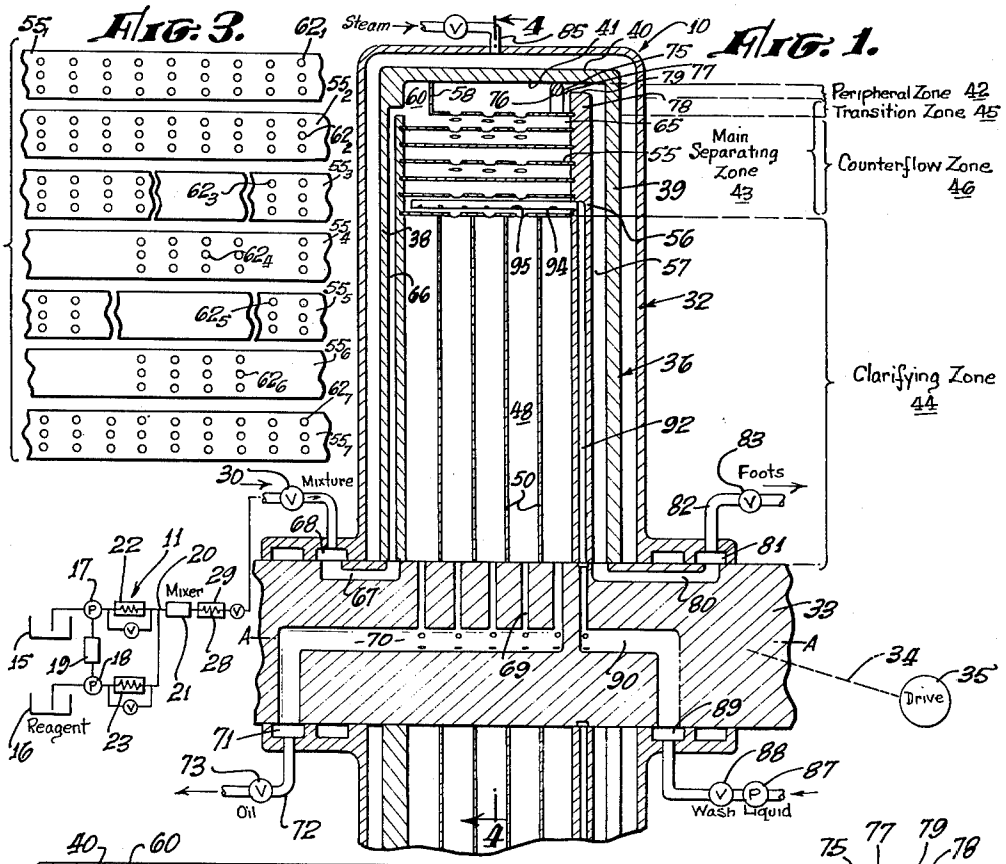
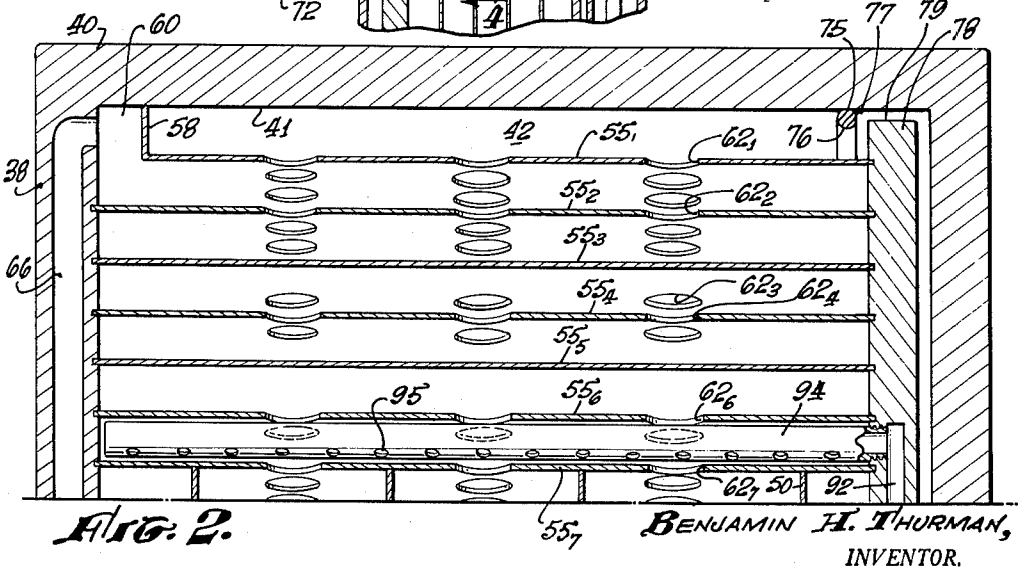
Aug. 24, 1965 B. H. THURMAN 3,202,347

COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

Filed May 2, 1960 5 Sheets-Sheet 1





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Aug. 24, 1965 B. H. THURMAN 3,202,347

COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

Filed May 2, 1960 5 Sheets-Sheet 2

FIG. 4.

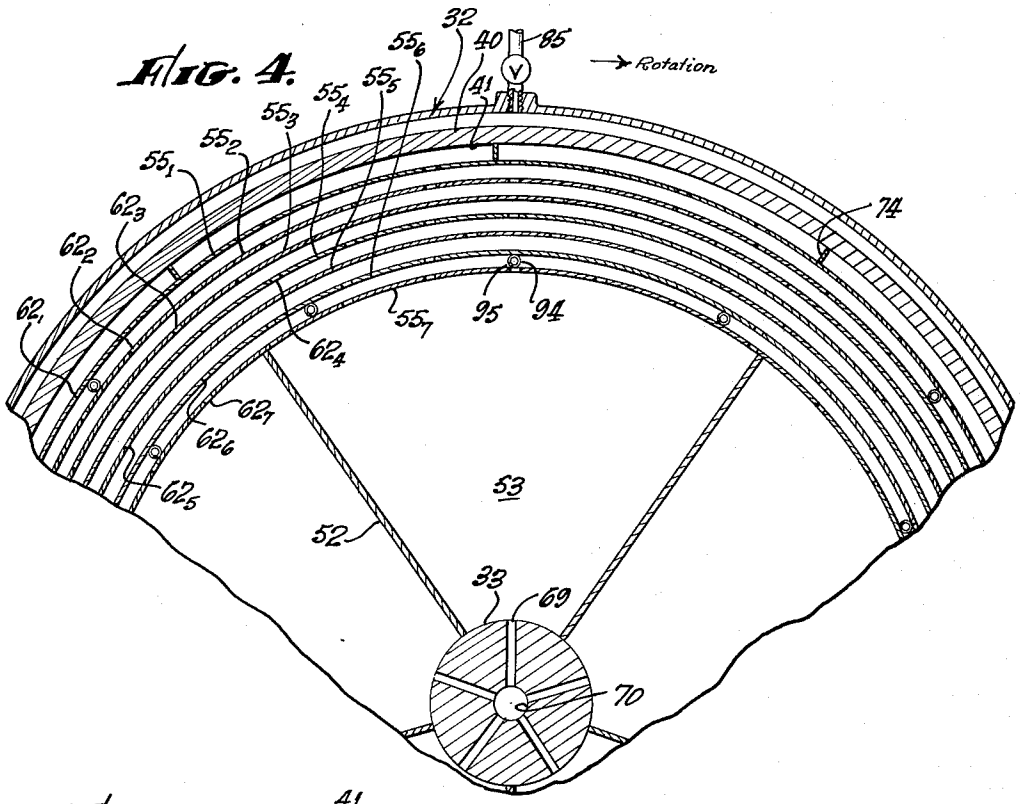
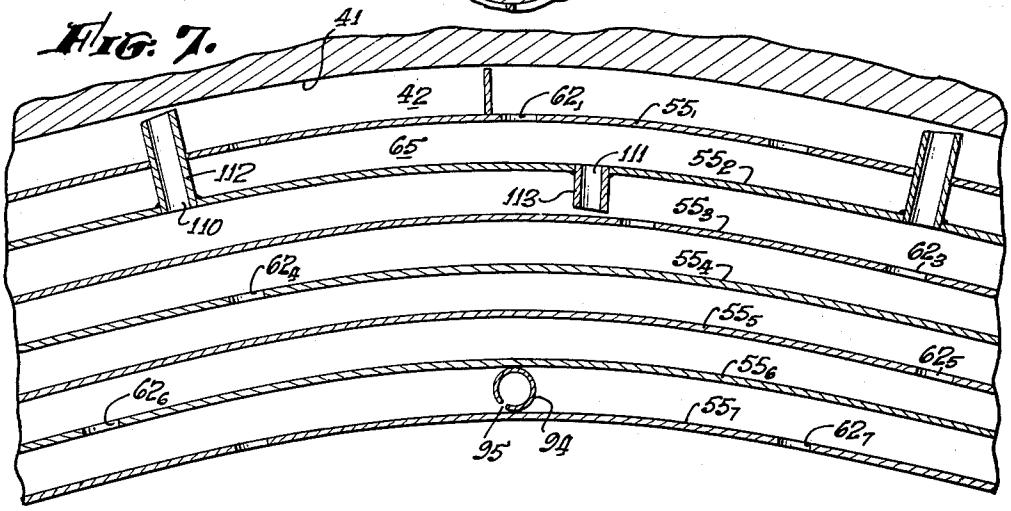


FIG. 7.



