July 19, 1966 T. D. SHARPLES 3,261,593

FLUID MIXING PROCESS AND APPARATUS

Filed Dec. 20, 1963 2 Sheets-Sheet 1

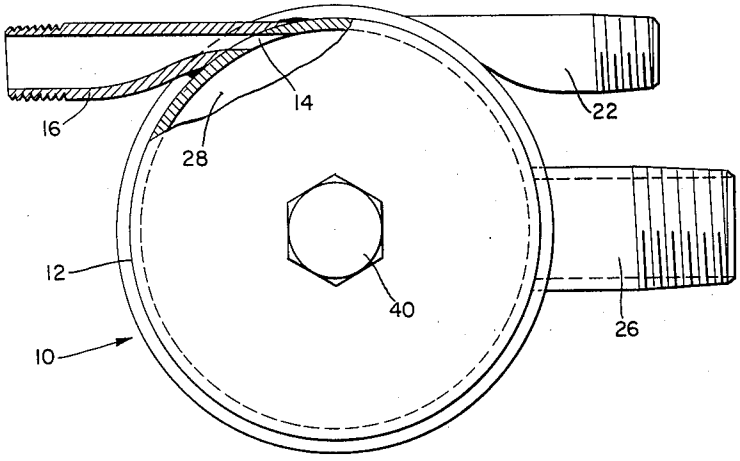


Fig. 1

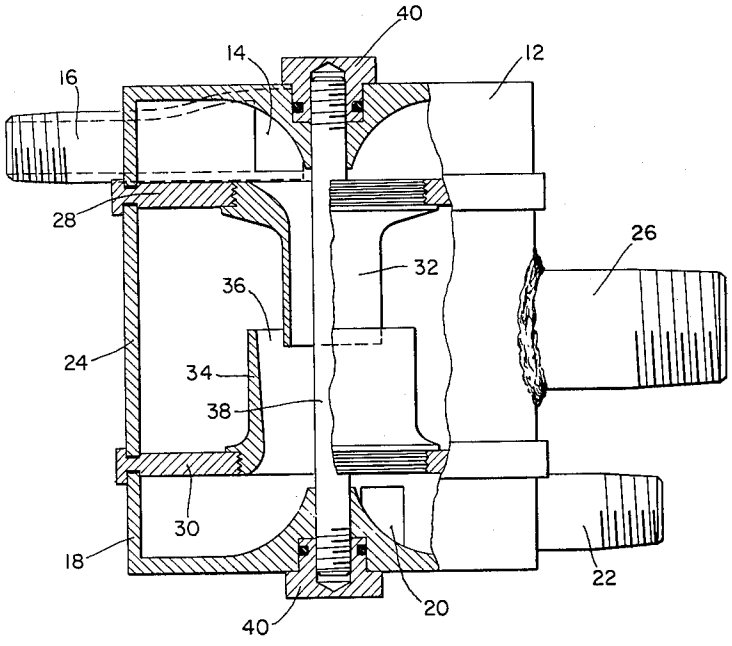


Fig. 2

INVENTOR.
THOMAS D. SHARPLES
BY Dallett Hoopes
ATTORNEY

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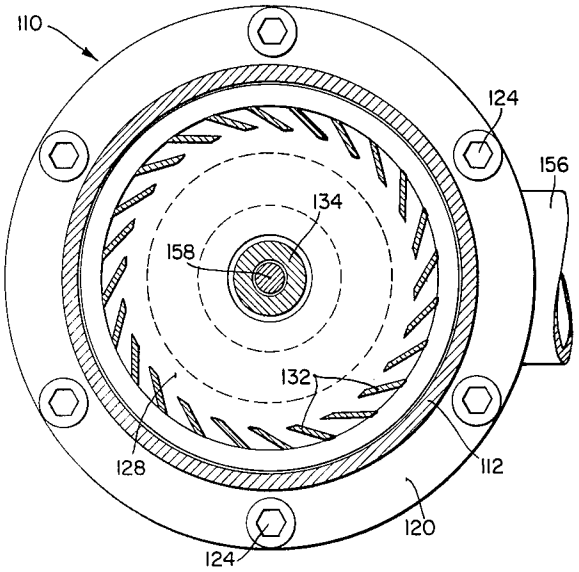


