United States Patent

[11] 3,563,454

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[33] **France**
[31] **PV111,337**

[54] **METHOD OF AND APPARATUS FOR SEPARATING THE VARIOUS PHASES OF A FLUID MIXTURE**
19 Claims, 15 Drawing Figs.

[52] **U.S. Cl.** **233/44**
[51] **Int. Cl.** **B04b 7/00**
[50] **Field of Search** .... 233/44, 40, 27—39

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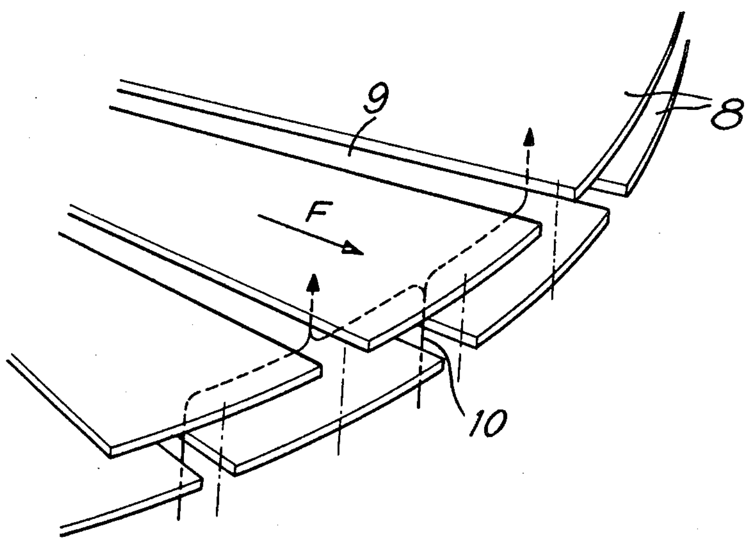
Primary Examiner—William I. Price
Attorney—Bucknam and Archer

ABSTRACT: A method of separating the various phases of a fluid mixture in which the mixture is subjected to a centrifugal field and simultaneously suddenly diverted along the whole of its flow path which is substantially perpendicular to the centrifugal directions. Also included is an apparatus for use in carrying out the method.