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COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

Filed May 2, 1960 5 Sheets-Sheet 3

FIG. 6.

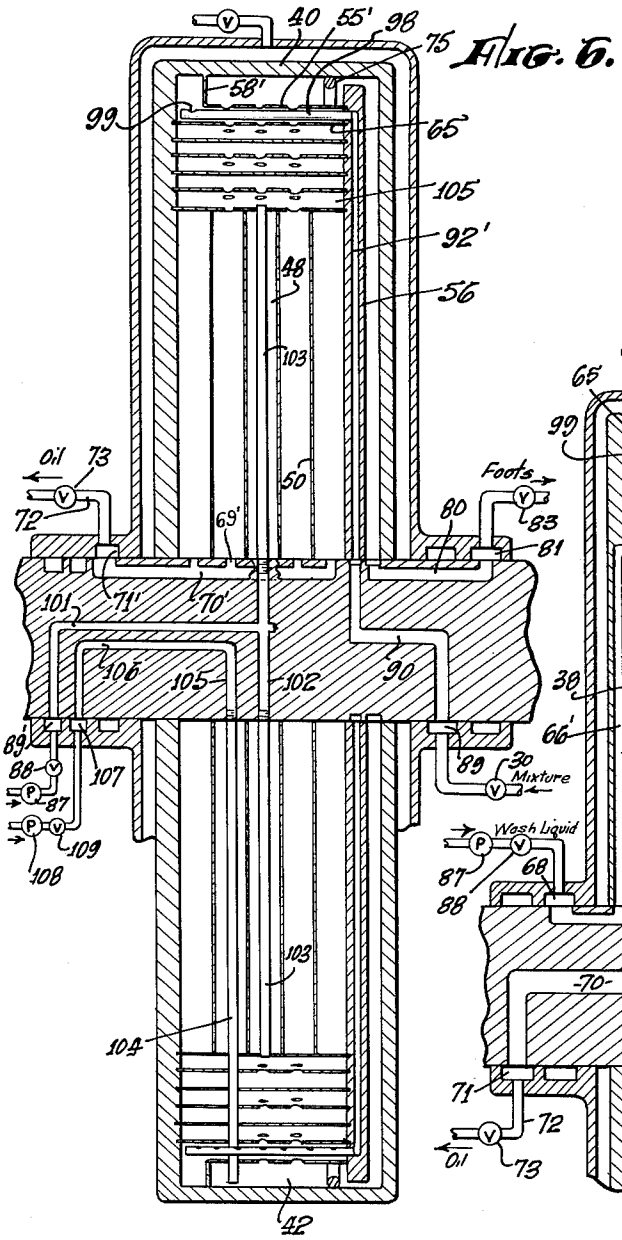
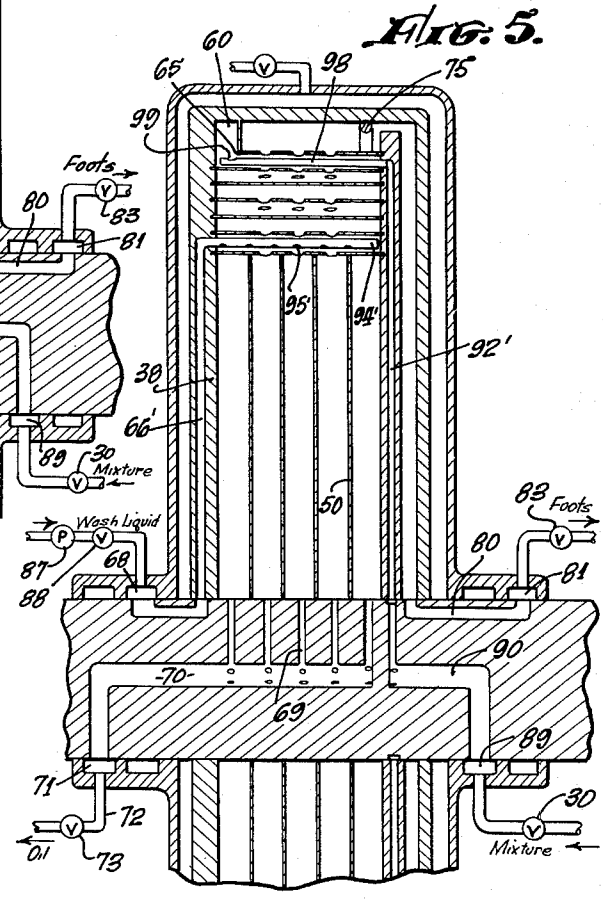


FIG. 5.



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Aug. 24, 1965 B. H. THURMAN 3,202,347

COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

Filed May 2, 1960 5 Sheets-Sheet 4

FIG. 8.

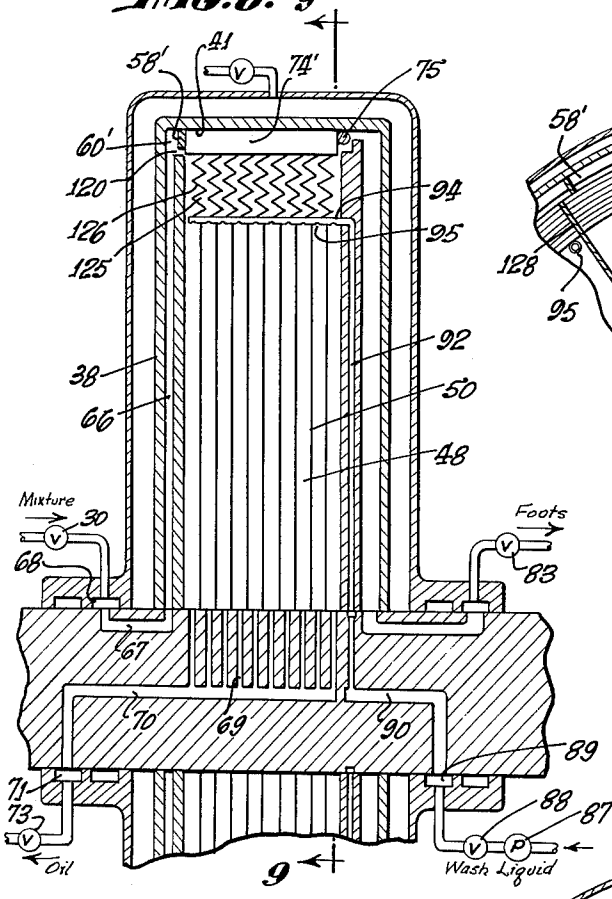


FIG. 9.

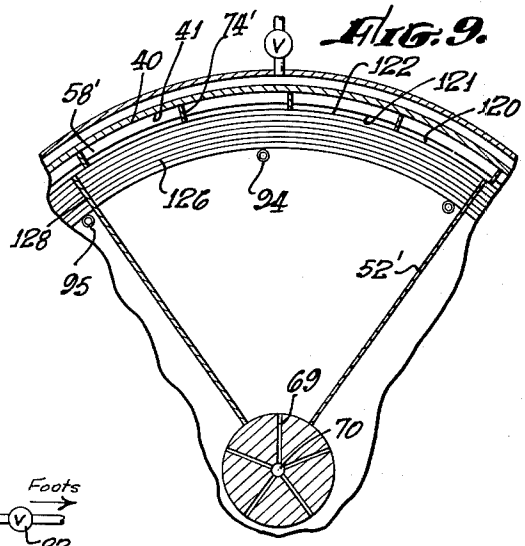


FIG. 10.

