

Dec. 19, 1961

J. A. SAMANIEGO ET AL

3,013,866

FLUID MIXER WITH ROTATING BAFFLES

Filed July 29, 1959

2 Sheets-Sheet 1

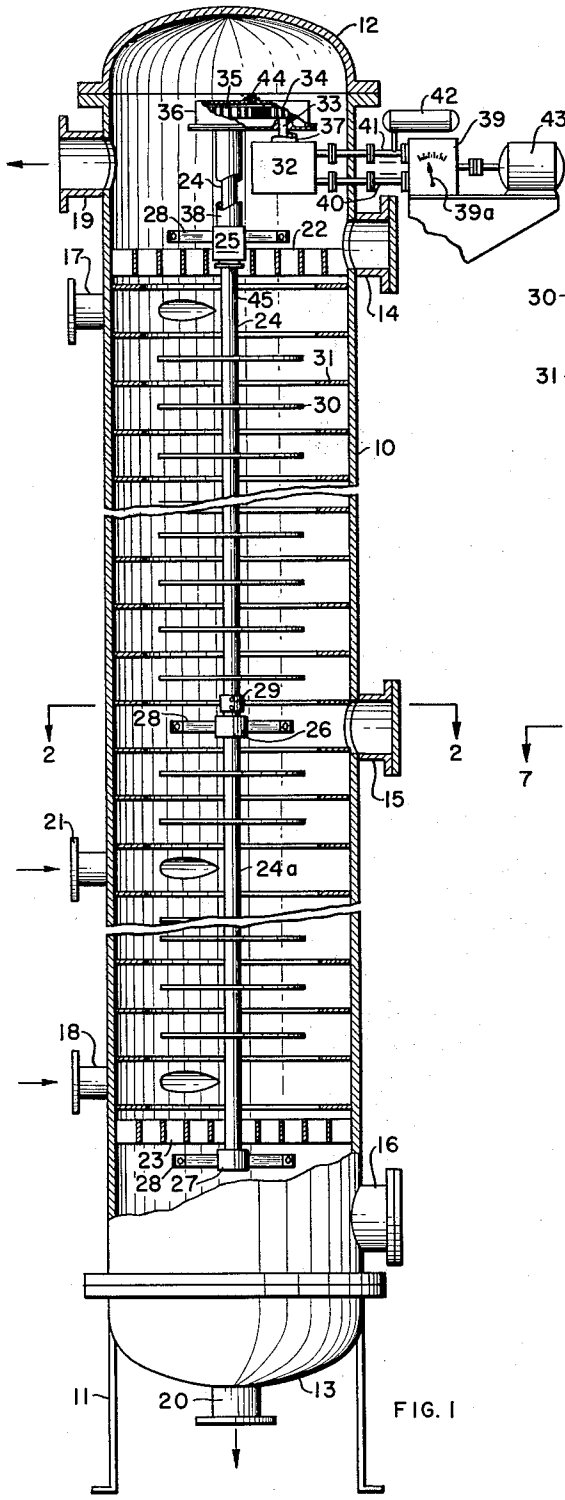
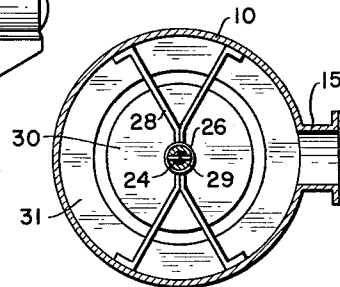


