FIG. 1 includes a plurality of separating tubes 2 mounted parallel to its axis of rotation 5, along two circular rows, around a hub consisting of a hollow cylinder 3 closed at both ends. This cylinder 3, the tubes 2 and a cylindrical casing 4 of the drum 1 are solidly connected with one another so that the tubes rotate around the horizontal axis 5 of the drum 1, the latter being driven by a driving device (not shown) at a given rotational speed. The drum 1 comprises, in addition, two transverse end walls or headers 6, 7 in the shape of a truncated cone which are solidly connected with the casing 4 and respectively prolonged by an inlet tube 8 and a discharge tube 9 attached thereto at their small base. The inlet tube 8 arranged axially at the inlet end of the drum 1 has a smaller diameter than the discharge tube 9 situated at the outlet end, these tubes 8 and 9 being mounted in bearings 10, 11, respectively. The tube 8 is closed at its free end with the exception of an axial opening through which passes, with clearance, a fixed pipe 12 for feeding the separator with emulsion coming from a suitable source (not shown). The emulsion introduced into the tube 8 spreads over the wall thereof owing to centrifugal force, advances along this tube and reaches an inlet chamber 13 where it meets a baffle 14 in the shape of a truncated cone arranged in the vicinity of the end wall 6 to form an annular passage 15 emerging into the inlet chamber 13. The latter is further provided with a transverse baffle 16 solidly connected to the casing 4 and provided with an axial circular opening 17 having a diameter larger than that of the tube 8. This baffle 16 is arranged upstream of the cylinder 3 and of the tubes 2 so as to form an annular passage 18 for bringing forward the emulsion to the entry end of these tubes. These baffles 14 and 16 are adapted to deviate the liquid mixture so as to separate therefrom any solid impurity, under the effect of centrifugal force, before entry into the tubes.

The tubes 2 emerge into an outlet chamber 19 bounded by another frustoconical baffle 20 mounted opposite the end wall 7 and solidly connected thereto, by means not shown in the drawing, so as to form an annular outlet duct 27 extending from the periphery of chamber 19 toward the rotational axis 5. A tube 21 fixed to this baffle 20 at the end of duct 27 extends coaxially within the tube 9 to provide an annular discharge channel **22** between these two tubes. The free ends of the tubes **21** and **9** bear outer flanges **23** and **24** for directing the separated fractions towards annular collectors **25** and **26**, respectively, constituted by a pair of coaxial channels.

The described separator operates in the following manner:

The inlet chamber **13** and the outlet chamber **19** of the drum communicate with the atmosphere through the tubes **8** and **9**, **21**, respectively. Owing to centrifugal force, the liquid mixture arriving through the pipe **12** spreads on the inner surface of the rotating inlet tube **8** and advances along the latter towards the entry chamber **13** where it is driven radially outward through the passage **15**, then returns towards the axis **5**, between the baffles **14** and **16**, to the opening **17** from which it overflows and is then driven through the annular passage **18**. The liquid thus reaches inlet end of the tubes **2** wherein it flows towards the exit chamber **19**. The centrifugal separation takes place in the tubes **2** in the manner described below.

It will be assumed that the emulsion consists of two constituents, of which a constituent A of lower density is dispersed in the form of globules in the other constituent B of higher density. These two constituents will hereinafter be referred to by the name of "light fraction" and "heavy fraction", respectively. Owing to the rotation of the tubes **2** around the axis **5**, the liquid mixture circulating in these tubes is subjected to the action of centrifugal force. Because of the difference in density between the two fractions, the globules of the light fraction are subjected to a thrust directed towards the axis of rotation **5**, thereby providing a progressive separation of the two fractions along the tubes **2**. The heavy fraction is thus gradually brought to the far side of each tube **2**, that is the side remote from the axis of rotation **5**, while the globules of the light fraction accumulate, by coalescence on the inner surface of the tubes **2**, on the side which is nearer to the axis **5**.