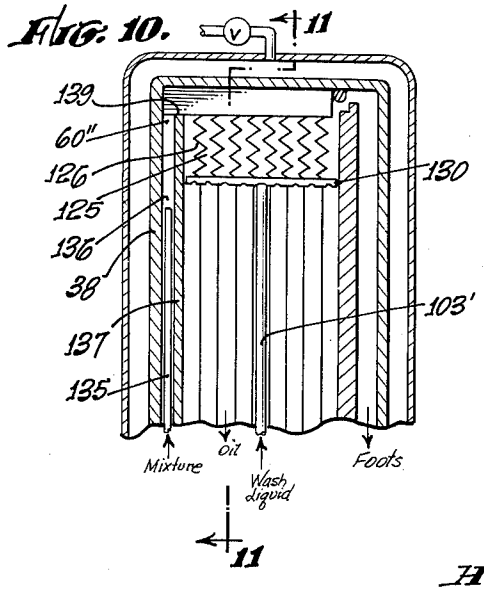
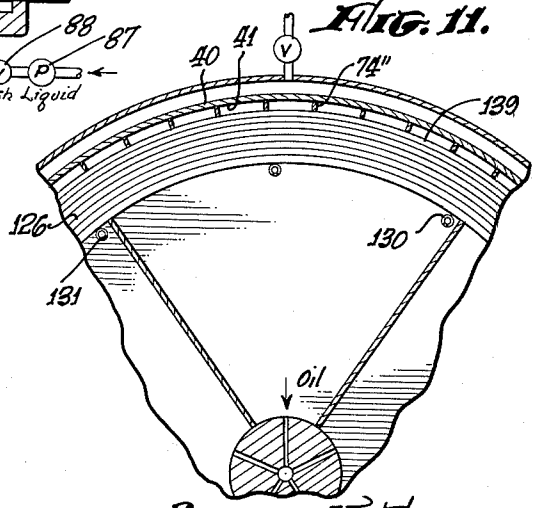


FIG. 11.



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Aug. 24, 1965 B. H. THURMAN 3,202,347

COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

Filed May 2, 1960 5 Sheets-Sheet 5

FIG. 12.

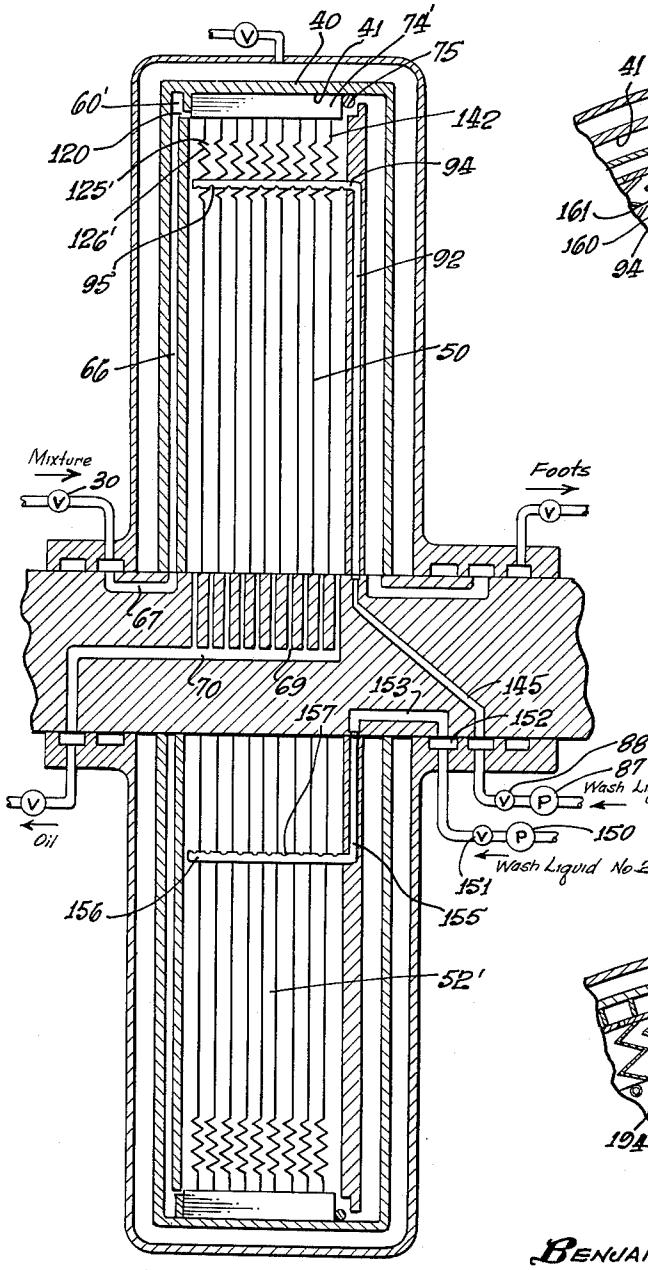


FIG. 13.

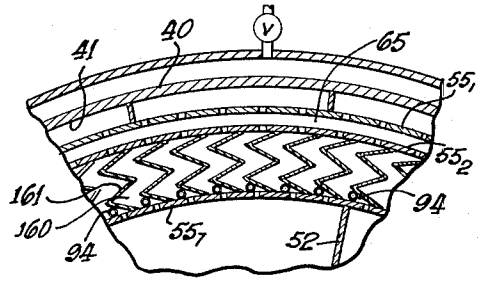
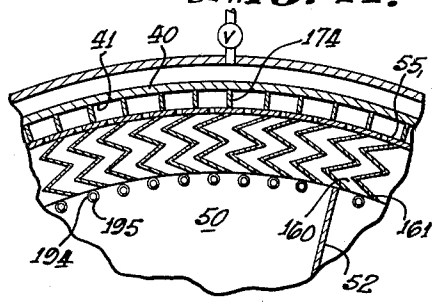


FIG. 14.



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United States Patent Office 3,202,347
Patented Aug. 24, 1965

3,202,347

COUNTERCURRENT FLOW CENTRIFUGAL SEPARATOR

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Filed May 2, 1960, Ser. No. 26,033
2 Claims. (Cl. 233—15)

My invention relates to a centrifugal separator particularly suited for the processing of mixtures of glyceride oils and the like containing centrifugally separable materials, typically foots produced in the degumming, refining or rerefining of oils of this type. The invention relates also to centrifugal processes useful in this art for separating such materials and, if desired, washing the resulting oil during the centrifugal separation.

The invention will be particularly exemplified with relation to the processing of a mixture of oil and foots stabilized by soaps or other emulsifying agents because the separation problem is particularly severe in this art. Unless otherwise qualified, the term "foots" is herein used in a broad sense and includes the gums separated in the degumming of crude glyceride oils by mixing water or dilute reagents therewith, the soapstocks produced and separated in the alkali refining of crude or degummed glyceride oils, the color and other impurities made available for separation in the rerefining of glyceride oils, and the impurities precipitated or put into form for separation by difference of specific gravity in other known processes for purifying or deriving diverse products from glyceride oils.

There is known a centrifugal extractor in which the rotor turns about a horizontal axis and is provided with bands mounted in concentric relation at different radial distances from the horizontal axis throughout the active internal zone of the machine. The concentric annular spaces between such bands are interconnected at intervals by openings or slots through the bands. The lighter liquid is moved countercurrently through the heavier liquid in the stages formed by the annular spaces, the liquids alternately mixing in the slots and tending to be separated by centrifugal force in the interband spaces. Such machines have enjoyed considerable success in liquid-liquid extractions but attempts to use them as centrifugal separators to remove foots from oils, either by centrifugal action alone or as a result of a washing action combined with the centrifugal action, have not been satisfactory. One reason for this is that the slippage between the impure oil and such circular bands tends to produce undesirable emulsions. This is particularly troublesome as concerns the partially purified oil advancing inwardly in an inner zone of the rotor toward the withdrawal position. It is an object of the invention to move such oil inwardly between outwardly extending discs or baffles in this zone and to prevent such slippage therein as would cause emulsification or impede the production of effluent oils of the desired purity. A further object of the invention is to provide novel methods of separating oil-foots or similar mixtures in which the separation of the dispersed material is clean and in which this material flows smoothly from the machine.

It is another object of the invention to provide, in a large rotor having a diameter of at least 20", discrete annular zones at different radial positions in the rotor space in which particular functions are performed. It is thus an object of the invention to provide an outer peripheral zone from which the collected dispersed material is withdrawn, a main separating zone into which the mixture is introduced, and an inner clarifying zone through which the partially purified oil moves to its withdrawal position. In some instances it is an object to introduce

water or a suitable washing medium at a position radially inward of the position at which the mixture is introduced, namely at the outer boundary of the clarifying zone. In this instance an inner portion of the main separating zone forms a counterflow zone through which the wash medium moves outwardly while the partially purified oil of the mixture moves inwardly. It is thus an object to wash the oil in the same rotating equipment in which the foots are separated, thus often eliminating a separate washing step and the tendency for the oil to hydrolyze between separating and washing steps in equipment where these actions are separate.