FIG. 2

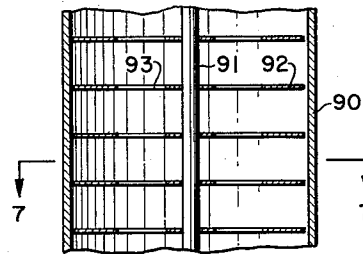


FIG. 6

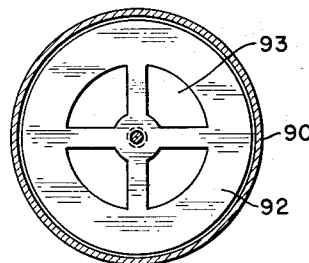


FIG. 7

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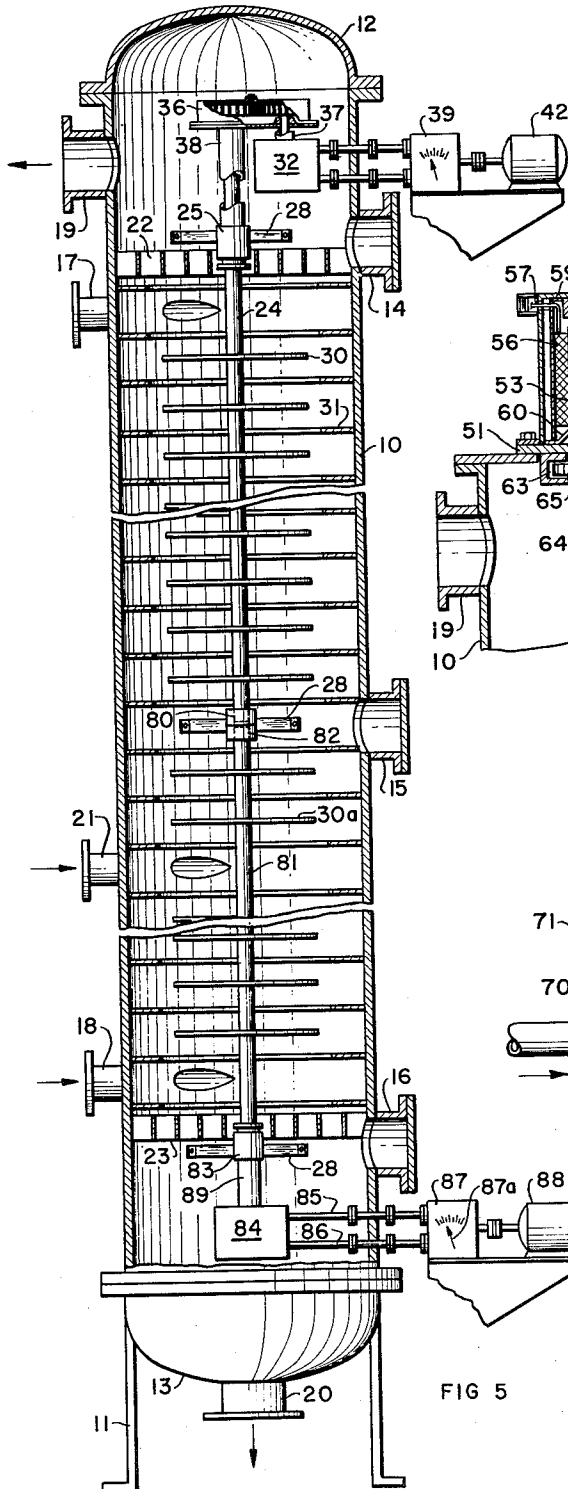


FIG 5

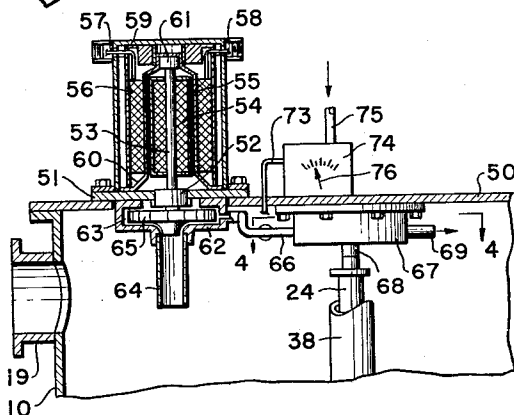


FIG. 3

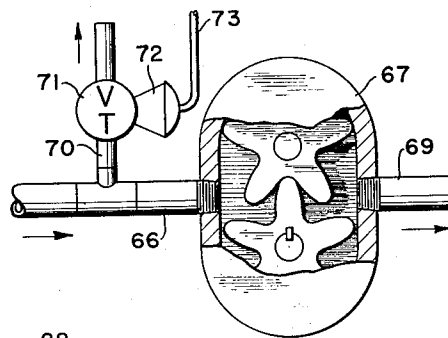


FIG. 4

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FLUID MIXER WITH ROTATING BAFFLES

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8 Claims. (Cl. 23-270.5)

This invention relates to internally baffled, multistage fluid mixing apparatus suitable, for example, as a reactor or as contacting apparatus to effect intimate contact between two or more at least partially immiscible fluid phases. When used as a reactor a single fluid phase may be passed through the several stages; the device is then a homogeneous reactor. However, several phases may be flowed through the reactor concurrently. When used as a contacting device, e.g. to effect chemical reactions or for solvent extraction, two phases are present, and usually flow countercurrently through the several stages. All applications are herein generically referred to as fluid mixing apparatus.