On arrival of the two fractions in the chamber **19**, the heavy fraction B is first driven outwardly to the periphery of this chamber, then passes between the baffle **20** and the end wall **7** and thereupon flows into the discharge channel **22** at the outlet of which this heavy fraction passes over the flange **24** and is drained off by the collector **26**. On the other hand, the enlarged globules of the light fraction A, which are subjected to a thrust towards the axis **5**, accumulate before the inner end of the tube **21**. The light fraction thus separated then flows into the tube **21** and proceeds toward the flange **23** which deviates it towards the collector **25**.

When, as opposed to the case assumed above, the liquid mixture in question has a heavy fraction dispersed within the light fraction, the separation through centrifugal force will be obtained in the same manner in the tubes **2** except that the globules will then be separated on the side remote from the axis **5**.

It may be noted that the circulation through centrifugal force takes place in the described separator thanks to the difference in "level" or hydrostatic head, with regard to the axis **5**, of the liquid present in the entry chamber **13**, on one hand, and end the exit chamber **19**, on the other. As a matter of fact, these levels which are indicated in FIG. **1** are formed owing to the centrifugal force acting on the liquid, on the one hand, and to the atmospheric pressure prevailing in the inlet and outlet chambers on the other hand. The inner end of tube **21** constitutes an outlet orifice through which the light fraction A can flow over while forming, in the outlet chamber **19**, the level shown in FIG. **1**. Moreover, the annular duct **27** extending radially inward up to the vicinity of the inner tube **21** allows this level to be established while at the same time ensuring discharge of the heavy fraction from the periphery of the outlet chamber **19**.

The separating tubes could also be inclined in relation to the axis of rotation so that their distance to the latter increases from their inlet toward their outlet, to enhance circulation in the tubes through an increased centrifugal pumping effect. Moreover, the cross-section of the tubes may, if desired, be noncircular and in particular asymmetrical so as to promote coalescence of the globules separated therein. Thus, for example, each tube may have an inner surface which is more concave in the zone where the globules are accumulated. Similarly, the separating tubes need not necessarily be rectilinear as described above. One may contemplate using, for example, helicoidal tubes having a large pitch in relation to the winding diameter, to render the separator more compact in length.

As the separation is achieved through the effect of centrifugal force, the device may be arranged with its axis in any desired position other than the horizontal.

The centrifugal separator according to the second embodiment shown in FIGS. **2** and **3** comprises a rotatable drum **1** with a vertical axis **5**, forming at its upper end an admission chamber **13** provided with a circular axial inlet **8** communicating with the ambient atmosphere and at its lower end an outlet chamber **19** likewise communicating with atmosphere. The intermediate part of the drum comprises a multitude of vertical separating tubes **2** distributed equidistantly around the axially positioned cylindrical hub **3** and extending, parallel to the rotational axis **5**, between the admission chamber **13** and the outlet chamber **19**.

This general arrangement is similar to that of the described separator shown in FIG. **1**, the axis **5** being vertical instead of horizontal for mechanical reasons only. Moreover, the circulation of the emulsion as well as the separation of its constituents occurs in exactly the same manner in both cases since they both depend on the action of centrifugal force only.

As is shown in FIG. **2**, the drum **1** is mounted on the hollow cylindrical hub **3** which is driven by an electric motor **28** mounted on a vertical base **29**. Moreover, the separating tubes **2** are arranged side by side so as to form a nest of tubes filling the annular space between the hub **3** and the cylindrical casing **4** of the drum **1**. Assembly of the tubes **2** may be effected by using a suitable mass, of adhesive material for example, allowing them to be solidly connected together.

In this second embodiment according to FIGS. **2** and **3**, the admission chamber **13** is not equipped with deflecting means such as the deflectors **14**, **16** shown in FIG. **1**, as such means are not required in numerous applications of the separator where the emulsion to be separated does not contain solid impurities.