In some instances better results can be obtained by introducing washing media at two different radial positions. Thus, if a first washing medium is introduced as aforesaid and a second medium or an additional quantity of the first medium is introduced at another position the operation will be better. In some instances the second introduction can be directly to the peripheral zone to dilute the foots therein or make them move more uniformly from the rotor space. In other instances the second introduction can be at a position closer to the rotational axis than the first, for example into the aforesaid clarifying zone, in which event the second medium may counterflow the oil in a second counterflow zone. It is an object of the invention in some of its method and apparatus concepts to introduce a second medium or a second portion of a wash medium into a rotating space and to deliver same to such space through separate passages, preferably as controlled by separate pumps.

In any counterflow zone it is desirable that the inwardly moving oil and the outwardly moving wash medium be brought into intimate contact. I have found that this is aided by introducing the wash medium at a relatively large number of peripherally spaced positions in a manner to form droplets dispersed in the oil environment and further by mingling the oil and droplets by a controlled turbulence in the counterflow zone. It is an object to obtain such controlled turbulence by creating to-and-fro or a zig-zag flow tending to mingle but not emulsify the counterflowing materials. As will be described, such a flow can be obtained by disposing concentric perforated bands in the counterflow zone with their perforations out of alignment radially or in the direction of the rotational axis or by otherwise forming outwardly extending zig-zag, to-and-fro or serpentine passages in the counterflow zone by use of spaced crinkled members that extend generally outward or in the general direction of the rotational axis.

The peripheral zone should contain a radially thin layer of the separated foots and it is desirable to dispose fins in this zone extending substantially parallel to the rotational axis to drive the foots at rotor speed and facilitate their discharge from the rotor. The mixture can be delivered to the rotor space at a position quite close to the peripheral zone and it is an object to deliver the mixture in a manner to flow substantially parallel to the rotational axis during the initial separation of its constituents, which separation is quite rapid. Another object is to introduce the mixture at a position near the innermost edges of such fins, either to a delivery space that is radially adjoining such edges but immediately inward thereof or to an interfin delivery space that is divided by the fins into peripheral sections.

One desirable arrangement is to employ a limited number of circular apertured bands in the main separating zone, surrounding outwardly extending discs or baffles within the clarifying zone. It is an object of the present invention to introduce the mixture into one end of an interband delivery space the mixture flowing therealong toward the other end thereof in a direction substantially parallel to the rotational axis.

Another object is to deliver the mixture to an equaliz-

ing space preparatory to flow into one end of a delivery space. A further object in some of the embodiments is to provide a structure whereby the mixture is delivered to an equalizing space that is adjacent but separated from the aforesaid peripheral zone of the rotor.

As the mixture moves along the delivery space the foots progressively separate and are thrown outward to the peripheral zone. In the latter the collected foots move in the same axial direction toward a weir at one end of such peripheral zone providing an inwardly facing crest determining the inner boundary of the separated material and over which this material flows. It is an object of the invention to incorporate such a weir in a centrifugal separator of this type; also to dispose an outwardly facing spill-over lip adjacent but spaced beyond the weir.

A further object is to collect only a radially thin layer of the foots in the peripheral zone and to apply sufficient heat to the outermost portion thereof to melt or liquefy the entire layer, as distinct from an outermost lamina thereof, to facilitate uniform discharge thereof from the rotating equipment.

Another object of the invention is to dispose the mixture inlet and the inlet for the wash medium on opposite or axially spaced sides of the centrifugal machine. Another object is to provide a centrifugal machine in which the mixture and the wash medium move outwardly in rotor passages at opposite sides of the radial midplane of the rotor.

Further objects and advantages of the invention will be evident to those skilled in the art from the following description of exemplary embodiments.

Referring to the drawings:

FIG. 1 is a fragmentary vertical sectional view of one embodiment of the invention;

FIG. 2 is an enlarged fragmentary view of the upper section of the rotor of FIG. 1, showing the apertured bands in the main separating zone;

FIG. 3 is a view diagrammatically illustrating the aperture arrangement of the bands of FIG. 2;

FIG. 4 is a fragmentary sectional view taken along the line 4—4 of FIG. 1;

FIG. 5 is a view similar to FIG. 1 illustrating an alternative embodiment;

FIG. 6 is a view similar to FIG. 1 illustrating a further embodiment;

FIG. 7 is a fragmentary sectional view taken similarly to FIG. 4 but illustrating an alternative band arrangement employing incomers and outcomers;

FIG. 8 is a sectional view similar to FIG. 1 showing an alternative embodiment of the invention;

FIG. 9 is a fragmentary sectional view taken along the line 9—9 of FIG. 8;

FIGS. 10 and 11 are views similar to FIGS. 8 and 9 illustrating a further alternative embodiment;

FIG. 12 is a sectional view of an embodiment incorporating the double washing feature;

FIG. 13 is a view similar to FIG. 4 illustrating another embodiment; and

FIG. 14 is a view similar to FIG. 13 illustrating a further embodiment.

In all of the above views the apparatus is shown somewhat diagrammatically, not to scale and often with wall thicknesses increased inordinately to illustrate better the flow paths and the structure producing them. To those skilled in the art of designing the seals, influent and outlet arrangements, etc. of horizontal extractors and in the designing of mountings of internal components of centrifugal machines, the principles of the invention and the somewhat diagrammatic showings of the drawings will be clear and will guide in the design of commercial machines.

FIG. 1 of the drawing shows a centrifugal separator 10 of the invention connected to equipment 11 adapted to produce the oil-foots mixture to be separated. This latter equipment is typical of that employed in the alkali refining of glyceride oils to remove fatty acids therefrom. Streams of the fatty oil and an alkali refining agent are respectively drawn from sources 15 and 16 by proportioning pumps 17 and 18 driven at variable volumetric ratios by a device 19. The pumps are desirably of the high-pressure type and deliver streams of oil and reagent to a junction 20 and thence to a mixer 21 of any suitable type. The temperature of the streams can be adjusted by flow through respective heat exchangers 22 and 23 which can be by-passed by valved lines shown.

The resulting mixture can be conditioned for the forthcoming separation by passing through a coil 28 which may be a part of a heat exchanger 29 if additional adjustment in temperature is desired. The coil 28 may provide a suitable residence time and such flow-induced turbulence as will uniformly distribute the foots or otherwise condition the mixture for separation, all in a manner previously known. In the example under discussion, the foots will be largely dispersed in the oil and will comprise soaps and other impurities commonly present in alkali soapstocks. The soaps may be the result of reaction between an alkaline refining agent and the free fatty acids of the oil. In other instances, the foots may be substances dispersed or dissolved in the oil, such as gums, coloring matter, etc., originally present in the oil or products resulting from the reaction or association of the reagent with components of the oil other than free fatty acids. The soaps and some of the other impurities are emulsifying agents.

The resulting oil-foots mixture while still at the high pressure induced by the pumps 17 and 18 is delivered as a stream through a flow restricting valve 30 to the centrifugal separator 10. This centrifugal separator 10 includes an openable housing 32 in which is suitably journalled a shaft 33 connected as indicated diagrammatically at 34 to a suitable drive 35. A massive rotor 36 is connected to the shaft 33 to rotate within the housing 32. The rotor includes side members 38 and 39 and a peripheral member 40 providing an internal peripheral wall 41 extending substantially parallel to the axis A—A of the shaft 33.

The rotor space inside the rotor 36 provides distinct zones, designated to the right in FIG.1 as to their approximate boundaries, including a peripheral zone 42, a main separating zone 43 and a clarifying zone 44 in inward progression. In instances where a washing medium is supplied to the interior of the rotor the main separating zone 43 can be further divided into a transition zone 45 and a counterflow zone 46. It is desirable that the peripheral zone 42 be quite shallow in radial dimension. It is usually preferable that the clarifying zone 44 occupy at least about one-half the radial distance from the shaft to the peripheral wall 41 but ranges of relative sizes of the several zones will be later mentioned.

The clarifying zone 44 is divided into a plurality of side-by-side circular zones 48 between axially spaced discs or baffles 50 extending outward from the shaft throughout the clarifying zone 44. The number of such baffles is not critical and may be substantially increased over the number shown in FIG. 1. Nor is the individual width of the circular spaces critical so long as these spaces are narrow, the width of these spaces usually being between about $\frac{1}{20}$ inch and $\frac{1}{3}$ inch. It is important that circular slippage or relative movement between the liquid and the surfaces of the baffles 50 should be impeded or prevented in substantially all portions of the clarifying zone 44. For this purpose the invention employs one or more caulks or barriers 52 in each circular zone 48, dividing same into one or more sectorial zones 53, see FIG. 4.