Mixing apparatus of this type includes an elongated, usually vertical shell which contains a rotor comprising a shaft and carrying fast for rotation therewith a plurality of transverse, generally flat rotor baffles spaced along the shaft and subdividing the shell into compartments or mixing zones which are in serial communication. In a common embodiment the shell further contains a series of transverse stator baffles having aligned openings and mounted at intervals, between the rotor baffles and in axially spaced relation thereto, although such stator baffles may in some instances be omitted. Such apparatus is sometimes known as a rotating disc contactor. The general principles of construction and operation and the vortex patterns created by the baffles when used as a contactor are disclosed in U.S. Patents Nos. 2,601,674, 2,729,544 and 2,729,545.

A considerable amount of power is required to drive the rotor shaft in such mixers and this has heretofore been applied by extending the rotor shaft out of the shell, e.g. through a running seal, and coupling it to an electric motor or other mechanical drive means. Such external drives are objectionable under certain circumstances, as when the mixer is operated under a considerable superatmospheric pressure and sealing of the shaft at its point of emergence from the shell becomes a problem. Such conditions are encountered, for example, when a hydrocarbon oil is extracted with liquid SO_2 at a temperature above 120°F. , at which pressures above 116 lb. per sq. inch occur, or deasphalting of residual oil with propane at temperatures of $200\text{--}300^\circ \text{F.}$, which involves pressures of several hundred lbs. per sq. inch. External drives are also difficult to apply when it is desired to operate different sections of the apparatus at independent speeds; it then becomes necessary to employ two or more rotor shafts which carry rotor baffles within different vertical zones and to provide independent drives for these shafts.

It is known in the fluid treating art to activate rotors by means of one of the fluids being treated, as by discharging it as a jet against an impulse wheel fastened to the rotor shaft. Such arrangements are not, however, practicable for elongated mixers which consume large amounts of power and/or wherein the feed rates of the fluids are subject to variation, and in any case where it is desired to control the rotor speed independently of the fluid feed.

In summary, according to the invention the rotor shaft is driven by a fluid-actuated motor situated within the mixing vessel and coupled to the shaft—either mechanically or through an auxiliary fluid pump and

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motor—and the first mentioned fluid motor is connected to a pump by a high-pressure feed duct and a flow passageway interconnecting the fluid outlet of the motor to the suction intake of the pump, the said pump being driven by a suitable drive means, such as an electric motor situated outside the vessel. The pump may be situated outside the conduit and driven mechanically or situated inside the vessel. When more than one rotor shaft is present it is advantageous to drive at least one of the shafts by such a fluid pump-motor set; when shaft seals become a problem all may be driven by independent pump-motor sets.

The invention will be further described with reference to the accompanying drawing forming a part of this specification and showing several specific embodiments by way of illustration, wherein:

FIGURE 1 is a vertical sectional view through a mixing apparatus according to the invention, parts being broken away;

FIGURE 2 is a transverse sectional view taken on the line 2—2 of FIGURE 1;

FIGURE 3 is a fragmentary vertical sectional view of the upper part of the apparatus, showing a modified construction;

FIGURE 4 is a transverse sectional view taken on the line 4—4 of FIGURE 3, parts being broken away;

FIGURE 5 is a vertical sectional view through a mixing apparatus according to another modified construction, employing two independently driven rotor shafts;

FIGURE 6 is a fragmentary vertical sectional view showing a modified construction of the mixing baffles; and

FIGURE 7 is a transverse sectional view taken on the line 7—7 of FIGURE 6.