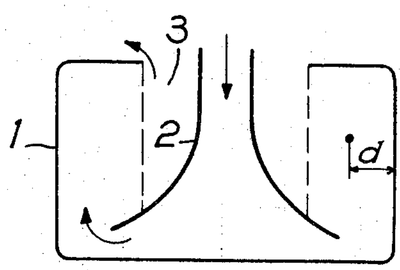


Fig. 1
PRIOR ART

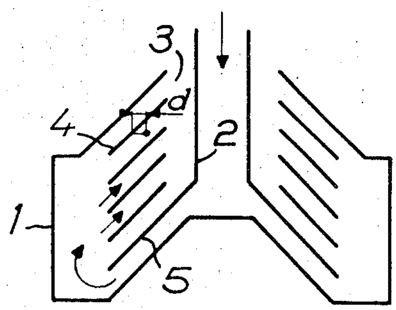


Fig. 2
PRIOR ART

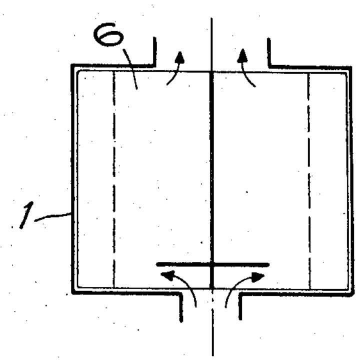


Fig. 3
PRIOR ART

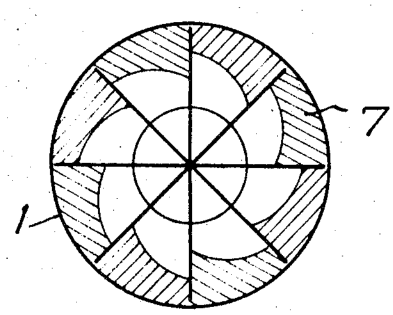


Fig. 4
PRIOR ART

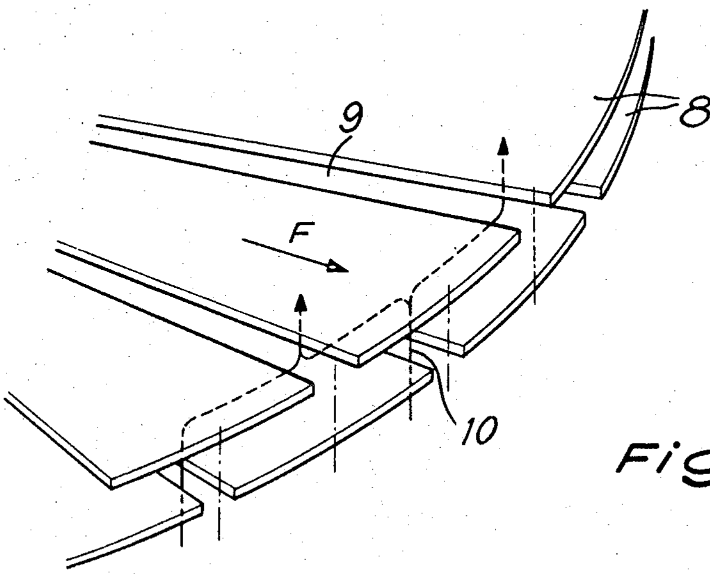


Fig. 5

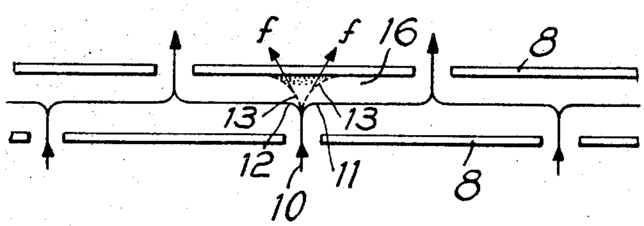


Fig. 6

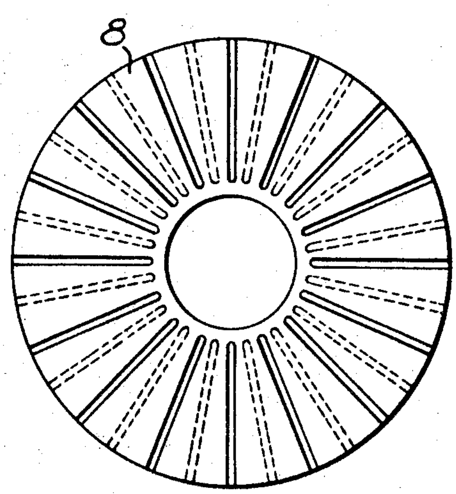


Fig. 7