Fig. 3

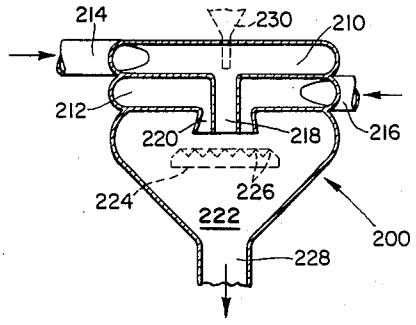


Fig. 5

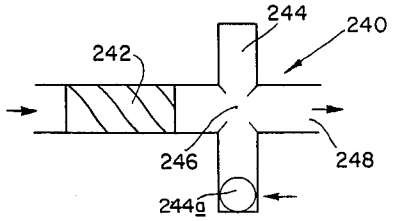
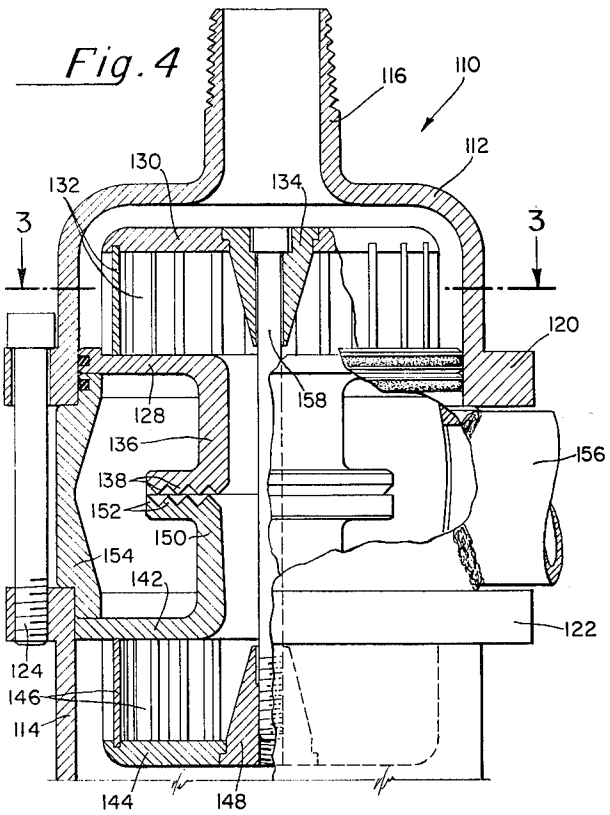


Fig. 6

Fig. 4



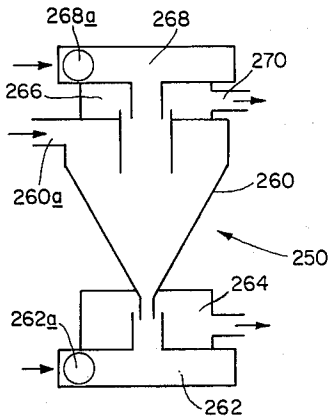


Fig. 7

INVENTOR.
THOMAS D. SHARPLES
BY Dallett Hoopes
ATTORNEY

United States Patent Office

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FLUID MIXING PROCESS AND APPARATUS

Thomas D. Sharples, Lansdale, Pa., assignor to Pennsalt Chemicals Corporation, Philadelphia, Pa., a corporation of Pennsylvania

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14 Claims. (Cl. 259—4)

This invention relates to fluid mixers. More specifically this invention relates to mixers especially adapted for liquids which normally tend to resist mixing into a homogeneous phase.

In the prior art, attempts have been made to provide liquid mixers having no movable parts and especially adapted for mixing liquids which are difficult to mix. An example of such prior art is shown in the U.S. Patent 2,645,463 which issued July 14, 1953, on an application by R. F. Stearns. In some prior art devices the separate liquids have been brought into separate agitating or turbulence-creating chambers. From these chambers after having been made turbulent the liquids have passed into a mixing zone. The contact of the turbulent liquids in the mixing zone has broken up particles of the two liquids and mixed them. The mixed liquid has discharged from the mixing zone.

For some liquids the turbulence produced in the prior art agitation zones has not produced in the contact of the two liquids the mixing desired. For instance, in the use of such prior art devices with separate high density caustic and vegetable oil the desired degree of mixing has not been achieved. The high density caustic has remained in globules and streamed past the vegetable oil so that the discharge has not been a homogeneous mixture but instead a suspension of large caustic globules in the vegetable oil.