As may further be seen in FIG. **2**, the feed pipe **12** for introducing the emulsion into the admission chamber **13** is equipped with a valve **30** for adapting the emulsion feed rate to the constituents to be separated in each case. The emulsion entering the admission chamber **13** is driven radially by the centrifugal force due to rotation of the drum **1** and forms, between header **6** and hub **3**, an annular body of liquid centered on the axis of rotation **5**, as indicated by dash-dotted lines in FIG. **2**, with an inner cylindrical boundary of radius R1 which is slightly greater than the radius ofinlet opening **8** but less than that of hub **3**. The emulsion coming from the admission chamber **13** passes through the tubes **2** where the separation of its constituents occurs under the action of centrifugal force in exactly the same manner as already described with reference to FIG. **1**. Moreover, the subsequent complete separation of the lighter constituent A from the heavier constituent B in the outlet chamber **19** and their separate discharge from this chamber likewise occur in a similar manner in both cases.

In this second embodiment, the lighter constituent A is discharged by means of a group of discharge tubes **31** each mounted at an orifice in the partition **20** so as to communicate with chamber **19**. These tubes **31** are evenly distributed on a circle with radius R2 (see FIG. 3), this radius being larger than that of the axial inlet **8** but smaller than the radius of the hub **3**. Similarly, the annular outlet duct **27** formed between the partition **20**, the end wall **7** and serving to bring back the heavier constituent B from the periphery of the outlet chamber **19** toward the axis **5**, emerges in a group of discharge tubes **32** mounted equidistantly on the end wall **7** on a circle with the same radius R2. As may be seen from FIG. **2**, the tubes **31** and **32** each comprise a first longitudinal portion followed by a second outwardly turned radial portion emerging in a fixed annular collector **25** and **26**, respectively, which communicates with the ambient atmosphere. The radially extending legs of the generally L-shaped tubes **31** and **32** open with clearance into the nested channels **25** and **26**, respectively.

The lighter constituent A, arriving at the inlet of the tubes **31** communicating with the atmosphere, flows into these tubes while forming around the axis **5** a liquid-overflow level situated at an equal distance R2′ therefrom. This liquid level formed in the outlet chamber **19** and in the longitudinal entrance portion of tubes **31** is indicated by dash-dotted lines in FIG. **2**. The heavier constituent B arriving at the inlet of the discharge tubes **32** after passing through the annular duct **27** flows into these tubes while likewise forming a liquid-overflow level in the annular duct **27** and in the longitudinal entrance portion of the tubes **32**. This overflow level formed by the heavier constituent B, also indicated by dash-dotted lines in FIG. **2**, surrounds axis **5** at an equal radial distance R2″ therefrom, this distance being greater by a few millimeters, at the most, than the radial distance R2′ of the overflow level formed by the lighter constituent A. The constituent A discharged from the tubes **31** is thus collected by the fixed annular collector **25** while the heavier constituent B discharged from the tubes **32** is collected by the fixed annular collector **26** which, in the present case, is formed between the base **29** and the outer collector **25**.

It may be readily seen that the separators described above are of simple and compact design. They nevertheless permit emulsions to be separated into their constituents very effectively at a high rate. These substantial advantages are obtained through the particular arrangement of the separating passages and of the common admission and outlet chambers in the rotating drum.

As a matter of fact, the use of separating passages surrounding a hub and extending longitudinally in the rotating drum between common admission and outlet chambers provided with the described inlet and outlet means, in conformity with my present invention, allows very effective use of a multitude of separating tubes and, consequently enables very high flow rates to be achieved without, however, necessitating the use of complicated feed and discharge means as was hitherto the case. Indeed, a closely spaced arrangement of the tubes, as shown in FIG. **2**, allows the annular space between the hub **3** and the casing **4** of the drum to be subdivided into a maximum number of separating passages **2** and hence affords very high flow rates in the separator with minimum space requirements. Moreover, this subdivision into a multitude of separating passages allows a very small hydraulic diameter to be obtained in each passage whereby the centrifugal separation is promoted to a great extent for reasons explained below.