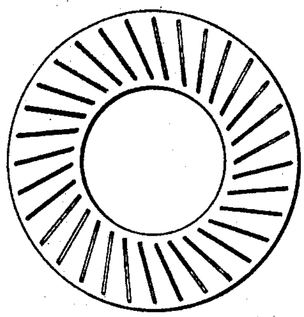


Fig. 8

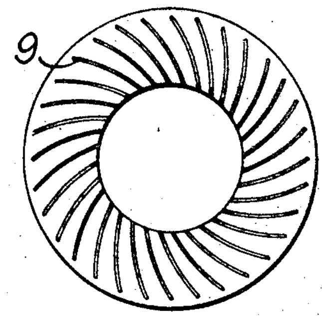


Fig. 9

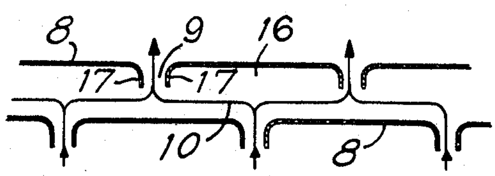


Fig. 10

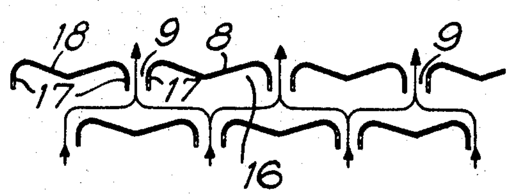


Fig. 11

FIG.12

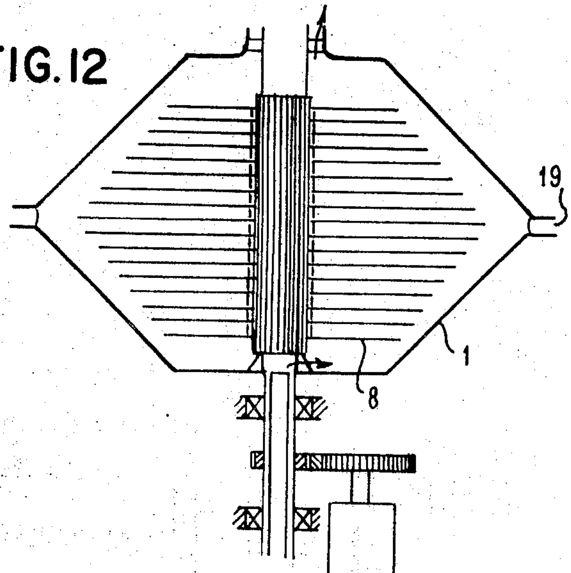


FIG.13

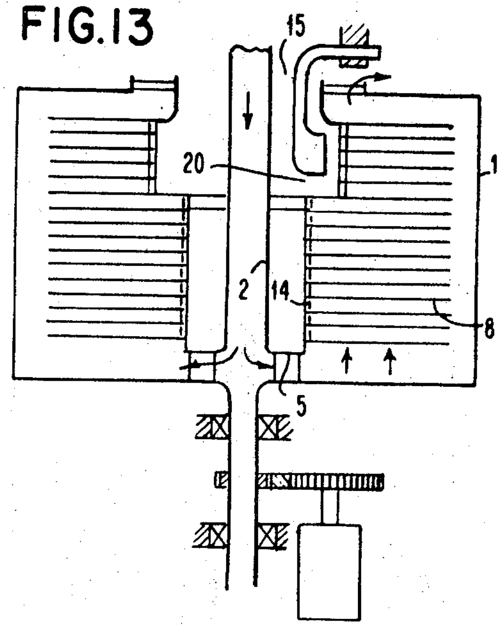


FIG.14

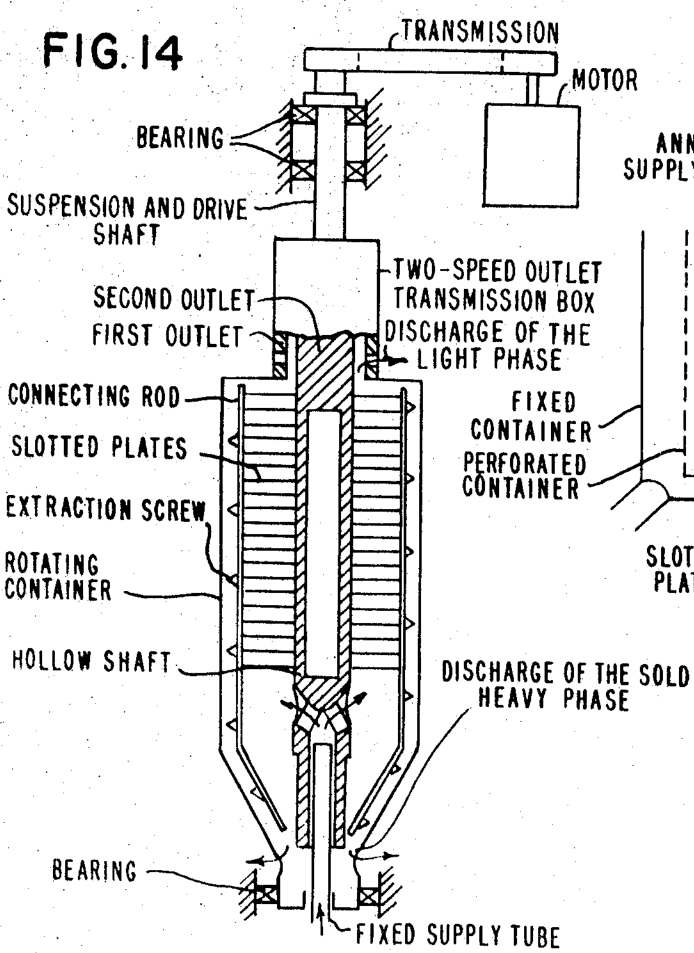
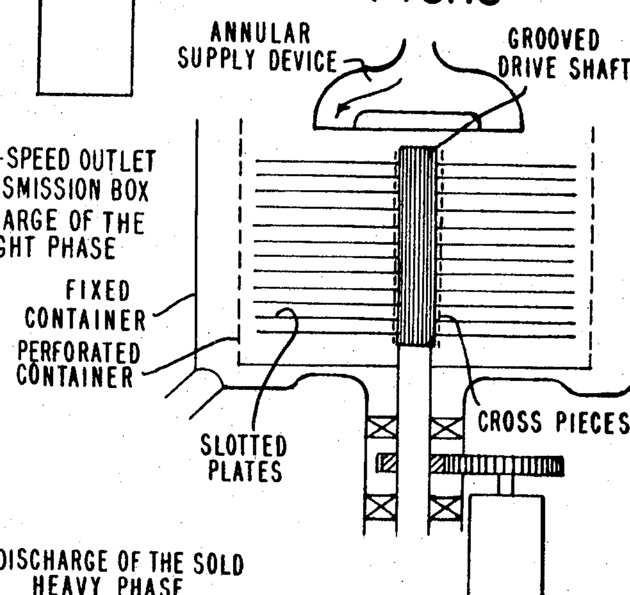