By means of the present invention it is possible to mix liquids in an extremely efficient manner. This is done by creating counter-rotating vortices of the separate liquids and introducing the counter-rotating liquids into a common mixing chamber. In the mixing chamber the two liquids, each having tremendous rotational energy and rotating in opposite senses, violently contact and annihilate their respective velocities.

The efficiency of the subject of the present invention is marked in contrast to the prior art devices wherein mere turbulence was created in chambers adjacent the mixing chamber prior to the contact of the two liquids. Apparatuses embodying the present invention guide the liquids into smooth, steady swirling vortices demonstrating a tremendous measure of energy relative to the mere turbulence of the prior art means. It can readily be visualized that the liquids having this energy will in contacting and neutralizing their velocities encounter tremendous shear forces, break up and mix with unusual effectiveness. An additional benefit of the means in accordance with the present invention is that the respective vortices may be precisely controlled so that the energy of the contacting streams is equal. Further, because the turbulence is kept to a minimum prior to the contact of the liquids, apparatuses embodying the present invention feature greater stability of operation, and smoother flow.

These and other features of the invention will be evident from the drawings and the following illustrative description.

In the drawings:

FIGURE 1 is a top plan view of an apparatus embodying the invention;

FIGURE 2 is a side elevational view, partly in section, of the apparatus of FIGURE 1;

FIGURE 3 is a sectional view of a modified form of the apparatus embodying the invention and taken on the line 3—3 of FIGURE 4;

FIGURE 4 is a side elevational view, partly in section, of a modified apparatus embodying the invention;

FIGURE 5 is a diagrammatic view of another modification embodying the invention;

FIGURE 6 is a diagrammatic view of still another modification embodying the invention; and

FIGURE 7 is a diagrammatic view of a further modification embodying the invention and especially useful in extraction processes.

Briefly, then, the invention involves at least a pair of adjacent vortex chambers inducing opposite rotation in the liquids to be mixed and a mixing chamber into which the oppositely rotating liquids from the vortex chambers are led to mix.

Referring more specifically to the drawings, an apparatus embodying the invention is shown in FIGURE 1 and generally designated **10**. It comprises a first cup-shaped vortex housing **12** having a tangential inlet passage **14** about which is secured on the outside of the housing the inlet tube **16**. At the opposite end of the apparatus (FIGURE 2) a second vortex housing **18** is provided with a tangential inlet passage shown partly at **20** around which on the outside of the housing is secured the inlet tube **22**. As may be noted from the drawings, the inlets **16** and **22** are directed toward their respective housings in opposite tangential directions.

Intermediate the two vortex housings is a common mix housing defined by the circular wall **24**. An opening in the circular wall has outlet tube **26** secured thereabout.

Further defining the compartments are a pair of partitions **28** and **30**, respectively, which are clamped between the cup-shaped vortex housings **12** and **18** and the circular wall **24**, respectively. The partitions **28** and **30** are each provided with central apertures which are preferably threaded and receive coaxial discharge conduits or nozzles **32** and **34**. Preferably the nozzle **34** is of greater diameter than the nozzle **32** and its end overlaps the end of the nozzle **32** defining an annular passageway **36** between the two nozzles. Preferably the inner surface of the nozzle **34** flares somewhat outwardly for reasons which will be later explained.

Holding the mixer in assembly is the drawbolt **38** which extends axially and has its opposite ends threaded to receive the compression caps **40** on the outside of the mixer.

The nozzle **34** has been shown in larger diameter than the diameter of nozzle **32**. This is of benefit especially in mixing liquids of substantial difference in density. In use, the liquid of greater density is made to form a vortex in the housing **12** connected with the nozzle **32** of smaller diameter, while the liquid of lesser density is formed into a vortex in the housing **18** connected with the nozzle **34**. Thus as the counter-rotating vortices meet in the passageway **36** the contact is enhanced as the heavier liquid tends to move out and the lighter tends to move in. For some applications many of the benefits of the

invention may be realized by having the nozzles of identical diameter, with a substantial gap between the ends thereof.

The embodiment of the invention shown in FIGURES 1 and 2 is especially adapted for use with low pressures and its operation will be understood by visualizing the delivery of a lighter liquid tangentially into the housing **18** to create smooth swirling action in that housing. Simultaneously the heavier liquid is introduced into the housing **12** through the passage **14** to create a smooth swirling vortex in that housing and rotating in the direction counter to the vortex in the housing **18**. The mixer **10** normally operates almost completely filled with liquid except for a vapor core of small diameter in some instances, and it will be understood that by suitable regulation of the respective incoming liquids an equilibrium condition will be achieved wherein the separate liquids pass in swirling movement through the respective nozzles and into the common mix housing **24** from which they are discharged as a single mixed liquid through the outlet **26**.

Those skilled in the art will understand that the rotary speed of the separate liquids as they pass through the respective nozzles will be greater than the rotary speed of the liquids at the greatest internal diameter of the respective housings **12** and **18**. This results as the swirling liquid particles moving inward from the periphery of the housing to the lesser radius of the nozzles swirl in advance of the outer particles picking up rotary speed in accordance with the laws of conservation of angular momentum. Thus remarkable rotary speed is achieved at the diameters of the respective nozzles.

In the embodiment shown the nozzle **34** flares outwardly to avoid the entrapment by centrifugal force in the nozzle **34** of heavier liquid discharging through nozzle **32**.

As shown the nozzles **32** and **34** may be readily replaced by simply disassembling the unit and unscrewing them, substituting the desired nozzles and reassembling the unit. It will be understood by those skilled in the art that the particular shape and size of the nozzles selected will depend on the density of the liquids being mixed, their viscosity, their pressure, and other factors.

Referring now to the embodiment shown in FIGURES 3 and 4, which is especially suited for operating at higher pressures, the structure is generally designated **110**. It comprises a pair of identical end caps **112** and **114** which are each provided with an axial threaded inlet pipe. The pipe of cap **112** is designated **116**. The pipe of cap **114** is not shown. The mouths of the end caps are provided with outward flanges **120** and **122**, respectively. These are apertured to receive draw bolts **124**.

Within the end cap **112** is disposed a circular vortex chamber defined by the housing wall **128** and the housing end plate **130**. Connecting the housing wall **128** and the end plate **130** are a plurality of spaced flow directing vanes **132** disposed at a uniform radial distance from the axis and evenly spaced thereabout. The end plate **130** is centrally apertured and receives a hub **134** having a central bore. As shown the housing wall **128** has a central opening and an axial downward extension **136** which corresponds to the discharge conduit or nozzle **32** of the first embodiment. The lower end of the extension **136** bears an outward flange and its lower radial face is provided with a number of concentric annular ribs **138**.

The lower end of the mixer **110** is very similar to the upper end. It comprises a second vortex chamber defined by a housing wall **142** and an end plate **144** spaced therefrom. Connecting the end plate **144** and the housing wall **142** are a plurality of flow directing vanes **146** directed oppositely from the vanes **132** of the first vortex chamber. Disposed centrally in an opening in the end plate **144** is the hub **148**.

The housing wall **142** has a central opening and is formed with an axial extension **150** toward the extension **136**. The upper end of the extension **150** is formed with an outward flange which presents on its upper radial face a number of concentric ribs **152** which interfit with the ribs **138** of the extension **136**.

Holding apart the housing walls **128** and **142** is the circular mix housing wall **154** which may be reduced adjacent its ends to provide shoulders engaging the mouths of the end caps **112** and **114**, respectively. A mix housing outlet tube **156** is provided.

Holding the parts which define the vortex chambers in proper position is the draw bolt **158** which passes through the hub **134** and threadedly engages the hub **148**. The hubs **134** and **148**, for instance, may be formed to help direct the vortices into the nozzles.

The operation of the higher pressure version of the apparatus as shown in FIGURES 3 and 4 may be readily visualized. The liquids to be mixed are connected respectively to the axial inlet pipes of the caps **112** and **114**, and a supply of the respective liquids is made to flood the two vortex chambers within the flow directing vanes respectively. In passing inward through the vanes **132** and **146** the liquids are deflected in a more or less tangential path to cause a swirl movement within the respective chambers. Since the vanes **132** and **146** are oppositely directed, the swirling vortices will be in opposite directions. These flow directing vanes may take different forms and have different angles, i.e., air foil shapes, slots and even adjustable angle construction. As the respective liquids pass through the conduits defined by the extensions **136** and **150** they swirl at rotary rates above those at the peripheries of the respective vortex chambers in accordance with the law of conservation of angular momentum. As the counter-rotating liquids contact each other in the space between the ribs **138** and **152** violent mixing action occurs to the extent that virtual annihilation of the rotary speed of the respective liquids with high and intense shear ensues. After such mixing the mixed liquids are drawn off through the outlet pipe **156**.

As shown in FIGURE 4 the inside face of the extension **150** comprising the conduit for the vortex of low density liquid may flare outwardly upward for the purpose as explained in connection with the earlier embodiment.

A further variation embodying the invention is shown in the mixer of FIGURE 5. In this embodiment, easily fabricated from glass, for instance, designated **200**, a first vortex chamber is shown at **210** and a second at **212**. The inlets **214** and **216** respectively to those two chambers direct the liquid oppositely to induce counter-rotation. As shown the outlets **218** and **220**, respectively, deliver their energy-laden vortices to the mixing chamber **222**. Preferably the liquid of greater density is delivered through outlet **218** of smaller radius than the outlet **220** through which the lighter liquid flows out; thus the respective densities cause the lighter liquid to move in and the heavier out, enhancing the contact. The outlet **220** may be flared for reasons stated. As with the other embodiments the counter-rotating character of the two liquids as they enter the mix chamber **222** causes excellent mixing through high shear accompanying the virtual annihilation of the respective velocities.

As shown in phantom in FIGURE 5, a target **224** may be provided in the mix chamber. This target may present annular concentric ribs **226** to deflect the incoming liquids and effect greater commingling to enhance the mixing. The mixed liquid discharges through port **228**.

It should be understood that in some of the earlier embodiments a comparable third component feed means **230** may be used, especially in low pressure operation. If the operation of the embodiment is at a higher pressure it may be necessary to inject the third component under pressure.

A further embodiment of the invention is shown in the variation of FIGURE 6 wherein the mixer **240** comprises an in-line swirl-inducting baffle **242** which forms the liquid into a forced vortex immediately downstream.

As shown the baffle **242** may comprise a simple plug having screw-shaped passages. Downstream from the baffle **242** is a vortex chamber **244** which guides the incoming second component at **244***a* into a swirl rotating counter to the swirl of the first liquid. The counter rotating vortices meet in the mix zone **246** and their respective velocities are virtually annihilated as they move downstream to the outlet **248**.

It should be noted that preferably the liquid of greater density is introduced into the mixer through the baffle **242** so that the lighter liquid which enters the vortex chamber **244***a* will have a tendency to displace the heavier liquid by moving inward, thus enhancing the mixing action. As with the earlier embodiments the mixing action may be precisely controlled by adjusting the respective pressures of the light and heavy liquid as they are introduced into the mixer.

A further embodiment is designated **250** and is shown in FIGURE 7. This embodiment is especially useful in countercurrent extraction processes wherein a number of countercurrent extraction stages are cascaded. In the embodiment the mix from an earlier stage is introduced tangentially to the cyclone **260** at **260***a*. The underflow from the cyclone **260** discharges at the lower end of the cyclone and possesses considerable rotational energy. A light liquid with which it is desired to contact the underflow is delivered to the vortex chamber **262** in a tangential inlet **262***a* to create in the chamber **262** a vortex having rotational energy in the opposite direction from that of the underflow from the cyclone **260**. In the mix chamber **264** the two liquids contact. It will be noted that the outlet from the underflow is of smaller diameter than the outlet nozzle for the chamber **262** to enhance the mixing action as with earlier embodiments. From the mix chamber **264** the discharge mixture may be separated centrifugally in the next stage of extraction. The centrifugal separation may be effected by cyclone or centrifuge.

The overflow from the cyclone **260**, possessing rotary energy imparted to it by the cyclone **260**, is delivered to the mix chamber **266**. A liquid of greater density with which it is desired to contact this overflow is delivered tangentially to the vortex chamber **268** through passage **268***a* so as to guide the heavy liquid into a vortex having rotary energy in the opposite sense of direction from the overflow from cyclone **260**. It will be noted that the heavy liquid is delivered in the mix chamber **266** at a lesser radius than the lighter overflow from cyclone **260** to enhance the mixing. From the chamber **266** the mixed liquid discharges through port **270** for delivery to a centrifugal separator which may comprise the next stage of extraction. It will be noted that in the FIGURE 7 embodiment the cyclone **260** itself represents one of the vortex-forming chambers and that the cyclone imparts the desired rotary energy to the incoming liquid.

From the above illustrations it will be clear that I have developed an extremely simple and inexpensive mixer having no moving parts and which is especially suited to achieve an effective mixing of liquids which have a tendency to resist such a mixing. The mixer of my invention may take many forms.

It is to be understood that the above particular description is by way of illustration and not of limitation, and that changes, omissions, additions, substitutions, and/or other modifications may be made without departing from the spirit of the invention. Accordingly, it is intended that the patent shall cover, by suitable expression in the claims, the various features of patentable novelty that reside in the invention.

I claim:

1. A fluid mixer comprising at least two vortex housings each having an inlet directing incoming fluid to one side of the axis thereof for producing vortices rotating in opposite senses of direction when viewed from one end of the mixer, a mixing housing, wall means separating each vortex housing from the mixing housing, the wall means having central openings permitting communication from the vortex housings, respectively, directly with the mixing housing, the mixing housing having an outlet for mixed fluids.

2. A liquid mixer comprising a pair of coaxial generally circular vortex housings having inlet passages for separate liquids entering the housings from directions to produce opposite rotational movement of liquid within the housings when viewed from one end of the mixer, a mix housing, wall means disposed between each vortex housing and the mixing housing, respectively, the wall means having central axial discharge conduits extending directly into the mix housing, the mix housing having an outlet for mixed liquid.

3. A liquid mixer as described in claim **2** wherein the central axial discharge conduit from one of the vortex housings is smaller in diameter than the conduit from the other.

4. A liquid mixer as described in claim **2** wherein one of the central discharge conduits flares outwardly into the mix housing.

5. A liquid mixer as described in claim **2** wherein the mix housing is intermediate the vortex housings.

6. A liquid mixer as described in claim **2** wherein the mix housing is disposed on the opposite side of one of the vortex housings from the other vortex housing.

7. A liquid mixer as described in claim **6** wherein one of said vortex housings has an axial inlet through which a third component can be introduced into said mixer.

8. A liquid mixer as described in claim **2** wherein the inlet passage for one of the vortex housings is in the form of a screw-shaped baffle.

9. A liquid mixer as described in claim **2** wherein the mix chamber is provided with a radial surface having concentric annular ribs against which at least one of the discharge conduits directs a discharge from one of the vortex housings.

10. A liquid mixer as described in claim **2** wherein one of the vortex housings is defined about its periphery by spaced generally tangential vanes.

11. A liquid mixer as described in claim **2** wherein one of the vortex housings is a cyclone.

12. A liquid mixer comprising a pair of coaxial generally circular vortex housings having respectively opposite tangential inlet passages directing liquid and inducing vortical flow within the vortex housings of opposite senses of rotation, respectively, when viewed from one end of the mixer and confronting axial outlet nozzles, one of the nozzles being smaller in diameter than the other and extending thereinto, the larger nozzle flaring outwardly as its distal end is approached, a mix chamber intermediate the vortex housings and enclosing said nozzles and being provided with an outlet for mixed liquid.

13. A process for mixing two liquids of different densities comprising the steps of forming separate but adjacent counter-rotating vortices of the two liquids, withdrawing central portions of each vortex into a common mixing zone disposed coaxial with the vortices, the liquid of greater density being withdrawn from its vortex at a lesser radius than the liquid of lesser density, and withdrawing the mixed liquids from the mixing zone.

14. A process for mixing two fluids comprising introducing the respective fluids to free-vortex-forming zones along imaginary lines to one side of the axes of the zones, respectively, the lines and related zones being generally in planes perpendicular to the axes of the zones respectively and at distances from the axes of the zones, respectively, to produce counter-rotating free vortices in the zones respectively, withdrawing from each zone a central portion only of each vortex of outside radius smaller than the distance from the axis to the line of

the said zone, delivering each portion directly into a common mixing zone and withdrawing the mixed fluids from the mixing zone.

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WALTER A. SCHEEL, *Primary Examiner.*

IRVING BUNEVICH, *Examiner.*

J. M. BELL, *Assistant Examiner.*