Referring to FIGURES 1—2, the apparatus includes a vertical, cylindrical vessel 10, circular in cross section and supported on columns 11. It has top and bottom closures 12, 13, access manways 14, 15 and 16 which, during use, are closed by cover plates. The vessel has upper and lower inlet pipes 17 and 18, respectively, which are preferably tangential as shown and through which the process fluids are admitted, an upper discharge pipe 19 and a lower discharge pipe 20, the last being formed in the bottom closure. The vessel may optionally be provided with additional inlet and/or draw-off pipes, such as the intermediate pipe 21, also preferably disposed tangentially in conformity to the direction of flow therethrough. Current-suppressing baffles, such as grids arranged as egg-crate structures 22 and 23, may be mounted beyond the upper and lower inlets to separate the mixing section from the terminal discharge zones, at least one of which serves as a settling chamber. An axial rotor shaft, which may suitably consist of two sections 24 and 24a when the column is of considerable length, e.g. 40 feet, is mounted by a radial-thrust bearing 25 and radial bearings 26 and 27, secured to the vessel wall by spider brackets 28. The two shafts are coupled at the bearing 26 by a coupling means 29. The shafts carry axially spaced rotor baffles 30, e.g. circular, imperforate discs which subdivide the shell into intercommunicating compartments. A plurality of stator baffles 31 may be provided, and should be provided when imperforate rotor baffles of the type shown as used. The stator baffles are annular plates fixed to the vessel wall and having central, circular openings large enough for passage of the rotor baffles.

The coupled shafts 24 and 24a are driven by a fluid-driven motor 32 which is suitably mounted within the upper part of the vessel and has an output shaft 33. The motor may, for example, be a hydraulic positive displacement motor, which may be constructed as a pump.

Leakage of hydraulic fluid is negligibly small in commercially available motors due to isolation of the fluid from the output shaft and/or provision of running seals at the shaft 33 which are long-lasting because exposed only to hydraulic fluid, such as oil. Further, in many instances the hydraulic fluid used to drive the pump may be the same as one of the process fluids being treated or similar thereto, or even different and a readily separable from the process fluids the leakage is not a problem. The shaft 33 is mechanically coupled to the shaft 24 via spur gears 34 and 35, which are advantageously encased in a housing 36. Tubular casings 37 and 38 surrounding the shaft 33 and the part of the shaft 24 above the bearing 25, respectively, are preferably provided both to shield the process fluids within the upper part of the vessel from the moving parts and so to facilitate settling, and to protect these parts from the fluids being contacted, so as to permit lubrication and prevent corrosion. The motor 32 is powered by a pump 39 which is independent of the means for admitting the process fluids to the inlet pipes 17, 18 and 21 and is situated outside of the vessel. The pump is connected to the motor by a high-pressure duct 40 for feeding a hydraulic fluid to the motor and a lower pressure duct 41 for returning the fluid to the pump. The pump is preferably of the positive, variable displacement type, having a control element represented diagrammatically at 39a for indicating the displacement. This feature is not, however, in every case essential. The pump may be provided with suitable means, including a reservoir 42, for supplying fluid to compensate for loss due to leakage. The pump is driven by any suitable means, such as an electric motor 43, which is preferably (particularly when the pump is not of the variable displacement type) of the type capable of being driven at a variable speed. One example of a variable-displacement pump suitable for this purpose is a tilting-block or wobble-plate pump having a plurality of pistons and cylinders, wherein the piston strokes can be varied by adjusting the inclination of the block.

The encased parts may optionally be lubricated by admitting a lubricant to the housing 36 and casings 37 and 38 through a fill-hole which is normally closed by a plug 44. A running seal, e.g., a packing gland 45, is preferably provided at the bearing 25 to retain the lubricant and minimize entry of the fluids from the vessel into the encased parts. This expedient is desirable when the process fluid is corrosive and/or when isolation between the pump fluid and the process fluids is desired.