FIG.15



METHOD OF AND APPARATUS FOR SEPARATING THE VARIOUS PHASES OF A FLUID MIXTURE

This invention relates to a method and apparatus for treating a mixture of materials so as to separate the various phases thereof.

It is known to use centrifugal apparatus for phase separation and, as will be seen from FIG. 1 which is a diagrammatic axial section, these generally comprise a rotatable container 1 and a central hub 2 which widens towards the bottom of the container. The mixture to be treated is introduced through the hub and driven in rapid rotation by the container so as to produce within the mixture a centrifugal field, the intensity of which is a function of the nature of the mixture.

The heavy phase is driven under the action of the centrifugal field towards the container 1, while the light phase moves towards the hub 2, whence it is evacuated by overflowing through an opening 3.

In known centrifugal apparatus having containers of large diameter three phenomena appear during their operation which reduce the efficiency thereof. These are as follows:

- the decantation distance, i.e. the distance *d* over which the heavy particles must pass to reach the wall of the container 1, is considerable and the separation time is therefore increased in comparison to what it would be in a centrifugal apparatus of small diameter;
- the movement of the various annular layers of mixture relative to each other and to the container is such that the speed of rotation of the container is not attained by the layers and the centrifugal field is therefore not as intense as it should be within the mixture;
- various turbulences due to the impulsion in the feeding zone, to thermal gradients and to the driving energy of the centrifugal field itself are set up in the mixture and disturb the decantation.

In order to remedy these disadvantages with a view to improving the efficiency of these known centrifugal apparatuses, various means have been employed.

In a first known method of operation, illustrated by the diagrammatic axial section of FIG. 2, truncated cone-shaped parts 4, generally known as plates, are positioned in the container 1 and rotatably driven in synchronism therewith. For this purpose the plates 4 are located one above the other and separated by uniform distances and are fixed to the lower widened end 5 of the hub 2. The assembly constituted by this hub, the plates and the container 1 is rotatably driven and, as in the previous case, the mixture to be treated is introduced through the hub and circulates in the container and between the plates. The light phase is evacuated through the opening 3, while the heavy phase moves toward the internal wall of the container 1.

The plates 4 enable the decantation distance *d* to be reduced and constitute a collection element for the heavy particles. They eliminate cohesive turbulence by dividing the flow of mixture into thin layers. They also improve the rotational propulsion of the mixture by internal friction.

However, these plates have numerous disadvantages:

- because of their truncated cone shape they increase the vertical size of the apparatus and complicate its shape. This results in an increase in the cost of manufacture of such an apparatus and of the ratio of the cost to the amount of mixture treated. Moreover, their own net cost is high;
- the angle of the plates is not always the same and it must in effect be modified in numerous cases to take into account the coefficient of friction of the deposited sediments. The construction of the apparatus must thus be adapted to each particular treatment;
- the sediments which reach the periphery of the plates fall back into the feeding zone of the latter and are partially brought back into suspension;
- the flow of mixture between the plates is subjected to a radial centripetal component which reduces the efficiency of decantation. This component increases when the mixture moves towards the center, the annular flow section decreasing. The centrifugal field diminishes when the treated mixture moves towards the center and the separation effect is thus reduced. Under these conditions, since, for the mixture circulating from the periphery towards the center, the separation effect diminishes and since, by contrast, the propulsion effect increases, only the peripheral zones of the plates operate efficiently;
- cleaning of the plates is almost unavoidable in numerous cases due to imperfect sliding of the sediments towards the periphery. Such cleaning is difficult, especially if the plates are very close together to provide efficient separation;
- when a mixture of two liquids is to be treated, regulation of the surface of separation of the two liquids must be effected with precision because this surface must be stabilized in a narrow zone defined by holes formed in the plates. The less dense liquid, located on the side of the surface of separation corresponding to the holes, must be evacuated through these holes towards a central opening, the denser liquid at the other side of the surface being evacuated towards a peripheral opening.