As is well known, the Reynolds number (Re), which corresponds to the product of the flow speed w in a passage times the hydraulic diameter d divided by the viscosity (ν) of the fluid considered, is generally used for defining the flow conditions of a fluid. Now, as is likewise known, an effective centrifugal separation becomes difficult or even impossible to achieve when the mixture to be separated passes through the separating passage under turbulent flow conditions. It is thus generally necessary to ensure laminar flow conditions, i.e., a flow corresponding to Reynolds numbers ($Re = wd/\nu$) of less than about 2,000, in a centrifugal separating passage. Since, however, the viscosity ν is given for a given liquid mixture or emulsion, either the flow speed w or the diameter of each passage, or both, should be reduced in order to be able to ensure laminar flow. It is evident, however, that a reduction of the speed of flow through a separator with a given cross-section will entail an undesirable restriction of the flow rate and hence of the capacity of the separator. In the same way, the choice of a separator with greater cross-section in order to ensure a reduced velocity for a given flow rate is likewise undesirable on account of the corresponding increase in the dimensions of the separator, which is obviously a major disadvantage in a centrifugal separator. As a matter of fact, owing to mechanical limitations, any increase in the diameter of a rotating separator entails a reduction of the maximum speed at which it may be operated and thus leads to a reduction in the centrifugal separating effect which may be achieved.

Now, as a rule, a reduction in the diameter of each separating passage allows laminar flow to be achieved at a higher flow velocity. However, in order to ensure a high flow rate it is necessary to use a correspondingly large number of narrow separating passages. As opposed to known centrifugal separators, wherein the use of a large number of passages is excluded for reasons depending essentially on the techniques used hitherto for feeding each passage individually with the liquid mixture and for discharging the separated constituents, the separator according to this invention allows efficient use of any desired number of separating passages. This is due, in particular, to the fact that all the passages are fed with emulsion from a common admission chamber or entrance manifold and emerge in a single outlet chamber forming part of an exit manifold. The presence of a great number of coaxial rows of passages of small diameter thus does not, in fact, pose any constructional problem whatsoever. Indeed, apart from the described nest of tubes, a multitude of separating passages may be readily obtained in various ways, for example by means of an annular honeycomb structure or by an assembly of juxtaposed corrugated plates.

It will be noted that, in both embodiments of my invention, the entrance and exit manifolds **13** (or **13, 18**) and **19, 27** formed between the generally frustoconical headers **6, 7** and the closed hub **3** converge radially outwardly toward the zones of the tubular passages **2**. On the outlet side, the increased radial pressure differential due to this outward convergence promotes the gravitation of the light fraction toward the central axis, thereby enhancing the separation of the constituents. On the inlet side, at least in the system of FIGS. **2** and **3**, the progressive narrowing of the chamber **13** increases the axial pressure differential driving the liquid through the conduits **2** clustered about hub **3**.

The distribution of a multitude of separating passages around a central hub moreover allows these passages to revolve around the rotational axis at a distance therefrom which is many times greater than the diameter of the passages. Consequently, the effect of the centrifugal force acting on the mixture present in each passage does not vary notably across the section thereof, i.e., between the point nearest to and the pont farthest from the rotational axis. It thus becomes possible to avoid any substantial transverse circulation of the emulsion in each passage, as would result from a significant variation in centrifugal force therein and would disturb the laminar flow which is necessary for ensuring satisfactory centrifugal separation. The use of common admission and discharge chambers or manifolds vented to the atmosphere as described makes it possible to ensure in a particularly simple and effective manner, owing to centrifugal force, a uniform feed of the emulsion to the numerous separating passages, advance of the emulsion in the passages during separation and discharge of the separated constituents. As a matter of fact, it thus becomes possible to vary the supply rate over a relatively wide range without appreciably affecting the laminar flow of the emulsion or the centrifugal separating effect, since the spontaneous establishment of the above-described liquid levels allows a self-regulating effect to be achieved during operation at different feed rates. Moreover, since the movement of the emulsion and of the separated constituents is ensured through centrifugal force only, the use of separate pumping means, i.e., of a pump to force the emulsion under pressure through the separator, is no longer necessary. This allows a considerable simplification of the auxiliary equipment of the separator and hence saves in the equipment costs and running expenses of the separator.

The various advantages pointed out above may be illustrated by the following example:

EXAMPLE

A separator such as shown in FIGS. **2** and **3**, comprising a steel drum with an outer diameter of 56 cm and a hub with a diameter of 40 cm, includes an array of 830 tubes with an inner diameter of 1 cm. Rotation of this drum at 2,000 r.p.m. allows a centrifugal acceleration to be achieved which, depending on the distance of each tube from the rotational axis of the drum, is about 900 to 1,250 greater than the acceleration due to gravity. The maximum flow rate at which laminar flow and hence complete separation may be achieved will depend from case to case on the size of the liquid globules to be separated from the emulsion. Thus, for example, for a tube length of **20** cm, the drum having the above dimensions and rotating at 2,000 r.p.m. enables complete separation with flow rates as high as 47 m^3/h when the size of the globules to be separated is 0.03 mm. Similarly, the maximum flow rate for ensuring complete separation of an emulsion comprising globules of 0.01 mm would be about 4 m^3/h.

It may thus be readily seen that the described centrifugal separator avoids the cited disadvantages of known separators in a most simple manner. As a matter of fact, as was pointed out, this is a direct consequence of the provision in a rotating drum, of a multiplicity of separating passages with relatively small cross-section, extending longitudinally in the drum, around a hub of much larger diameter than that of the passages, between common admission and outlet manifolds each communicating with the atmosphere. Thanks to this particular arrangement, it thus becomes possible to achieve, in a most economical manner, not only optimum separating conditions but also a very high separating capacity with a rotating drum of very simple and compact design.

The described separator may be readily applied in a widely varying range of technical fields. Indeed, it no longer is necessary to comprise, for each application, between the degree of separation desired and the flow rate of the treated liquid mixture.

Thus, for example, my improved system may be used with advantage for treating waste waters such as the water used for washing the tanks of oil tankers or the effluents of steel-mills.

Moreover, the separator may be used in various industrial fields, for example in industrial mineral chemistry and extraction.

Another important field of application of this separator is the food processing industry. Thus, for example, it is most suitable for the treatment of milk and vegetable oils or fish oils.

I claim:

1. A centrifugal separator for dividing an emulsion into a light and a heavy fraction, comprising:

a drum rotatable about a central axis, said drum having a cylindrical casing with a pair of end walls and a closed hub within said casing axially spaced from said end walls, one of said end walls forming a first header defining an entrance manifold with said hub, the other of said end walls forming a second header defining an exit manifold with said hub, said first header being provided with a central opening of a radius smaller than the hub radius connecting said entrance manifold with the atmosphere;

a multiplicity of axially extending conduits clustered about said hub, said conduits forming passages between said manifolds of a diameter substantially smaller than their distances from said axis;

feed means for introducing an emulsion into said entrance manifold, said feed means passing with clearance through said opening;

baffle means in said exit manifold dividing same into an annular duct for the heavy fraction and an outlet chamber for the light fraction, said duct being open toward said passages near the periphery of said casing and extending inwardly along said second header in spaced relationship therewith;

first collector means communicating with said duct for extracting said heavy fraction therefrom while venting said duct to the atmosphere; and

second collector means communicating with said outlet chamber for extracting said light fraction therefrom while venting said chamber to the atmosphere, both said first and second collector means communicating with said exit manifold at locations spaced from said axis by distances larger

than the radius of said opening but smaller than the radius of said hub.

2. A separator as defined in claim 1 wherein said second header and said baffle means are generally frustoconical, said chamber converging radially outwardly in a zone containing the outlet ends of said passages.

3. A separator as defined in claim 2 wherein said first header is generally frustoconical, said entrance manifold converging radially outwardly in a zone containing a pair of coaxial channels.

4. A separator as defined in claim 1 wherein said first and second collector means comprise a pair of coaxial channels.

5. A system as defined in claim 4 wherein said first and second collector means further comprises two sets of tubes opening with clearance into said channels.

6. A system as defined in claim 5 wherein said tubes are generally L-shaped and provided with substantially radial legs received within said channels.

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