Operation of the mixer as a countercurrent contactor is as follows: It is assumed that the heavier process fluid is a liquid and is to form the continuous phase and that the lighter process fluid is to be dispersed therein and is also a liquid. The column is filled through the inlet 17 with the heavier process fluid. The rotor shafts 24 and 24a are rotated in the direction of the tangentially entering fluid by operating the motor 43 to drive the pump 39. This causes hydraulic pump fluid to circulate via the ducts 40 and 41 at a rate controlled by the displacement, as set by the control element 39a, to operate the hydraulic motor 32 and, thereby, the gears 34 and 35. When the vessel is filled, admission of heavier process liquid is continued and the lighter process liquid is additionally admitted via the inlet 18. The latter is dispersed in the heavier liquid as fine drops because of the toroidal vortices set up within each compartment. The greater part of the dispersion is recirculated within each compartment and the balance gravitates upwards and downward into the adjacent compartments in accordance with its settling direction. These flow patterns are further described in the above-cited patents. The contacted lighter liquid eventually settles upwards through the upper calming grid 22 into the settling chamber above it, in which an interface occurs. The settled lighter liquid is discharged continuously via the discharge pipe 19. The heavier liquid descends through the lower calming grid 23 and any entrained lighter liquid settles upwards with-

in the calm, lower settling chamber, from which it settles upward through the said grid. The heavier liquid is discharged continuously through the discharge pipe 20, at a rate to maintain the desired interface level at the top of the column above the grid 22. The control means for regulating this discharge of contacted liquids are described in the aforesaid patents and are, therefore, not further described herein. When it is desired to disperse the heavier process fluid within the lighter process fluid the above-described operations are also followed with the difference that the vessel is filled with the lighter fluid before admitting the heavier fluid.

As is understood in the rotating disc contacting art, it is often necessary to vary the rotor shaft speed, e.g. to control the degree of shear and, thereby, the fineness of the dispersion, or to operate the contactor alternately at high and low speeds to reduce back-mixing. The speed of the rotor shaft can be varied by means of the pump displacement control 39a and/or by changing the speed of the motor 43.

By avoiding running seals or stuffing boxes on the rotor shafts where they would, in known constructions, emerge from the vessel, the apparatus can be operated under considerable superatmospheric pressure and temperature.

The construction described above is satisfactory in most instances; however it can still present a sealing problem at extreme temperature and pressure conditions, e.g., at temperatures above 200 to 300° F. In such instances leakage within the motor 32, at its shaft 33 and at the gland 45 may develop with time and result in loss of lubricant and pump fluid and/or entry of process fluid from the contactor into the pump. Such leakage may be tolerated when the pump fluid is the same as or compatible with the process fluids. When not, e.g., when one of the latter is corrosive, and extreme conditions prevail, it is recommended that the modified construction shown in FIGURES 3 and 4 be used.

Referring to FIGURES 3 and 4, the cylindrical vessel 10 is fitted with a flat top closure 50 carrying a hermetically sealed motor-pump unit (sometimes known as a "canned pump") which includes a base 51 mounted in sealed relation over an opening in the closure 50 and having a central opening within which is mounted a thrust bearing 52 in which is journaled the lower end of the shaft 53 of a squirrel-cage rotor 54. The rotor is hermetically enclosed by a thin-walled, welded, stainless-steel housing 55. The motor stator includes a winding 56 having terminals 57 and 58 and mounted within an outer casing 59 outside of a thin-walled partition can 60 which is likewise of stainless-steel and is hermetically sealed to the base 51. Process fluid from the vessel 10 which may enter the space inside the partition can 60 through the bearing 52 (or otherwise) is thereby prevented from reaching the rotor or stator windings. The can 60 contains a radial bearing 61 in which the upper end of the rotor shaft is journaled. Secured to the bottom of the base is a pump casing 62 providing a pump scroll passage 63 and having a central opening to which a suction tube 64 is fitted, this tube having sufficient length to be immersed in process fluid within the vessel 10. Within the pump casing is an impeller 65, fixed to the rotor shaft 53. This motor-pump unit is shown only diagrammatically, being known per se and commercially available; see Westinghouse Electric Corp. Descriptive Bulletin 57-550 (February 1955), and an article in Chemical Engineering Progress, vol. 50, No. 9 pp. 436-444 (September 1954).