In this embodiment of the invention the main separating zone 43 contains a plurality of apertured bands 55 extending around the axis A—A and spaced radially from each other. The edges of these bands on opposite sides of the radial midplane of the rotor are suitably secured to the side member 38 and to a side plate 56 spaced from the side member 39 to define an effluent passage 57 for a purpose to be described. The outermost band is shown

as terminating short of the side walls 38, being joined to the peripheral wall 40 by a radial member 58 which may be attached to or integral with the band or with the peripheral wall, the latter being suggested in FIG. 7. The walls 38 and 58 cooperate in providing an annular equalizing space 60 for a purpose to be described.

By way of illustrating an example of an arrangement which will be found to give satisfactory results, this embodiment of the invention is shown as including seven concentric bands designated, for purposes of description, as bands 55_1 to 55_7, counting from the outside. In the illustrated arrangement the outer two bands 55_1 and 55_2 are shown as perforated throughout their peripheries by small holes or apertures 62_1 and 62_2 exemplified as about 3/16 inch in diameter and spaced about 1 inch apart in three circular rows. Some of the apertures of these two bands will thus be in radial alignment while others will be out of such alignment. The innermost band 55_7 is illustrated as likewise being perforated throughout, the apertures being designated as 62_7. Bands 55_3 to 55_6 have spaced groups or clusters of apertures 62_3 to 62_6 staggered with respect to each other and thus out of radial alignment. Each band may have the same number of groups or clusters of such apertures equally spaced around its periphery. For example, each of these bands may include six groups or clusters each composed of apertures about 3/16 inch spaced circumferentially about 1 inch from each other in three rows, see FIG. 3 and FIG. 4 which approximates the staggered relationship that results.

Two of the bands of the group, preferably the two outermost bands 55_1 and 55_2 are spaced radially from each other to define a delivery space 65. As shown, the right-hand end thereof is closed but the left-hand end, on the opposite side of the radial midplane of the rotor, is open to the equalizing space 60. The mixture to be separated is continuously delivered to this equalizing space through flow passages 66 in the side walls 38 communicating inwardly with a passage means 67 of the shaft 33 and thence with a manifold 68 to which the mixture is supplied from the valve 30.

The equalizing space 60 serves the important function of manifolding the streams from the flow passages 66 and distributing the mixture uniformly to the open end of the delivery space 65 to flow therealong in a direction generally parallel to the shaft. During this flow the centrifugal force throws the foots or other separable material outwardly to be removed progressively through the apertures 62_1 of the outermost band 55_1 to collect in the peripheral zone 42 to the right of the wall 58. The partially purified oil likewise progressively leaves the delivery space 65 through the apertures 62_2 of the inner band 55_2 of the pair and then flows progressively through the interband spaces of the main separating zone 43 with some to-and-fro circumferential movement due to the staggered positions of the groups of openings in the bands 55_3 to 55_6. Centrifugal purification continues during this flow and the partially purified oil then discharges through the apertures 62_7 of the band 55_7 for equal distribution into the sectorial zones 53. Therein the streams move radially inward without circular slippage and with progressively increasing inward velocity to an effluent or oil-withdrawal position from which the clarified oil moves through shaft passages 69 and 70 to a manifold 71 from which the oil flows through a pipe 72 through a valve 73. The oil is further purified during such movement through the clarifying zone 44.

The foots or other separated material collecting in the peripheral zone 42 move rightward therein to a discharge position. Particularly when heavy foots are present in this peripheral zone it is desirable to employ a plurality of fins 74 (FIG. 4) extending substantially parallel to the shaft axis to drive the foots at shaft speed and facilitate uniform discharge thereof. These fins 74 are preferably attached to the outermost band 55_1 and extend substantially perpendicularly to the peripheral wall 41. The fins can sometimes be eliminated when processing those mixtures which produce a layer in the peripheral zone that is quite liquid.

An important feature of the invention is the use of an annular weir 75 attached to and protruding inwardly from the peripheral wall 41 at a position on the opposite side of the radial midplane of the rotor from the equalizing space 60. This weir has an inwardly facing crest 76 determining the inner boundary of the body of foots or other separated material and over which this material flows to an annular withdrawal passage 77 between the weir and an annular spill-over member 78 shown as an extension of the side plate 56. This spill-over member has an outwardly facing spill-over lip 79 rightwardly beyond the weir and of a diameter larger than the inwardly facing crest 76. A weir-controlled stream of the separated material thus flows through the withdrawal passage 77 over the spill-over lip 79 to the effluent passage 57, moving inwardly therein to a passage means 80 of the shaft and thence to a manifold 81 to discharge through a pipe 82 equipped with a valve 83.

The height of the weir 75, measured radially, is exaggerated in FIG. 1 for the purpose of clarity. Particularly when separating viscous or heavy foots or soapstock which tend to collect in the peripheral zone 42 as a semi-solid mass, best results will be obtained if the height of the weir is such as to maintain only a very thin layer of material in the peripheral zone, preferably a layer of about 3/16–1/3 inch in radial dimension. This compares with much thicker layers of foots or soapstock collecting in previously used vertical-axis centrifugal machines in which the thickness would be in the neighborhood of at least .5–1 inch in a machine having a capacity of two tank cars per day.

Another factor of importance in this connection is the large diameter of the peripheral wall 41. The resulting increased area not only spreads the foots in a thinner layer but makes it possible to melt and liquefy the entire thin layer by supplying steam to the space around the peripheral member 40 by a pipe 85. By use of the invention it is possible to melt and liquefy the entire thin layer rather than merely to soften an outermost lamina thereof to facilitate slippage, as has been previously proposed in vertical-axis machines. The ability to liquefy semi-solid materials of low heat conductivity and discharge them over the weir 75 in uniformly liquid form, often at an effluent temperature above that of the effluent oil, gives rise to a stability of operation not possible if the outer lamina alone was softened. This is because the unsoftened laminae in such a differentially heated layer tends to slip and discharge nonuniformly over the spill-over lip 79 and create surging which upsets the steady equilibrium conditions required to insure the cleanest separation of the oil and foots in a centrifugal machine of the present type.

Even in the separation of liquid soapstocks or liquid materials which require no heating the weir 75 has been found to stabilize the overall operation of the machine and to prevent surging, priming or "break-over" that has occurred in machines of this type not equipped with the weir. In earlier machines not so equipped it has been often necessary to control the influent and effluent valves by careful manipulation to maintain a low difference in pressure therebetween to thereby prevent break-over, evidenced by discharge of oil through the heavy effluent valve 83 or foots through the light effluent valve 73. When the same machines are equipped with this weir this critical condition is alleviated and the machine operates continuously under equilibrium conditions and without constant attention even at pressure differentials as high as 10 to 15 p.s.i.

In many instances it is desirable to introduce a washing medium into the rotor space during the aforesaid centrifugal separation action. In this connection water or other wash liquid can be forced into the separator by

a pump 87 under the control of a valve 88 to a manifold space 89 and thence through a passage means 90 of the shaft to flow passages 92 shown as being in the side plate 56. Several such passages are preferably used, each communicating with one end of a perforated pipe 94 having its other end closed. Such perforated pipes preferably extend parallel to the axis A—A in the interband space at the junction of the clarifying zone 44 and the counterflow zone 46. The water or other wash liquid usually discharges sidewardly therefrom preferably in a trailing direction with the holes 95 angled toward the shaft about 45° from the radius, see FIG. 7. As an example, 12 perforated pipes 94 each with eleven holes 95 of a diameter of about 3/32" will usually be satisfactory. The water or wash medium thus discharged mixes adequately with the partially purified oil in the corresponding interband space. This intermixing is continued as the wash medium flows outward through the counterflow zone 46 through the apertures of the several bands and in a direction opposite to the inwardly flowing oil, this oil flowing inwardly because of the pressure induced by the pumps 17 and 18.

The use of such a wash medium gives two important results in the processing of certain mixtures. In the first place it tends to dilute the foots or other separated material by raining outwardly through the delivery space and flowing concurrently with the foots a short distance to collect in the peripheral zone 42. The collected foots are thus diluted by the wash medium and assume a more liquid state from which they can more readily and uniformly discharge from the machine. In some instances such dilution is the primary objective of adding a small amount of water or other wash medium. In the second place, however, it is often possible to use a small amount of water or other wash medium to wash the oil during the centrifugal operation and thus avoid the necessity of washing in separate equipment, with many advantages. In this latter connection washing in separate equipment is not only costly but often produces a hydrolyzation which is avoided by the internal washing in the same rotor space as induces the separation. Furthermore, it has been found that substantially less water is required for such internal washing as compared with washing as a separate step. This is important not only in saving water but also in simplifying the disposal problem which has plagued many refineries which must dispose of the wash water in ways other than discharge into sewers, rivers or lakes.

The embodiment of FIG. 5 is generally similar to that of FIG. 1 except for the mixture inlet means and the water inlet means which are reversed in general position and of modified construction. The water or other wash medium here enters the manifold 68 through a valve 88 and flows outward in flow passages 66' in the side member 38 to pipes 94' closed at their right-hand ends and providing openings 95' oriented as previously described. The incoming mixture here flows from the valve 30 to the previously mentioned manifold 89 and through the passage means 90 to flow passages 92'. These passages here extend outwardly to a position opposite the delivery space 65 where they open respectively on pipes 98 which are imperforate except for slots or openings 99 near the far ends thereof which openings communicate primarily with the equalizing space 60. The discharged mixture forms an annular mass in the equalizing space open to the left-hand end of the delivery space 65 at all positions not occupied by the pipes 98. The arrangement of apertures in the bands of FIG. 5 may be similar to that described with reference to FIG. 1 and the flow paths throughout the rotor will be similar to those previously described, taking into account the reversal in the sides at which the mixture and the wash medium enter the machine.

The pipes 95, 95' and 98 may be of an external diameter equal to or slightly less than the width of the corresponding interband spaces. They thus act as barriers for these interband spaces and prevent or impede any circular slippage of the liquids therein relative to the surfaces of the bands.

In the embodiment of FIG. 6 the mixture inlet arrangement is similar to that shown in FIG. 5, as is also the manner of removing the separated foots or heavy material. The radial member 58' is here attached to the peripheral member 40 and supports the left-end of the outermost band 55_1. The purified oil flows through shaft passages 69' and 70' to a manifold 71' in somewhat different position but still feeding the effluent pipe 72 and the valve 73 previously described.

In FIG. 6 the wash medium enters the valve 88 and moves through a manifold 89', flowing along a shaft passage means 101 through radial portions 102 which respectively traverse the passage means 70' and threadedly receive the inner ends of radial pipes 103 which may act as the caulks or barriers of the corresponding circular zone 48. The outer ends of these pipes are open to the innermost interband space 105 into which the wash medium is here discharged to spread axially or laterally and flow outwardly through the staggered groups of apertures in the inner series of bands to counterflow the inflowing partially purified oil in a manner previously described. Here as in the other embodiments the wash medium rains outwardly through the mixture advancing at right angles along the delivery space 65.

FIG. 6 illustrates also one or more pipes 104 communicating with radial passages 105 to conduct a foots-diluting medium directly to the peripheral zone 42 on which the outer ends of these pipes 104 open. This acts directly to dilute the separated material and may be used to advantage where this action is desired, as when separating extremely heavy soapstocks and when no counterflow wash medium is used. This feature can also be employed in any of the other embodiments of the invention if desired. The diluting medium may be water or a portion of the wash medium received from the passage means 101, particularly if the pipes 103 are blocked off or not used. As shown, however the radial passages 105 are fed from a passage means 106 opening on a manifold 107 to which the diluting medium is supplied by a pump 108 under the control of a valve 109. In FIG. 6, therefore, the liquid may be supplied either to the counterflow zone or to the peripheral zone depending upon which pump 87 or 108 is operating. It is even possible simultaneously to introduce the same or different media at the two radial positions by operating both pumps.

In the embodiment of FIG. 7 the band arrangement is generally similar to that previously described except that the band 55_2 is not openly apertured but provides interspaced series of holes 110 and 111 throughout its periphery. The holes 110 respectively register with outcomers 112 which traverse the interband delivery space 65 and extend outward through the outermost band 55_1 to terminate in the peripheral zone 42 near the peripheral wall 41. These outcomers may be short sections of tubing attached to the bands 55_2 with their outer open ends cut at a slight angle to face away from the direction of rotation. The outcomers 112 conduct the outwardly moving wash medium, typically soapy water, through the delivery space 65 without mingling with the mixture which is therein undergoing its initial separation as previously described.

In like manner, incomers 113 register with the holes 111 and form the exclusive path by which the partially purified oil separating in the delivery space 65 is forced inwardly into the next inward interband space by the pressure of the incoming mixture. These incomers 113 may likewise be short sections of tubing connected to the band 55_2 with their open ends terminating close to but spaced from the band 55_3 and cut at a slight angle to face away from the direction of rotation. They traverse any shallow layer of the heavier wash medium building up immediately inside the band 55_2 preparatory to discharge through the outcomers 112. Such an arrange-

ment of incomers and outcomers may be employed in any of the other embodiments of the invention and will often be found to produce superior results.

FIGS. 8–14 illustrate alternative ways of obtaining a to-and-fro motion in the counterflow zone by disposing outwardly extending zig-zag elements therein. They illustrate also alternative delivery means for the mixture and suggest a dual addition of wash media.

In the embodiment of FIGS. 8 and 9 the structure is generally similar to that of FIG. 1 with the following exceptions. The fins **74'** here extend inward from the peripheral wall **41** through the peripheral zone and into the main separating zone, being preferably increased in number as compared with FIG. 1. These fins are of sufficient radial dimension to permit the main separation of the foots to take place therebetween but this dimension need not be large as fins of a radial depth of from a major fraction of an inch to about 1.5 inches will suffice, fins of a radial depth of about one inch being preferred. The inner portions of the interfin spaces here compositely form the delivery space and the mixture flows from the equalizing space **60'** sidewardly through one or more orifices **120** into such interfin delivery space in such manner as to distribute the mixture equally to the interfin spaces at discharge positions inwardly of the thin layer of foots collecting in the peripheral zone. FIGS. 8 and 9 show a single annular orifice **120** between an inner lip **121** of the radial member **58'** and a smaller-diameter outer lip **122** of the side member **38**, see FIG. 9, but a plurality of orifices grouped to respectively discharge into the interfin spaces at said discharge positions can be used. In the embodiment of FIGS. 8 and 9 the centrifugal action moves the heavier foots outwardly to the peripheral zone as the mixture flows along the interfin spaces substantially parallel to the rotational axis.

The initially separated oil moves inward through zig-zag passages **125** between zig-zag members **126** to counterflow the wash medium delivered by the aforesaid pipes **94** through their orifices **95**. In this embodiment the zig-zag elements **126** are extensions of the discs or baffles **50** that are rippled throughout the counterflow zone to form alternating crests and troughs that extend circularly around the rotational axis. Each disc or baffle **50** may be made from a single circular sheet of metal stamped in its outer portion to form the undulating or zig-zag elements **126**. When assembled congruently such elements provide zig-zag passages therebetween of substantially uniform width measured parallel to the rotational axis. By distributing the wash medium to discharge adjacent the inner portion of each zig-zag space **125** and to break up into separate drops or masses a very desirable washing of the oil is obtained as such masses counterflow the oil, the turbulence created by the zig-zag flow paths serving to bring the wash medium into contact with all portions of the oil without creating emulsion problems.

The caulks or barriers **52'** in this embodiment traverse the interdisc circular zones as in FIG. 1 to drive the oil at shaft speed and prevent circular slippage of the oil relative to the discs or baffles **50**. While not always needed in the zig-zag passages **125** for this purpose it is usually desirable to shape the outer portions of the barriers **52'** as zig-zag portions **128** acting as separators for the zig-zag elements **126** in the counterflow zone. In this instance the zig-zag shape of the portions **128** will conform to that of the elements **126** and such zig-zag portions will have a combined spacing and driving function.

In FIGS. 10 and 11 the zig-zag elements **126** are similar to those in FIGS. 8 and 9 but the wash medium is introduced through pipes **103'** similar to the pipes **103** of FIG. 6 but equipped with cross pipes **130** which extend through holes **131** (FIG. 11) in the discs or baffles **50**. Each cross pipe **130** has orifices opening respectively on the interdisc spaces traversed thereby, these orifices preferably facing inwardly so that the wash medium is broken into droplets as it flows outwardly around the cross pipe into the zig-zag passages **125**. The mixture is discharged from the open outer ends of pipes **135** positioned in a space **136** beween the side member **38** and a side plate **137** which here bounds the left side of the clarifying and counterflow zones. The equalizing space **60''** is here the zone at the outer end of the space **136**, the mixture flowing sidewardly past a lip **139** of the side plate **137** and thence along the spaces between the fins **74''** similar in form and function to the fins **74'** of FIGS. 8 and 9 but preferably present in larger number.

In FIG. 12 the mixture discharges into the interfin spaces as in FIGS. 8 and 9 but the zig-zag elements **126'** terminate short of the peripheries of the respective discs or baffles **50** to leave nonrippled peripheral portions **142** outwardly beyond the rippled or zig-zag portion, the portions **142** lying substantially in the planes of the inner portions of the baffles. In effect, the zig-zag portion in FIG. 12 is shifted inwardly and the wash medium or a portion thereof can discharge directly into the zig-zag passages **125'**, an arrangement that can also be used in the other illustrated embodiments employing zig-zag passages. As shown the pipes **94** traverse the zig-zag elements **126'** and the openings **95** discharge inwardly into the respective zig-zag spaces **125'**. The wash medium is pumped by the pump **87** through the valve **88** and delivered through a passage means **145** to the flow passages **92** to the pipes **94**.

FIG. 12 shows another feature that can be employed in any of the embodiments of the invention, namely an arrangement for introducing a second wash medium or a second portion of the previously mentioned wash medium to the interior of the rotor at a different radial position. As shown, a pump **150** pressures such second wash medium and forces it through a control valve **151** to a manifold space **152** whence it flows through a shaft passage means **153** and through flow passages **155** to pipes **156** traversing the baffles **50** and having inward facing openings **157** discharging respectively into the interdisc circular zones, preferably into the aforesaid sectorial zones formed therein by the caulks or barriers **52'**. The pipes **156** are at a radius less than the pipes **94** and the wash medium discharges into the oil already washed by the first wash medium. This second wash by a second wash medium or a portion of the main wash medium is often very effective because it is fresh or uncontaminated and reaches the already purified or washed oil. The residual contaminants or foots of such oil are readily removed by the second wash. The relative volumes of wash media supplied at the different radial positions can be controlled by the valves **88** and **151** and the volumetric ratios can vary widely with satisfactory results. This is true in part because the wash medium introduced at the position of smaller radius moves outward through the passages disposed outwardly of such position and through the previously mentioned counterflow zone, exerting a washing action throughout the enlarged counterflow zone made possible by the second introduction. In some instances the introduction at the position of smaller radius can be used to the exclusion of wash medium flowing through the valve **88**. Use of two separate pumps is desirable, as compared with supplying portions of the same wash medium to the pipes **94** and **156** from the same manifold, because the flow ratios can be held constant or can be varied while the separator is in operation.

FIGS. 13 and 14 show alternative zig-zag passages **160** between zig-zag elements **161** having crests and troughs which extend substantially parallel to the rotational axis. Such elements can be substituted for and mounted similarly to some of the aforesaid bands **55**. As shown in FIG. 13 the outermost two bands 55_1 and 55_2 are used to form the delivery space **65** therebetween as previously described. The innermost band 55_7 is also retained but

the intervening bands are replaced by the spaced zig-zag elements 161 each having an outer end adjacent or confined against outward movement by the band 55_2 and an inner end adjacent the band 55_7. In FIG. 14 only the outermost band 55_1 is used and this primarily to anchor the outer ends of the zig-zag elements 161. If otherwise anchored this band can be dispensed with. As shown the outer ends of the zig-zag elements terminate adjacent the band 55_1 and the inner ends adjacent the outer peripheries of the discs or baffles 50. In FIG. 14 the mixture enters the spaces between fins 174 by the mixture delivery system of FIG. 8 or FIG. 10. The wash medium can be introduced through the aforesaid pipes 94, now positioned iin the zig-zag passages as suggested in FIG. 13, or through perforated pipes 194 extending through holes 195 through the discs or barriers 50 near the peripheries thereof, as suggested iin FIG. 14.

It is a feature of the invention that the processes performed in the machines can be effected in the presence of high superatmospheric pressures throughout the internal flow pattern. Thus influent pressures of 50–150 p.s.i. or more can be used with effluent pressures, created by the throttling action of the valves 73 and 83, of 10–150 p.s.i. to keep all of the materials in the liquid phase and in a condition facilitating separation. This is of particular importance in refining oils with volatile alkalis such as ammonia or with low excesses of soda ash with or without small amounts of caustic where CO_2 may tend to be released. Internal pressures of about 75–150 p.s.i. are desirable in such instances. High internal pressures also aid in maintaining the uniform effluent flows of which the invention is capable and which are to be distinguished from the surging or uneven flows that have been encountered in some older processes.

The high internal pressures discussed above are minimum pressures and are over and above the centrifugally induced pressures. In machines of a rotor diameter of about 30–48″ driven at speeds of about 800 to 3000 r.p.m. values of g. will be about 1100 to 3500. It is desirable that the invention employ rotors of a diameter of at least about 20 inches, preferably more, as such diameters are usually required to give sufficient radial depth to permit establishing the discrete annular zones, including the anular counterflow zone which is preferably positioned in the outer half of the radius.

Dimensional relationships are to various extents critical in the practice of the invention. Thus it is desirable to employ equipment of sufficiently large diameter to provide adequate room for the distinct flow patterns of the type outlined and to establish the distinct concentric zones wherein rather distinct bodies or strata of the materials are present undergoing treatment. Generally stated, rotors of a diameter less than about 20 inches will not be found satisfactory and it is preferred to use diameters of 24–48 inches although rotors up to 60 inches in diameter are quite feasible. Bowls of conventional vertical centrifuges do not exceed about 15″ in diameter.

As mentioned above, the radial depth of the peripheral zone 42, determined largely by the height of the weir 75, is about $\frac{3}{16}$–$\frac{1}{3}$ inch. In terms of radial depth, this peripheral zone is typically about 1–3% of the rotor radius. The radial depth of the transition zone 45 is not unduly critical but is usually in the neighborhood of about 1–6″ typically in the neighborhood of 4–20% of the rotor radius. The radial depth of the counterflow zone 46 may vary from a major part of the rotor radius to a small but significant fraction thereof, being most commonly in the range of about 5–70% thereof and usually about 10 to 25% in the type of equipment exemplified. It is preferred that the radial depth of the annular clarification zone 44 be a major fraction of the rotor radius, as previously mentioned and as herein exemplified, but in other instances this clarifying zone may have a radial depth of about 10–70% of the rotor radius. It should be understood, however, that these ranges are merely exemplary of best practice and that under some circumstances the invention can be successfully practiced with deviations from such ranges, which are given as guides in which the best operating conditions will be usually found.

The problem of separating foots from glyceride oils presents problems that are entirely different from the centrifugal separation of immiscible liquids differing widely in specific gravity, e.g. mixtures of kerosene and aqueous material which separate almost instantaneously. The problems are particularly severe as concerns attempts to employ countercurrent washing in a portion of the same rotor that is used for the centrifugal separation. In removing foots from glyceride oils one is concerned with liquids differing only slightly in specific gravity, e.g. oil at about .92 and water at 1.00. To secure effective counterflow washing, the water must be mixed or remixed with the oil to become adequately dispersed throughout the volume thereof. Most importantly, this must be done without forming a permanent emulsion between the oil and the water. In addition, the oil-water mixture must be maintained or reformed so that it exists for a finite and significant period of time if an effective washing action is to be obtained. Use of the process steps and equipment herein described has been found to be very satisfactory in these regards.

One factor in the satisfactory operation of the present invention is that the mixture is introduced under pressure at a section relatively near the outer periphery of the rotor space and near the inner boundary of the peripheral zone in which the foots collect. The centrifugal force is greater toward the outer portion of the rotor space and the mixture is first exposed to nearly the maximum separating force, as compared with introducing the mixture at a position closer to the axis of rotation in which it would be required to move outwardly from a zone of smaller radius to a zone of larger radius before the maximum centrifugal action is encountered. Another feature of the invention is that the mixture is introduced into a delivery space to flow therealong in a generally axial direction during the initial separation.

The use of the caulks or barriers 52 in the clarifying zone 44 and the fins 74 in the peripheral zone have substantial significance in the success of the invention in preventing circular slippage of the liquids in the corresponding spaces. The use of the weir 75 is also important in stabilizing the operation of the equipment, as previously explained.

In the following examples of the operation of the invention the equipment employed included a rotor having an internal diameter of about 34″. Except as later indicated, the rotor included discs or baffles 50 occupying about 69% of the radial dimension between the shaft and the peripheral wall 41 and a series of bands occupying about 31% of such radial dimension the volumes of the counterflow and clarifying zones being approximately equal. Unless otherwise noted the equipment included a weir 75 of a radial height of about ¼ inch, the distance between the spill-over edge 79 and the peripheral wall 41 being about $\frac{3}{32}$″.