A second known method of operation has also been put into effect to obviate the disadvantages of centrifugal apparatuses such as that known in FIG. 1. In this second method of operation which is represented in FIGS. 3 and 4, which are an axial section and a diametric section respectively, the centrifugal apparatus has radial partitions 6 located within the rotatable container 1 and driven in synchronism therewith. These partitions have the advantage of ensuring good propulsion of the mixture at the speed of rotation of the container, but they do not enable the decantation distance to be reduced, and neither do they diminish the cohesive turbulence.

Moreover, they frequently lead to preferential concentrations 7 of sediments deposited against the lateral wall of the container, and this is especially so for apparatuses of large diameter. These concentrations are theoretically distributed in zones which are regularly disposed at the periphery, but in practice this distribution can occur other than aforesaid and lead to static and dynamic imbalances. Finally, when the container holds a considerable quantity of sediments the multiple radial partitions 6 are deeply buried in the sediment and their extraction can become particularly difficult.

A main object of the present invention is to combine the advantages of the two known methods of operation while removing their disadvantages, particularly in order to obtain maximum efficiency in centrifugal apparatuses.

According to the invention, a method of treating a mixture of various phases in order to separate them is characterized in that the mixture is subjected to a centrifugal field and the mixture flow is suddenly diverted along the whole of its flow path, which is substantially perpendicular to the centrifugal directions.

From another aspect, the invention includes an apparatus for carrying out the aforesaid method and comprising, within a rotatable container, a stack of plates concentrically surrounding the axis of the container and rotatably driven, the plates being spaced from each other and having angularly staggered orifices such that the plates constitute deflectors whose general direction is substantially axial.

In a preferred embodiment, the plate orifices are slots, preferably straight and radial and leading to the peripheral edges of the plates. The edges of the slots may be bent back towards the upstream direction of the zigzag axial flow path of the mixture to be treated. The plates may, moreover, be profiled between the slots to form swirl channels.

In order that the invention may be more fully understood, various embodiments in accordance therewith will now be described, by way of example, with reference to FIGS. 5 to 13 of the accompanying drawings, in which:

FIG. 5 is a partial perspective view showing the means characteristic of the invention, i.e. the slotted plates;

FIG. 6 is a diagrammatic end view of FIG. 5 illustrating the method of the invention;

FIG. 7 is a plan view of the stack of plates;

FIGS. 8 and 9 are views similar to FIG. 7 showing alternative embodiments;

FIGS. 10 and 11 are views similar to FIG. 6 showing other variants;

FIGS. 12 and 13 are diagrammatic axial partial sections showing several embodiments of the apparatus in which said plates are included.

FIGS. 14 and 15 are diagrammatic axial sections showing several embodiments of the apparatus in which said plates are included.

Referring to the drawings, the apparatus of the invention comprises a container 1 in which are mounted plates 8 concentrically surrounding its axis. The plates are driven in rotation and spaced one from the other so as to form free annular spaces through which the mixture to be treated can circulate. These plates are essentially characterized by the fact that they have orifices 9 which are angularly staggered from one plate to the next.

Thus, the free spaces between the plates and the staggered orifices in the plates constitute zigzag passages whose general direction is substantially parallel to the axis of rotation of the assembly. This results in the flow of mixture in the axial directions 10 being diverted each time it passes through a plate (FIGS. 5 and 6). Thus, there is produced a centrifugal effect *f* in the bends 11 and 12 of this flow 10 which tends to propel the heavy particles to the outside of the bends, i.e. towards the plate opposite along the trajectories 13.

The foregoing illustrates the operation of the method of the invention, which consists in subjecting the mixture to a centrifugal field F while suddenly diverting the flow 10 of the mixture along the whole of its substantially axial path. In other words, the effects of the centrifugal force F applied to the heavy particles or droplets (which centrifugal force is due to the rotation of the assembly of the container 1 and plates 8) are combined with the effects of the centrifugal force *f* due to the sudden changes in direction of the streams of treated fluid flowing in general axial directions.

The heavy particles or droplets propelled by the less dense fluid along the zigzag axial flow path 10 thus tend, at each sudden change of direction, to continue their trajectory in a straight line and hit the opposite plate 8, as in impact filters. The main centrifugal field F acts on all the heavy particles or droplets and causes them to move towards the periphery, and this is so for those within the mixture, as well as for those which are thrown against the plate 8. The main centrifugal effect F is orthogonal to the aforesaid deflection effect on which it has no direct disturbing influence and it is observed that it entirely retains its separating effect.

Moreover, the deflection effect tends to amass to heavy particles or droplets on the plates 8 along which the main centrifugal field causes them to slide rapidly towards the periphery. Under these conditions, amassing of the particles or droplets due to the deflection effect increases the volume/outer surface ratio of the particles or droplets and thus increases the speed of separation thereof. It is important to note that collection of the heavy particles or droplets occurs in a "dead zone" due to the effect of the wall. This results in these particles or droplets being no longer subjected to the propulsion effect of the circulating fluid, and this increases the efficiency of the centrifugal field. Moreover, the passage of the mixture through the orifices and between the plates encourages rotation of the mixture at the angular speed of the rotor, so that movement of the fluid layers relative to each other and to the rotor is diminished, or even eliminated. The apparatus thus possesses the advantages of radial partition centrifugal apparatuses, but without their drawback of periodicity in the distribution of the sediments. Again, the choice of an angle of taper is no longer of prime importance, as in the plate type centrifugal apparatuses. The field of application of the method and apparatus of the invention is very wide and can include the treatment of liquids loaded with solid particles, as well as mixtures of liquids, or again gas loaded with solid particles or droplets and also includes washing gases by collecting water on the plates, etc...

In the embodiment shown as a preferred but nonlimitative example in FIGS. 5 to 7, the plates 8 are flat annular discs in which the orifices are constituted by slots 9. These discs are coaxially stacked and conveniently separated one from the other, being fixed together and to the rotatable assembly which includes the container. However, during stacking and fixing of the discs, it is necessary to take the precaution of staggering, by half the width of a plate portion between two slots, the slots of discs in even rows relative to the slots of the discs in odd rows, with the object of creating through the system of these slots zigzag paths having an axial direction.

The slots 9 can be straight (FIGS. 7 and 8) or curved (FIG. 9) and they can extend radially (FIG. 7) or with a certain incidence so as to take into account the sliding of the layers, even though this is reduced to a minimum. The slots can lead to the peripheral edge of the discs (FIG. 7), or to the central edge of the discs (FIG. 9), or may not lead to either of these edges. Moreover, the slots, instead of being elongated, can be formed in the discs as a series of holes of any shape. The width of the slots is preferably uniform, but it can also be variable from the center towards the periphery to take into account flow variations in the fluid streams.

A simple means for mounting the discs 8 in the container 1 consists, as shown in FIG. 13, in tying them together in the vicinity of their central edges by means of rings 14 and fixing the stack thus constituted, by means of tie bars for example, to the lower widened portion 5 of the hollow central hub 2, radial arms 15 also being used to connect the upper disc 8 to the hub. There is thus obtained a perfectly rigid assembly which is very easy to construct.

The distance between the discs is generally constant, but it can nevertheless be varied from one end of the container 1 to the other as a function of the denseness obtained and the possible losses of pressure which result therefrom.

It is indicated in the foregoing, considering the axial zigzag flow of the mixture, that it forms "dead zones" 16 (FIG. 6) downstream of the slots on the plates situated opposite, in which zones the heavy particles or droplets collect due to the deflection effect and avoid being propelled by the zigzag flow of the fluid streams. In order to accentuate the aforesaid deflection effect and at the same time produce the "dead zone," it is advantageous to provide turned back edges 17 on the plates 8, as shown in FIGS. 10 and 11, which edges extend along the whole length of the slots 9 and projecting in the upstream direction of the zigzag fluid flow 10. These edges 17 can be formed by pressing from the discs and their edges can be sharp at the points where they meet the fluid streams.

The deflection effect can be further improved by shaping the unslotted portions 18 of the discs 8 between the slots 9 to form V sections pointing in the upstream direction. (FIG. 11). This particular shaping can moreover be dimensioned to give rise to small localized swirls in the "dead zones" 16 tending to in crease the effects of collection and evacuation of the heavy particles or droplets.

The bent back edges 17 and the shaped portions 18 form gutters in which the heavy particles or droplets collected under the deflection effect are channeled and directed under the effect of the centrifugal force towards the periphery. It is clear that the annular discs 8, instead of being flat, can have a slight conicity, which is much less accentuated than that of known plates. This conicity of the discs 8 is intended to take advantage of the main centrifugal force so that the latter tends to maintain the heavy particles or droplets applied against the walls 18 of the discs, whilst projecting them towards the periphery.

The discs 8 can have the same dimensions so as to form a cylindrical stack (FIG. 13). In certain cases, however, the stack can have a different shape in order to adapt the apparatus to particular problems which may arise. Thus, the outer diameter of the discs 8 can be variable so as to form, for example, a stack comprising two truncated cones producing an expanded median zone (FIG. 12). This particular embodiment is extremely advantageous in the case of an apparatus in which the heavy phase is automatically evacuated at the periphery, the container 1 of such apparatus having evacuation nozzles, valves, openings etc. at 19. In a similar manner the inner diameter of the discs can vary.

It is moreover possible, by variations in diameter or by cavities, to form preferential zones 20 (FIG. 13) intended to ensure, for example, the collection of light compact sediments, in which zone known means are provided for their removal.

Moreover, since the slots 9 extend largely radially, there no longer exists any difficulty in regulating the surface of separation of two liquids, which surface can, in effect, be located on any diameter, providing that it still passes through the slots.

In the foregoing the discs 8 are fixed together and to the container so that their angular speed is always strictly equal to that of the latter. In certain cases, it can be advantageous to drive the discs at a speed which is slightly different from that of the container, so as to produce a rotational movement of the discs relative to the container. For this purpose, the disc assembly is mounted on a rotatable support distinct from the container and driven at an appropriate speed. This embodiment is important when the container includes a peripheral helicoidal conveyor to propel the separated heavy products. In this case the conveyor is fixed to the stack of discs.

Naturally, the discs 8 having staggered slots 9 of the invention are applicable not only to centrifuges having plane walled containers 1, but also to dryers having perforated containers to facilitate the central flow of large quantities of liquid.

The invention is not limited to the embodiments shown and described in detail, since various modifications can be made thereto without departing from its scope.

I claim:

1. Centrifugal apparatus for effecting separation of a mixture comprising a rotatable vessel, a plurality of axially spaced plates mounted in said vessel for rotation about the same axis as said vessel, means for admitting said mixture to said vessel whereby the mixture is subjected to a centrifugal force, said axially spaced plates having a plurality of spaced openings arranged such that the spaced openings of adjacent plates are nonaligned, whereby mixture flowing axially from one spaced opening of one plate is directed toward a solid portion of another plate between the spaced openings in the latter plate, said mixture flow being thereby diverted laterally in that said diverted flow is in a general direction substantially perpendicular to a plane defined by the longitudinal axis of the vessel and by a radial line of said vessel.

2. An apparatus according to claim 1, characterized in that the openings in the plates are elongated slots.

3. An apparatus according to claim 2, characterized in that the slots are straight and radial.

4. An apparatus according to claim 2, characterized in that the slots are arcuate relative to a radial line.

5. An apparatus according to claim 2, characterized in that the slots lead to the peripheral edges of the plates.

6. An apparatus according to claim 2, characterized in that the plates have edges along the slots which are bent back in an upstream direction relative to the axial flow of the mixture to be treated.

7. An apparatus according to claim 6, characterized in that the plates are shaped between the slots in the form of two converging wall sections to form swirl channels.

8. An apparatus according to claim 1, characterized in that the plates comprise a plate assembly which is in the form of a truncated cone.

9. An apparatus according to claim 1, characterized in that the plates of the stack have same dimensions.

10. An apparatus according to claim 1, characterized in that the external diameter of each plate is variable according to its position in the stack.

11. An apparatus according to claim 1, characterized in that the internal diameter of each plate is variable according to its position in the stack.

12. An apparatus according to claim 1, characterized in that the plates are cut away over a part of their length.

13. An apparatus according to claim 1, characterized in that the spacing of the plates is uniform.

14. An apparatus according to claim 1, characterized in that the spacing of the plates is variable as a function of their position in the stack.

15. An apparatus according to claim 1, characterized in that the plates are driven in synchronism with the rotatable container.

16. An apparatus according to claim 1, characterized in that the plates are driven at a speed slightly different from that of the rotatable container.

17. An apparatus according to claim 1, characterized by a peripheral helicoidal conveyor to which the plates are coupled.

18. An apparatus according to claim 1, characterized in that the container walls are continuous.

19. An apparatus according to claim 1, characterized by a drying container constituting the rotatable container.