The pump casing has a pressure duct 66 by which fluid is conducted to a hydraulic motor 67 mounted on the closure 50; this motor may be constructed like a positive-displacement pump and has the output shaft 68 thereof coupled to the contactor shaft 24. The latter two shafts may be enclosed in a tubular casing 38 which extends to the motor housing, in the manner described for the previous

embodiment. The motor has a discharge pipe 69 by which fluid is discharged into the vessel 10.

The duct 66 has a bleed branch 70 which bleeds off a part of the liquid into the vessel at a rate controlled by a throttle valve 71. The latter is operated by any suitable valve operator 72, such as a spring-biased bellows, to which control fluid is admitted via a duct 73 which extends out through the closure 50 to a speed controller 74. Control fluid is admitted under pressure to the controller via a duct 75 from a source, not shown, and the controller regulates the pressure in the duct 73 in accordance with the position of the manually settable pointer 76. It is evident that the latter may be controlled remotely.

In operation, the electric motor rotor 54 drives the pump impeller 65 to draw process fluid from within the vessel 10 into the draft tube 64 and pump it via the duct 66 to the fluid motor 67, thereby rotating the shaft 24. To control the speed of the shaft independently of the speed of the rotor 54 and fluid slippage in the impeller pump, the capacity of the pump is designed sufficiently large to drive the rotor shaft 24 at slightly more than the maximum speed required, and the speed of the fluid motor 67 is regulated by bleeding off a part of the high-pressure fluid from the duct 66 through the bleed duct 70 and valve 71. The bleed rate is controlled by the controller 74 which increases the pressure in the duct 73 to move the valve 71 progressively toward closed position and thereby throttle the bleed flow to increase the rotor speed.

As was indicated above, the invention is well suited for driving a plurality of rotor shafts independently of one another, e.g. to produce different mixing conditions in various levels within the column. Such independently driven rotors are useful, for example, when the relative volumes of the phases change markedly between different parts of the vessel, due to transfer of solute and/or to the admission or discharge of process fluid at an intermediate level, as through the pipe 21, it is advantageous to operate different parts of the column at different mixing intensities. The use of rotors of different diameters in the different parts of the vessel and the provision of stators having correspondingly different openings could be resorted to but results in lack of flexibility as treating conditions are altered or different fluids are treated; further, it involves difficulties in the installation of the stator and rotor baffles. These problems can be overcome by driving the rotor baffles in different parts of the vessel at different speeds. Although rotor baffles of the same diameters and identical stator baffles can thereby be used throughout the column, this is not essential, inasmuch as the independent speeds are desirable in any event to achieve flexibility.

Such independently driven shafts are illustrated in FIGURE 5, wherein like reference numbers denote corresponding parts previously described for FIGURES 1 and 2. In this embodiment the shaft 24, situated in the upper part of the vessel, is again supported at the top by a radial-thrust bearing 25; its lower end is, in this instance, journaled in a radial bearing 80. A separate rotor shaft 81, carrying the rotor baffles 30a in the lower section of the vessel, is mounted coaxially beneath but independently of the shaft 24 in a radial bearing 82 and a radial-thrust bearing 83 and is coupled to a fluid-actuated motor 84 which is like the motor 32 except that it is mounted at the shaft axis for direct coupling thereto. It is connected by ducts 85 and 86 to a variable displacement pump 87 which has a displacement controller 87a and is driven by an electric motor 88. The part of the shaft 81 between the motor 84 and bearing 83 is preferably encased in a tubular sheath 89.

Operation is as was described for the first embodiment, with the difference that the rotation speeds of the shafts 24 and 81 can be controlled independently by varying the displacements of the pumps 39 and 87.

Although in the foregoing embodiments the contactor included stator baffles 31 fixed to the vessel at levels mid-