A crude cottonseed oil high in gums containing 2.0% free fatty acids and having cup loss of 9.0% was mixed with 20° Bé. caustic solution and delivered at a temperature of about 165° F. at a radius slightly less than 16 inches to the interband delivery space of a machine rotating at 2200 r.p.m. and equipped with bands radially spaced about .7″ having aperture patterns as in FIG. 3. The thick soapstock discharged continuously as thick, semi-solid sausages containing about 23.6% free oil, dry basis which is satisfactory as concerns a crude oil of this high gum content. The oil effluent was clear and contained somewhat less than 300 p.p.m. of soap. When about 5% of water was introduced at a radius of about

12⅞ inches the oil remained clear and the soap was reduced to about 60 p.p.m. as determined by the flame photometer method. The soapstock was fluid. The amount of water was very considerably less than would have been required by a separate washing step that would have been needed if the 5% internal wash had not been used.

A crude soya oil was mixed with a 10% ammonia solution in about 0.2 excess and the mixture was delivered to the outermost interband space at a radius slightly less than 16 inches at a temperature of about 178° F. and a pressure of about 64 p.s.i. The foots, largely gums, discharged in a stiff condition. The oil was clear and was throttled to a pressure of about 62.5 p.s.i. When about 4% of water was added to the innermost interband space at a radius of about 13 inches the gums softened and discharged smoothly. In another run, such mixture was discharged into the second-from-outer interband space at a radius of about 15$\frac{5}{32}$ inches and separated without addition of water. The operation was not as good as it was more difficult to insure a smooth and steady discharge of the foots. The rotor in this instance did not have the weir **75** therein and was equipped with two additional bands, the radial spacing of the bands being less toward the axis. Better results were later obtained by using bands spaced substantially equally.

The oil from the runs in the foregoing paragraph was combined and re-refined by mixing about 1.9% of 20° Bé. caustic before being delivered to the outermost interband space of a rotor equipped with the weir **75** and with extra bands spaced radially a lesser distance toward the axis than into the outer band section. The mixture was supplied at a pressure of about 50–57 p.s.i. and a temperature of about 164–172° F. and about 15% of water was supplied to the innermost interband space at a radius of about 13 inches. The oil discharged at about 45–54 p.s.i. at a temperature of about 122–148° F. being clear and containing only about .25% water and about 120 p.p.m. of soap after equilibrium was established. There was no emulsification and the heavy liquid discharged clean and uniformly without emulsified oil. The operation was stable even when the valve **83** was completely open and it was observed that no constant attention to the setting of this valve was required to maintain the operation smooth. Even better results are obtainable in this process with bands spaced uniformly, e.g., about .6–.7 inch, throughout the zone **43**.

In another instance, a crude coconut oil containing 2.7% FFA was preheated to about 160° F. and mixed with 12° Bé. caustic soda solution, 0.1 excess, and delivered at a temperature of about 160° F. at a radius slightly less than 16 inches to the interband delivery space of a machine rotating at 2200 r.p.m. equipped with bands radially spaced about 0.7 inch having aperture patterns substantially as in FIG. 3. The band area, viewed in a plane corresponding to that of FIG. 4, was about 427 sq. in., the disc area being about 468 sq. in. The soapstock discharged as a clear dark liquid containing 64.4% moisture and with extremely low free oil content of about .1%. The oil effluent was clear, containing .28% moisture, .02% FFA and 260 p.p.m. of soap.

A crude palm kernel oil containing 6.1% FFA was preheated to 160° F. and mixed with 10° Bé. caustic soda solution, 0.1 excess, and delivered at a temperature of 185° F. at a radius of slightly less than 15.5 inches to the interband delivery space of a machine rotating at 2100 r.p.m. and equipped with bands radially spaced as in FIG. 3. Without the presence of any weir or any added water, this oil produced a liquid soap-stock containing 1.9% free oil and containing 62.6% moisture. The oil effluent was clear, containing .06% FFA, .36% moisture and 300 p.p.m. soap.

As another example, a non-degummed crude soya oil containing 10% free fatty acids and .079% phosphorus was preheated to about 120° F. and mixed with 2.7% of

20° Bé. caustic soda solution. After passage through a coil the mixture was delivered at a temperature of about 150° F. at a radius slightly less than 16 inches to the interband delivery space of a machine rotating at 2100 r.p.m. and equipped with bands radially spaced about 0.7 inch having aperture patterns substantially as in FIG. 3. The soapstock discharged as a deep-yellow viscous flowing mass containing 10.9% free oil, dry basis, which is low, 37.0% moisture and 46.1% TFA (total fatty acids). The oil effluent was clear, containing 0.03% FFA and 210 p.p.m. soap. When about 12% water was added to the innermost interband space at a radius of about 13 inches, the soapstock became liquid. The oil continued to discharge clear and the soap content was reduced to 60 p.p.m. The liquid soapstock contained 2.5% free oil, dry basis, a very low value, and 62.7% moisture.

Various changes and modifications can be made without departing from the spirit of the invention as defined in the appended claims.

I claim as my invention:

1. A centrifugal separator for the processing of mixtures of glyceride oils and the like containing centrifugally separable material, said separator including: a rotor and means for journalling said rotor to turn about a horizontal axis, the outermost interior of said rotor providing a peripheral zone bounded outwardly by an internal cylindrical peripheral wall of said rotor extending substantially parallel with said axis, there being a main annular separating zone radially inward of said peripheral zone; a plurality of cylindrical apertured bands extending around said axis in said main annular separating zone and spaced radially from each other, the annular interband space between the two outermost of said bands being a delivery space open at one end thereof; walls forming an annular equalizing space on one side of the radial midplane of said rotor having its sole outlet to said one end of said delivery space, said equalizing space and said peripheral zone being spaced from each other in the direction of said axis, and including a wall therebetween separating the same, said separating wall extending between the outermost of said two bands and said peripheral wall of said rotor; means for delivering the mixture under pressure to said equalizing space for equal distribution to said one end of said delivery space, said mixture flowing along said delivery space in the direction of said axis, the separable material moving outward by centrifugal force through the apertures of the outer of said two bands to collect in said peripheral zone, the oil moving inward from the apertures of the inner of said two bands to an oil withdrawal position near said axis; means for continuously removing said oil from said oil withdrawal position to a position exterior of said rotor; and means for removing collected material from said peripheral zone.

2. A centrifugal separator for the processing of mixtures of glyceride oils and the like containing centrifugally separable material, said centrifugal separator including: a rotor and means for journalling same to turn about a horizontal axis, the interior of said rotor providing an outermost peripheral zone bounded outwardly by an internal cylindrical peripheral wall, a main annular separating zone radially inward of said peripheral zone, and a clarifying zone immediately inward of said main separating zone; a plurality of baffles extending outwardly of said axis in said clarifying zone, said baffles being spaced from each other in the direction of said axis to provide narrow circular clarifying spaces therebetween, the outermost peripheries of said baffles and the outermost portions of said circular clarifying spaces being at the junction of said main separating zone and said clarifying zone; a perforated circular distributor band at said junction surrounding said peripheries of said baffles and providing perforations opening directly on said outermost portions of said circular clarifying spaces; means for delivering the mixture to be separated to the interior of said rotor at a position near the outer portion of said main separating

zone, the dispersed material of the mixture moving outward by centrifugal force to said peripheral zone and collecting therein as a body of separated material leaving a partially purified oil; walls in said main separating zone inwardly of said mixture delivery position and outwardly of said perforated distributor band defining a tortuous passage conducting said partially purified oil to said perforations of said band for distribution into said outermost portions of said circular clarifying spaces; at least one outwardly extending barrier blocking each circular space against circular movement of its contained oil relative to the surfaces of the baffles bounding such circular space; an annular weir protruding inwardly of said cylindrical peripheral wall at one side of the radial midplane of said rotor, said weir having an inwardly facing crest determining the inner boundary of said body of separated material and over which such separated material flows, said crest defining the outlet of said peripheral zone; means for conducting the material flowing over said crest toward said shaft and from said rotor during continued rotation of said rotor; means for withdrawing clarified oil from said clarifying zones at positions relatively close to said axis during continued rotation of said rotor; and a multi-orifice discharge means opening on said main separating zone adjacent said juncture of said clarifying zone and said main separating zone but outwardly of said perforated circular distributor band, and including means for delivering another liquid to said multi-orifice discharge means.

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