way between the rotor baffles 30, it is evident that the invention is equally applicable to other specific forms of the contactor. For example, it is possible, by a modification of the rotor baffles, to eliminate the stator baffles. This is illustrated in FIGURES 6 and 7, wherein the vertical cylindrical vessel 90 contains an axial rotor shaft 91 (which may be mounted and driven as described for the shaft 24 in any of the previous embodiments). A plurality of rotor baffles 92 are fixed to the shaft at axially spaced levels; the vessel contains no stator baffles between the rotor baffles within the mixing zone. These rotor baffles subdivide the otherwise uninterrupted mixing zone into contacting compartments. Each baffle may be formed as a flat disc which is circular in outline, extends radially to the close proximity of the shell wall to provide only a very narrow annular clearance, and has a plurality of openings 93, to establish communication between adjacent compartments. These openings are advantageously positioned so that over half of the total open area lies within the inner half of the area (i.e. within a circle having a diameter 0.71 of the internal diameter of the vessel). Typically, the total open area (including the annular slit) is between 40 and 60 percent of the cross sectional area of the vessel and narrow slits, with areas less than 5% of said cross sectional area, are preferred. Operation is as was previously described, with the difference that the phases admitted at the upper and lower ends form toroidal vortex patterns within each compartment without the aid of stator baffles.

We claim as our invention:

1. A fluid mixing apparatus comprising: an axially elongated, closed vessel one end of which is higher than the other; a plurality of transverse, axially spaced baffles within said vessel defining therein a series of compartments which are in consecutive communication; a rotatably mounted shaft extending axially through said vessel and carrying at least some of said baffles for rotation therewith; means for admitting to the vessel at one end of the series a process fluid to be contacted and for discharging the contacted process fluid at the other end of the series; and means for rotating said shaft, said means including a fluid-actuated motor situated within the said vessel and coupled to the shaft for rotating the same, a pump independent of the said means for admitting process fluid to the vessel, a high-pressure feed duct for transferring driving pump fluid from the pump to the motor and a flow passageway interconnecting the discharge of the motor to suction intake of the pump, and means for driving said pump.

2. Apparatus according to claim 1 wherein said pump is situated outside of said vessel, said passageway is a return duct interconnecting the motor and pump, and said feed and return ducts extend through the wall of said vessel.

3. Apparatus according to claim 1 wherein said pump is situated within said vessel and said driving means includes a hermetically sealed partition the outside of which is isolated from the vessel, an electrical winding situated outside said partition, and a rotor situated inside said partition and coupled to said pump.

4. Apparatus according to claim 3 wherein said pump has the suction intake thereof disposed to receive said process fluid from within the vessel and the pressure outlet thereof connected by said high-pressure feed duct to the pressure intake of the motor, and the outlet of the motor is disposed to discharge fluid into the vessel.

5. In combination with the apparatus according to claim 4, means for controlling the speed of the rotor comprising a spill outlet in the said high-pressure feed duct, and flow-control means for said spill outlet operable from outside the vessel, whereby the speed of the rotor can be reduced by opening the said flow-control means to spill an increased amount of fluid.

6. Apparatus according to claim 1 wherein said vessel contains at least two rotatably mounted axial shafts carry-

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ing baffles as specified, the baffles carried by the respective shafts being situated within respectively different zones of the vessel, each said shaft being provided with an independent means for rotating the shaft including a separate fluid-actuated motor as specified, whereby the said shafts can be operated independently of one another.

7. Apparatus for countercurrent contacting of a process liquid with a process fluid which is at least partially immiscible therewith and of different density, comprising an upright, vertically elongated vessel; a plurality of vertically spaced transverse baffles within said vessel defining therein a vertical series of compartments which are in consecutive communication; a plurality of vertical shafts mounted for independent rotation within said vessel, the first shaft carrying at least some of said baffles within the upper part of the vessel for rotation therewith and the second shaft carrying at least some others of said baffles with the lower part of the vessel fast for rotation therewith; inlets at opposite ends of the vessel for admitting the said process liquid and process fluid; outlets at opposite ends of the vessel for discharging the liquid and fluid after contacting; and independent means for rotating said shafts,

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whereby the said shafts can be rotated at independent speeds.

8. Apparatus according to claim 6 wherein the means for rotating at least one of said shafts comprises a fluid-actuated motor situated within said vessel and coupled to said one shaft, a pump situated outside said vessel, a high-pressure feed duct for transferring pump fluid from the pump to the motor and a low-pressure duct for returning pump fluid from the motor to the pump, and means for driving said pump.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,013,866

December 19, 1961

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It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 3, for the claim reference numeral "6"
read -- 7 --.

Signed and sealed this 3rd day of July 1962.

(SEAL)

Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents