United States Patent [19]
Latinen, deceased

[11] 3,751,010
[45] Aug. 7, 1973

[54] MIXER

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(Under Rule 47)

[21] Appl. No.: **172,059**

[52] **U.S. Cl.** .... **259/9,** 23/252 R
[51] **Int. Cl.** **B01f 7/04**
[58] **Field of Search** .... 259/9, 10, 7, 8, 259/5, 6, 109, 110, 21, 22, 23, 24, 25, 26, 43, 44, 45, 46, 178, 68, 69; 23/252 R

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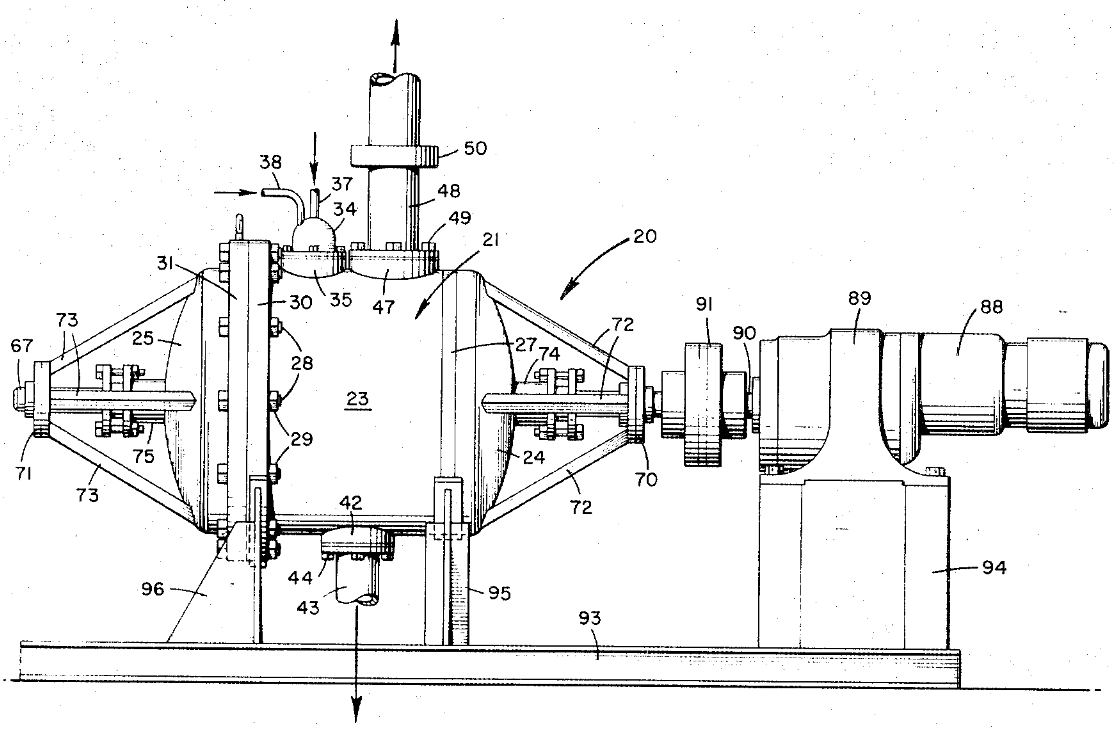
[57] **ABSTRACT**

A housing and paddle assembly adapted for use in processing and mixing highly viscous fluids is provided. The mixer employs a paddle assembly which rotates about a horizontal axis and which has at least one pair of diametrically opposed axially extending blade members which are slotted at diagonally opposite outside ends. In operation, the paddle assembly can sweep out substantially all of the housing interior and produce simultaneously in a fluid cyclical vertical displacement, rolling action, horizontal displacement, and, even, fold over action.

14 Claims, 15 Drawing Figures



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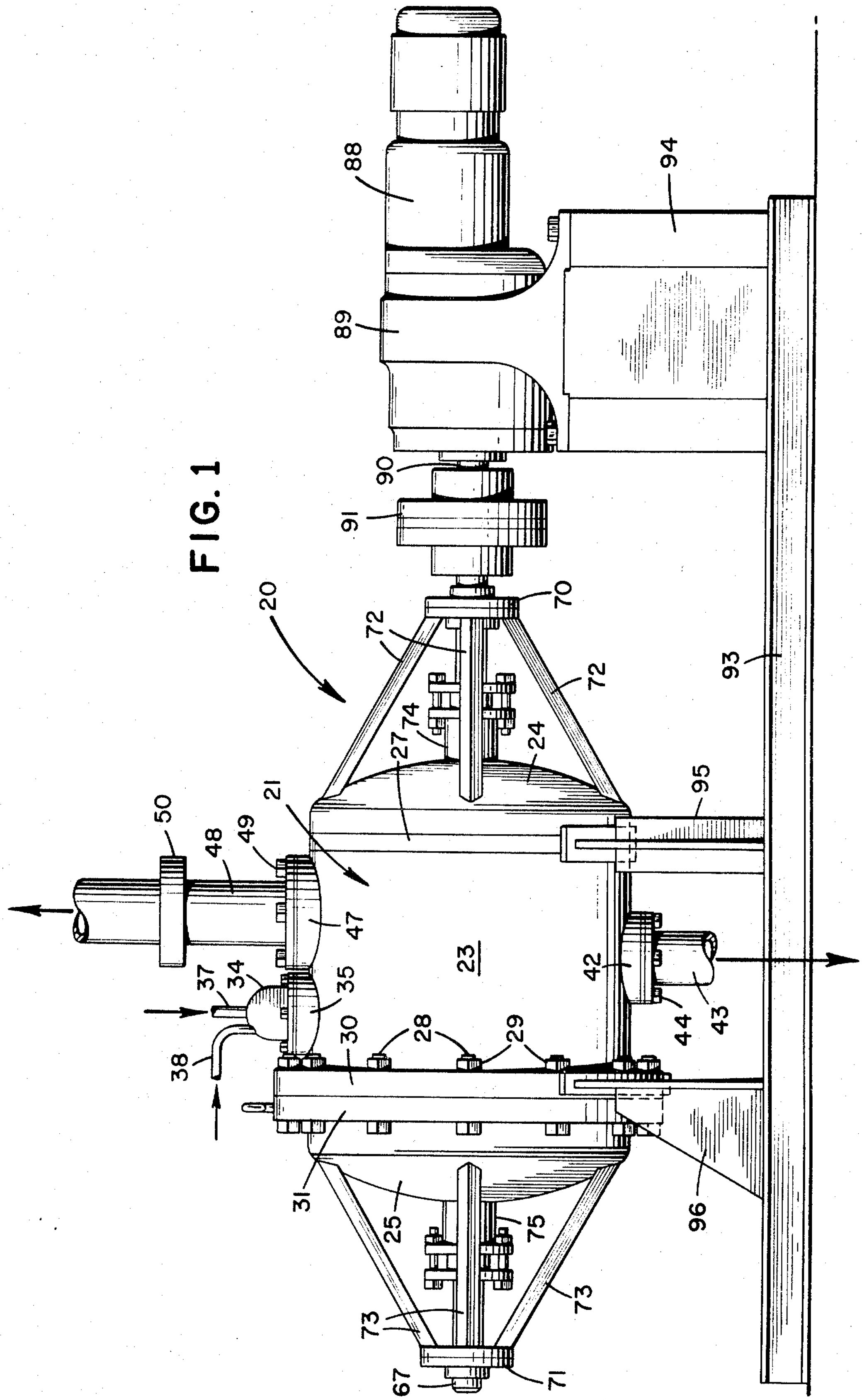

FIG. 1

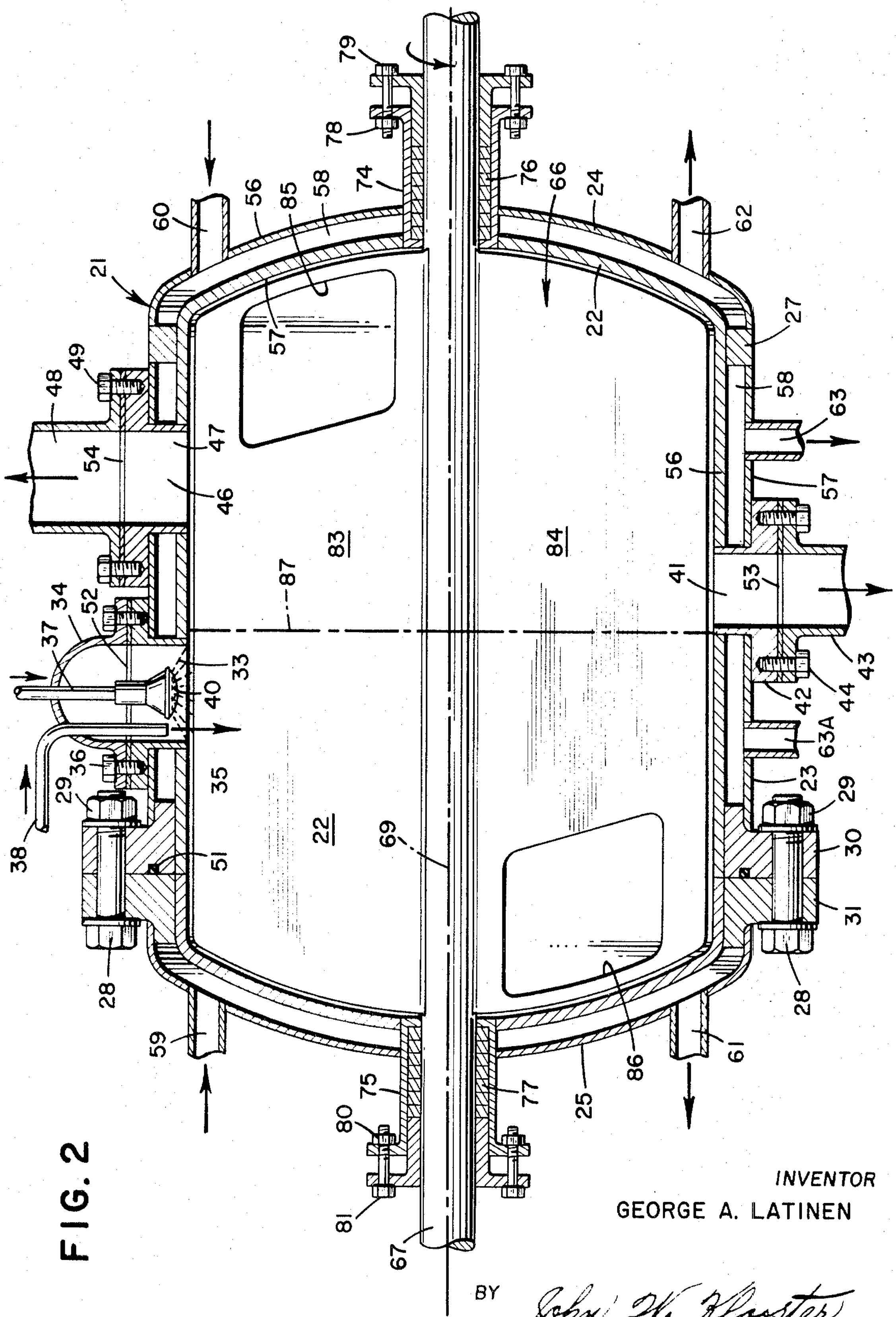

FIG. 2

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FIG. 5

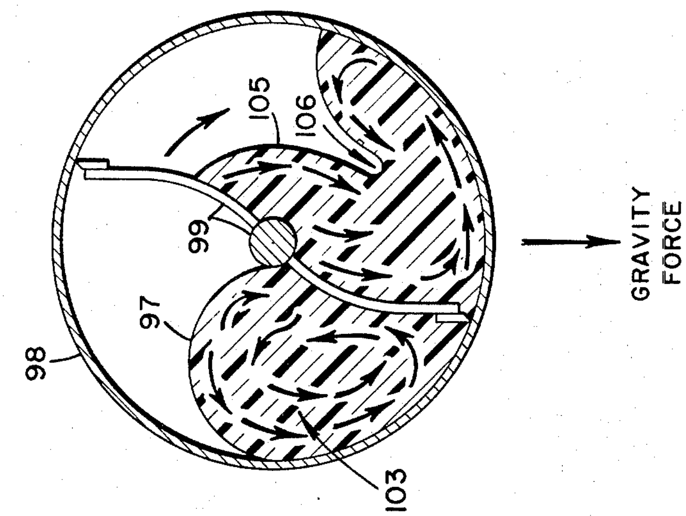

FIG. 4

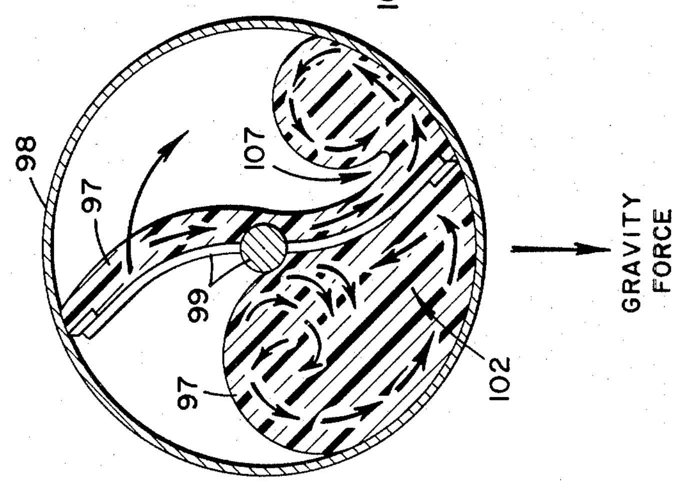

FIG. 3

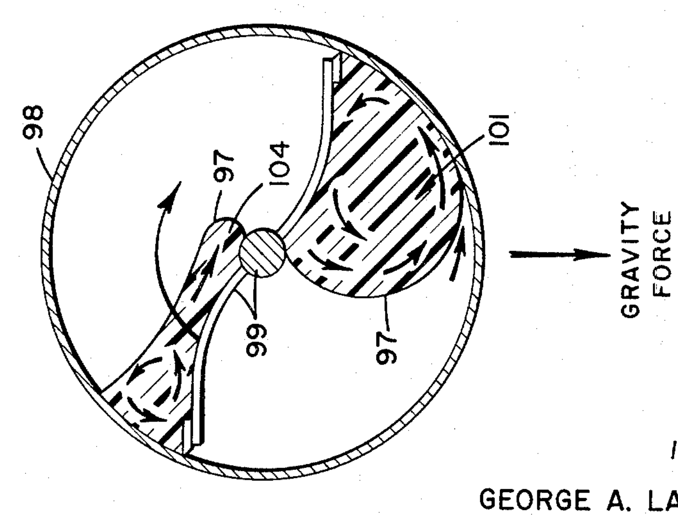

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FIG. 6

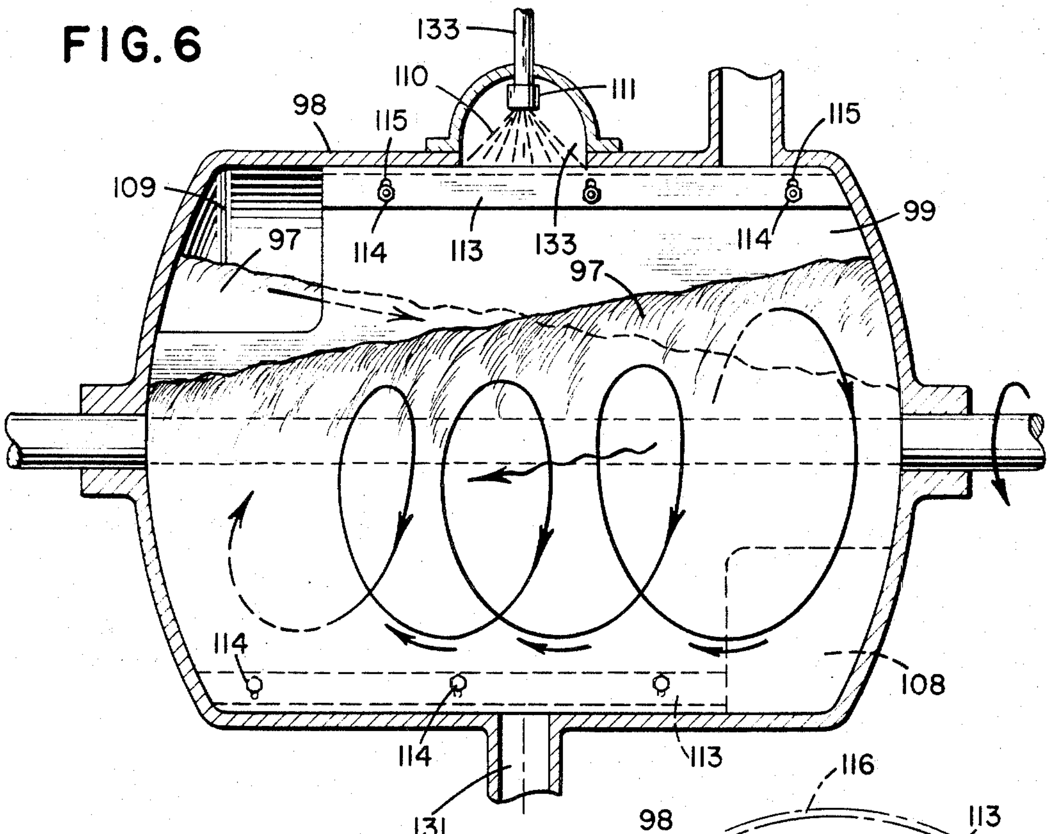
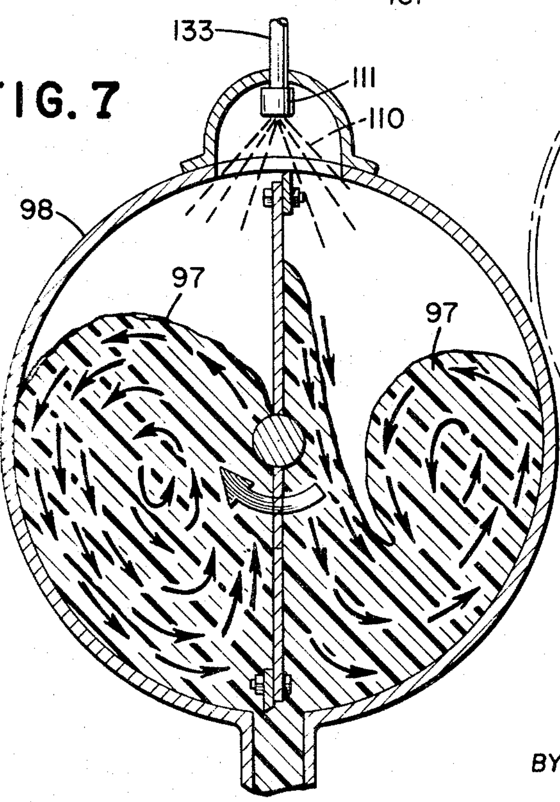


FIG. 7



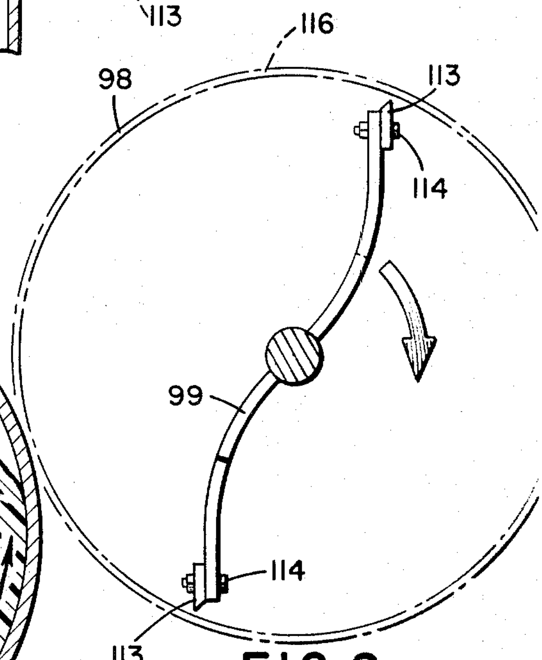


FIG. 8

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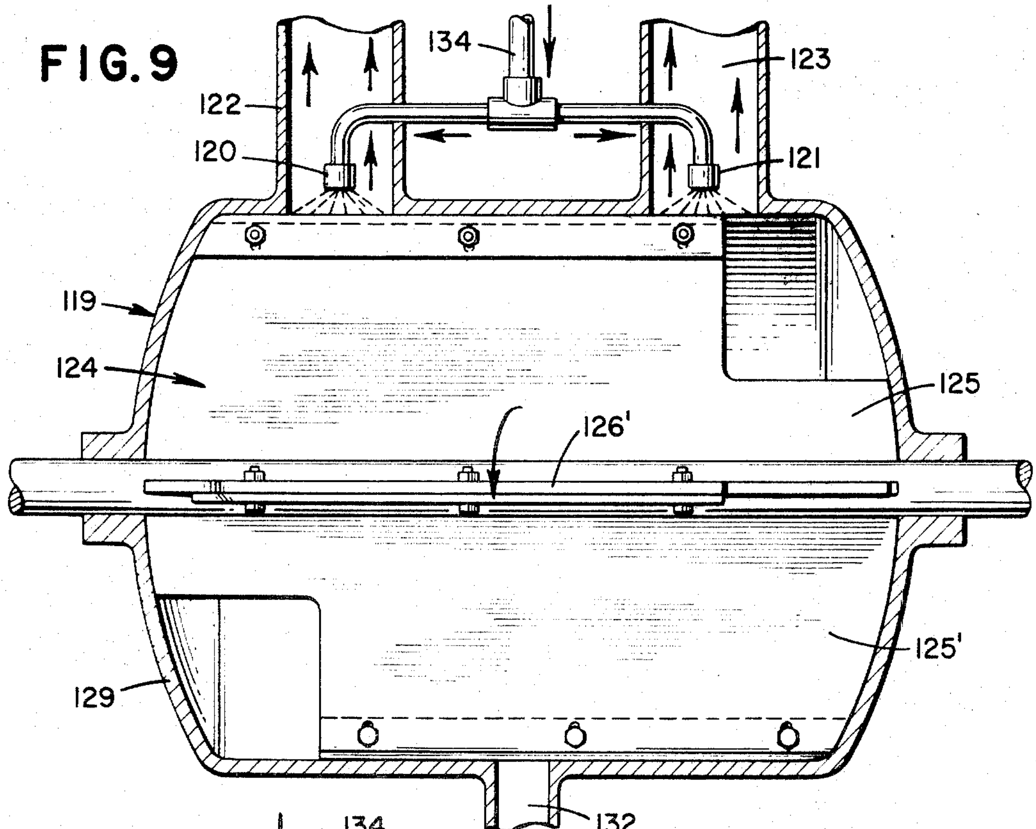
FIG. 9



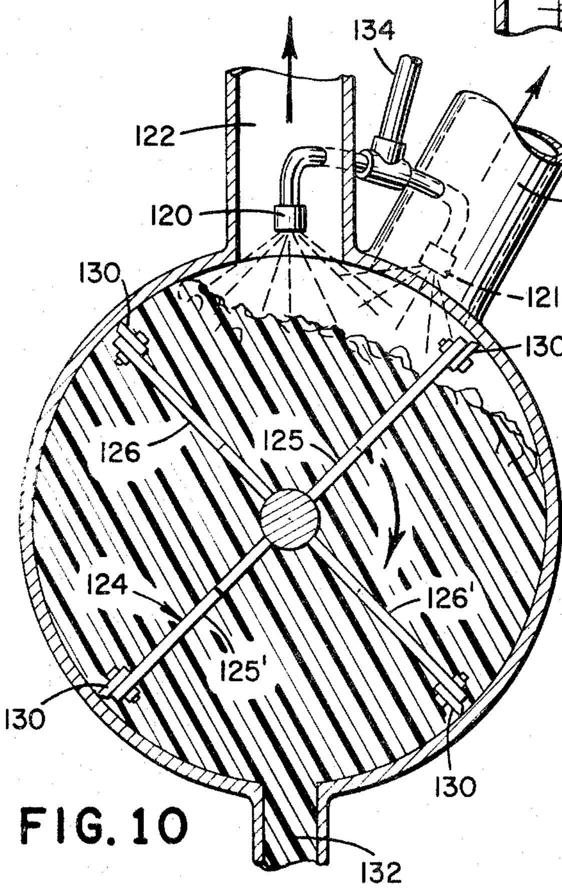


FIG. 10

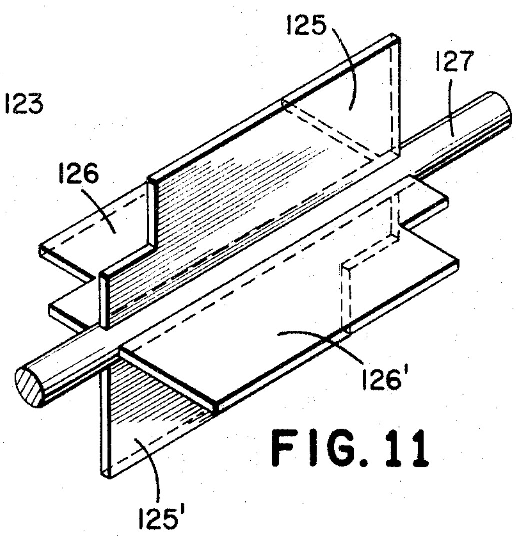


FIG. 11

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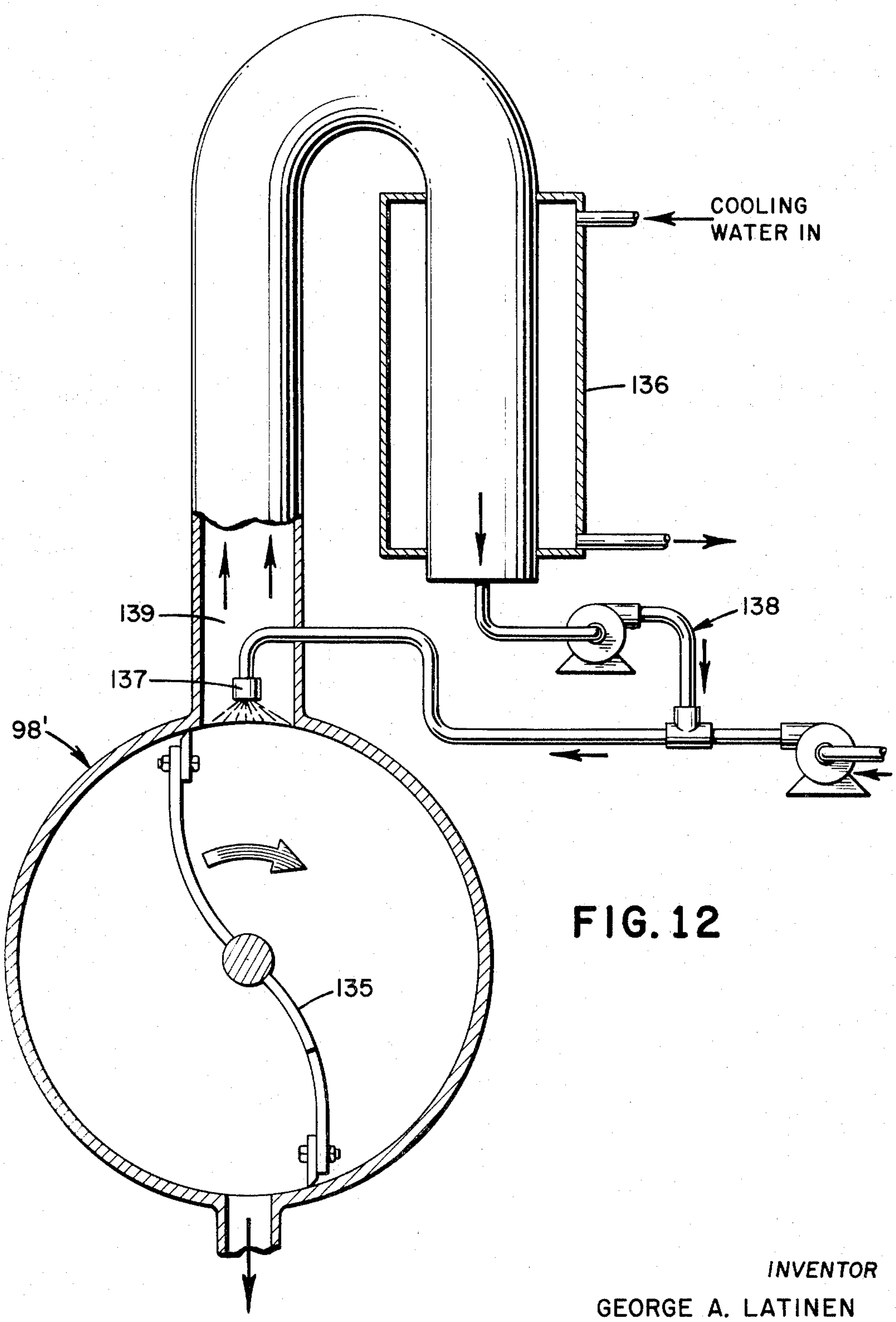

FIG. 12

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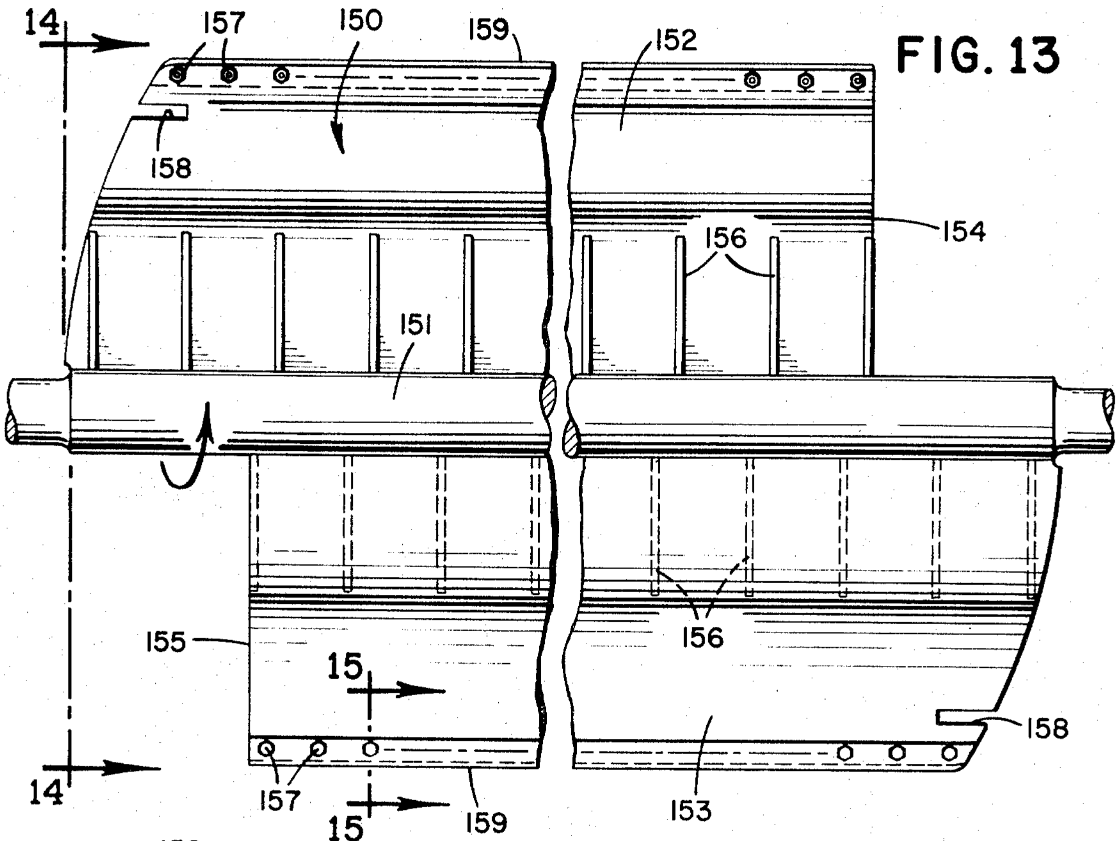


FIG. 13

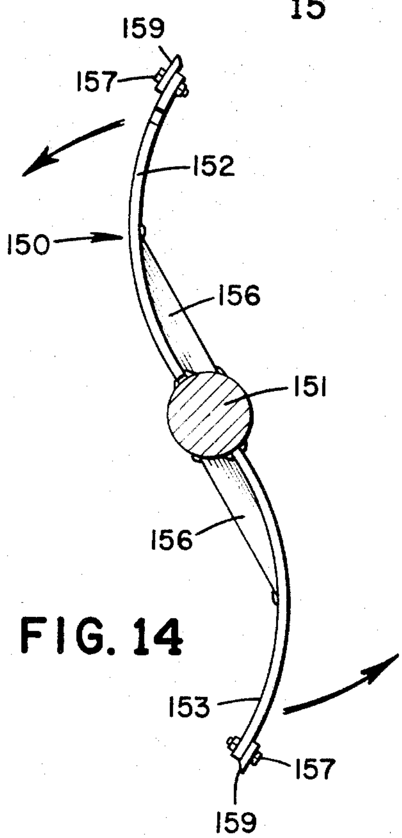
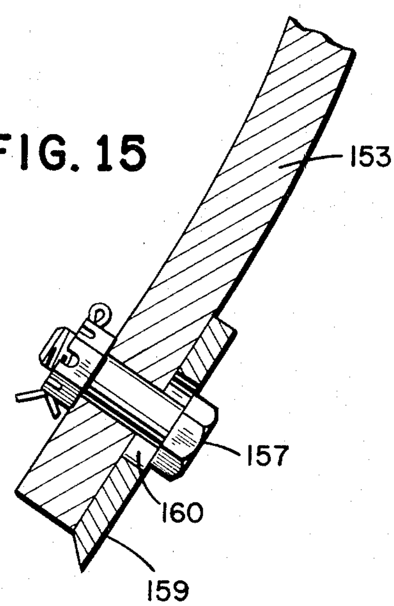


FIG. 14



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MIXER

BACKGROUND

In processing fluids, especially viscous fluids having viscosities generally greater than, say, about 10,000 centipoises, it is often necessary to blend therewith additives. In mixing operations involving such viscous fluids, many problems are encountered, and specialized mixing apparatus is desirable and commonly necessary. Complex mechanical and fluid forces are involved. The art has long sought new and improved mixing means adapted for use with highly viscous fluids, the end result generally desired being to achieve in such viscous fluids, or to maintain such viscous fluids in, a substantially uniform or homogeneous condition in the most efficient manner possible. One problem with conventional mixing means has been the large amount of power required to drive an agitator placed in a highly viscous fluid. Another problem therewith has been the difficulty of mixing a liquid of low viscosity (for example, one having a viscosity of less than about 10 centipoises) with one of high viscosity (for example, one having a viscosity of greater than about 10,000 centipoises). Still another problem has been the form and configuration of the agitator and of the mixer housing relative to the agitator.

One class of mixers recognized in the prior art characteristically has an agitator revolving generally (though not necessarily exactly) about a horizontal axis within a vessel or housing which is usually cylindrical. Such class of mixers is suitable (depending upon individual situations) for batch or continuous operation. There has now been discovered a new and improved mixer of this class wherein the mixing of highly viscous fluids (for example, of a low viscosity liquid into a high viscosity liquid) can proceed with unexpectedly low power and in a rapid and highly efficient manner. This mixer is especially well adapted for use conditions where the housing is only partially filled with a highly viscous fluid. The mixer is useful in a wide variety of end use applications involving mixing or agitation of fluids and produces a type of mixing action heretofore unknown.

SUMMARY

The present invention is directed to a mixer which is especially well adapted for use in processing highly viscous fluids, but which is also suitable for mixing fluid or fluidizable materials generally. The mixer incorporates a housing which encloses an interior chamber with side and end walls. The chamber walls are generally radially symmetrical (e.g., cross-sectionally circular) with respect to a longitudinal axis extending therethrough. The housing is preferably adapted to be oriented during mixer operation so that the longitudinal axis extends generally horizontally. The housing preferably has an input port above the level of the axis and has an output port preferably below the level of the axis, although a housing with only a single port may be used, if desired, as when an auxiliary fluid pump is used and the mixer is not used in a continuous operation. The housing can be formed of any convenient construction material though steel is presently preferred.

The mixer employs a paddle assembly which has a rotatably mounted shaft which extends generally longitudinally through said housing and generally parallel to said axis. From the shaft extends at least one pair of diametrically opposed blade members. Each blade member radially projects from the shaft preferably to near engagement with interior wall surfaces of the interior chamber of the housing. Each blade member generally axially extends continuously along the shaft. Each pair of diametrically opposed blades is slotted in the region of their respective diagonally opposite outside ends (or corners), with the effective total slot cross-sectional surface area in each blade ranging from about 3 to 50 percent of the total effective surface area of such blade (preferably ranging from about 4 to 20 percent thereof), though somewhat larger and smaller surface areas may be used without departing from the spirit and scope of the present invention, as those skilled in the art will appreciate. Preferably, the slots in each respective blade of such a pair of blades are substantially equally sized and similarly located at respective diagonally opposite outside ends. The diameter of each such pair of blade members in a paddle assembly in a mixer at any given location along the axis of the shaft except in slot locations is typically not less than about 90 percent of the diameter of the interior chamber of the mixer taken at about the same location.

The shaft of the paddle assembly is journaled at its opposite end regions in fixed relationship to the housing to adapt the shaft for rotational movements. Preferably, the shaft axis is coaxial with the housing's longitudinal axis. The paddle assembly can be formed of any convenient material of construction, though metals such as steel are presently preferred. Sealing means to prevent fluid leakage between the paddle assembly shaft and the housing are provided in an operating mixer, as those skilled in the art will readily appreciate.

The paddle assembly is in a mixer preferably adapted to rotate with substantially no contact betwen blade tips and chamber walls. For operation, a mixer is equipped with drive means for revolvably driving the paddle assembly shaft, including a power head and power transfer means. The paddle assembly when rotating during mixer operation with fluid in the chamber of the mixer housing can produce a simultaneous combination of cyclical vertical displacement, rolling action, horizontal displacement, and, even, fold over action. Preferably, the clearance between blade tips and housing wall ranges from about 0.01 to 1.5 inches, depending on mixer size, though preferably, in a mixer of this invention, the ratio of the clearance between the blade tips and the adjacent chamber walls to the chamber diameter measured at about the same location at substantially all locations in the chamber along the longitudinal chamber axis except opposite slot locations ranges from about 0.01 to 0.0001. Preferably, in a mixer, the paddle assembly is operated so as to produce during operation uniform rotational movements of the paddle assembly shaft.

The invention is further directed to the paddle assembly itself which is employed in a mixer of this invention.

DRAWINGS

Turning to the attached drawings, there are seen various illustrations intended to provide a better understanding of the present invention, as follows:

FIG. 1 is a side elevational view of one embodiment of a mixer of the present invention;

FIG. 2 is a vertical, longitudinal sectional view taken through the mixing chamber of the embodiment shown in FIG. 1;

FIGS. 3, 4, and 5 are diagrammatic representations of the fluid mixing mechanics in one embodiment of an operating mixer of the present invention as seen in cross-section;

FIG. 6 is a diagrammatic representation of the fluid mixing mechanics in the operating mixer of FIGS. 3 through 5, but as seen in a vertical, longitudinal section;

FIG. 7 is a view similar to FIG. 4, but using in place of the radially curved paddle blade configuration shown in FIG. 4, a radially flattened blade configuration operating in a fluid of differing viscosity from that shown in FIG. 4;

FIG. 8 is an end elevational view of another embodiment of a paddle assembly for use in a mixer of the present invention;

FIG. 9 is a view simlar to FIG. 2 but showing diagrammatically an alternative embodiment of a mixer of the present invention wherein two spray heads for feeding material(s) to a mixer are employed, two conduits for vapor removal are employed, and a four-bladed paddle assembly is employed;

FIG. 10 is a vertical, transverse sectional view through the embodiment of FIG. 9 showing the mixer filled to a maximum extent with a viscous fluid for preferred operation of a mixer in accordance with the teachings of the present invention;

FIG. 11 is an isometric view of a four-bladed paddle assembly of the type used in the embodiment of FIGS. 9 and 10;

FIG. 12 is a diagrammatic vertical, transverse sectional view through an embodiment of a mixer of this invention equipped with a reflux condenser whereby such mixer may be used as a continuous reactor;

FIG. 13 is a side elevational view of one preferred embodiment of a paddle assembly;

FIG. 14 is a sectional view taken along the line 14—14 of FIG. 13; and

FIG. 15 is an enlarged, detailed vertical sectional view taken through the region 15—15 of FIG. 13.

FIGURE DESCRIPTION

Referring to the drawings more particularly, there is seen in FIGS. 1 and 2 an embodiment of a mixer of this invention which is herein designated in its entirety by the numeral **20**. Mixer **20** has a housing designated herein in its entirety by the numeral **21** formed of steel or the like which encloses an interior chamber 22 (see FIG. 2). Housing **21** is formed by a central cylindrical portion **23** to which are secured at opposite ends thereof heads **24** and **25**, respectively. In the embodiment depicted, head **24** is secured to one end of cylindrical portion **23** by welding along flange **27**, while head **25** is secured to the opposite end of cylindrical portion **23** by a series of bolts **28** with mating nuts **29** extending through adjoining flanges **30** and **31** on cylindrical portion **23** and head **25**, respectively.

Housing **21** has formed therein an input port **33** located in the top mid-region of cylindrical portion **23**. An appropriately flanged conduit **35** connects port **33** to a feed dome **34**, conduit **35** and dome **34** being secured together by bolts **36** which extend through the flange of feed dome **34** into threaded rolls in the flange of head **35**. Through dome **34** extend feed pipes **37** and **38**. Pipe **37** terminates within dome **34** in a spray head **40** so located as to be adapted to spray material into a wide area of chamber **22** according to a preselected pattern, while pipe **38** terminates within dome **34** in a conventional orifice (not detailed) which delivers material into chamber **22** as a stream.

Housing **21** also has formed therein an output port **41**. An appropriately flanged conduit **42** connects port **41** to outlet pipe **43**, pipe **43** and conduit **42** being similarly secured together by bolts **44**. Pump means (not shown) may be provided to deliver material to, or to take material from, chamber **22**, via feed pipe **37** and/or **38**, or via pipe **43**, respectively. Additional input and output ports on a mixer **20** may be employed, of course, as desired.

Housing **21** further has formed therein a vent port **46** in the top mid-region of cylindrical portion **23**. An appropriately flanged conduit **47** connects port **46** to pipe **48**, meand **47** and pipe **48** being similarly secured together by bolts **49**. During a mixing operation, port **46** may serve as a safety valve permitting escape of pressurized gases from chamber **22** in the event of excessive pressure build-up in housing **21**, as through rupture of a rupture disc **50**. To isolate the interior of chamber **22** from the atmosphere and prevent during operation of mixer **20** leakage of fluid therefrom, appropriate seals **51** (for head **25** and cylindrical portion **23**), seal **52** for conduit **35** and dome **34**), seal **53** (for conduit **42** and pipe **43**), and seal **54** (for conduit **47** and pipe **48**) are provided. Vent **46** is also useful when mixer **20** is to be employed as a reactor wherein mixing of viscous fluids takes place, and wherein a reflux condenser (not shown in FIGS. 1 and 2, but see FIG. 12) is connected with vent **46**.

Housing **21** in mixer **20** is effectively formed by two walls, an inner wall **56** and an outer wall **57** with a space **58** thus being defined therebetween. This space **58** between walls **56** and **57** is conveniently maintained by such means as flanges **30** and **31**, conduits **35**, **43**, and **47**, flange **27**, and the like, with appropriate welds (not shown). Space **58** provides a cooling, or heating jacket for delivering heat to, or removing heat from, chamber **22**, as desired or necessary during operation of mixer **20** by circulating a fluid coolant, such as water, or a heated fluid, such as hot oil, hot water, steam, or the like in space **58**, such a cooled or heated fluid (not shown) being fed to space **58** through input ports **59** and **60**, and being removed from space 58 through output ports **61**, **62**, **63**, and **63**A. Any conventional means for insulating housing **21** may be used for a mixer **20**, if insulation is desired, as those skilled in the art will readily appreciate. Whether or not a mixer **20** needs insulation depends, of course, on the particular end use to which such is intended to be put in accordance with individual wishes.

Positioned and contained within chamber 22 of housing **21** is a paddle assembly designated herein in its entirety by the numeral **66**. Paddle assembly **66** serves as an agitator in mixer **20** and revolves on a shaft **67**. Shaft **67** in mixer **20** is generally coaxial with the longitudinal, horizontally extending axis **69** of housing **21**, and extends through respective housing **21** heads **24** and **25** into conventional bearing assemblies **70** and **71**, respectively. Any convenient bearing means may obviously be employed. Bearing assembly **70** is supported by and secured to, as by welding, bearing support spars **72** which, in turn, are similarly secured at their respective bases to head **24**, while bearing assembly **71** is supported by and secured to, as by welding, bearing support spars **73** which, in turn, are similarly secured at their respective bases to head **25**. In order to make shaft **67** be in sealing engagement with housing **21**, and thereby prevent fluid leakage from housing **21** around shaft **67** during operation of mixer **20**, a pair of conventional packing glands **74** and **75** are provided, one each in, respectively, head **24** and head **25**, circumferentially about shaft **67**. Any convenient sealing means between shaft and housing may obviously be employed. Pressure upon packing **76** and **77** in respective glands **74** and **75** is adjustable and is maintained at a predetermined value by means of tensioning nuts **78** on bolts **79** and nuts **80** on bolts **81**, respectively. Thus, shaft **67** is mounted for sealed, rotational movements within housing **21**.

A pair of diametrically opposed blade members **83** and **84** are each secured, as by welding, to shaft **67**. Each blade member **83** or **84** radially projects from shaft **67** to near (but not actual engagement with) interior wall surfaces of chamber **22**. Each blade member extends continuously and straight in an axial direction substantially without spiralling along shaft **67** in chamber **22**.

The pair of blade members **83** and **84** are similarly slotted at their respective diagonally opposite outside ends (or corners) to form slots **85** and **86**, respectively. Each slot **85** and **86** can range from about 3 to 20 percent of the total effective surface area of each blade **83** and **84**, respectively, in general. The exact cross-sectional size and location of the slot **85** or **86** in each blade can vary widely. Thus, a slot **85** or **86** may be open (not joined to, or circumscribed by) on one or two sides in a blade **83** or **84**. In general, a slot **85** or **86** does not extend longitudinally beyond the mid-line of a blade, such as mid-line **87** of blades **83** and **84**. Further, a slot **85** or **86** may extend down radially to the shaft **67** in a blade **83** or **84**. A pair of blade members such as **83** and **84** is preferably mathematically symmetrical as respects location and size of slots **83** or **84**. A single slot **85** or **86** may be comprised of more than one individual aperture in a blade **83** or **84**, depending on circumstances, such as blade strength considerations, size, etc.

A mixer **20** is adapted to achieve and maintain substantial homogeneity and uniformity in a liquid agitated by paddle assembly **66**. Preferably, a mixer **20** has a chamber **22** whose dimensions such that the ratio of the length of axis **69** in chamber **22** to the maximum diameter of chamber **22** range about 0.5 to 3.5, and more preferably, from about 1.5 to 2.5.

To rotatably drive the shaft **67**, an electric motor **88** is provided which interconnects with shaft **67** through a transmission **89** and a drive shaft **90**. Transmission **89** is equipped with a safety clutch **91** to prevent overloads. Clutch **91** can be considered to interconnect drive shaft **90** with shaft **67**. Any convenient means may be used to rotatably drive a paddle assembly-electrical, magnetic, mechanical, or the like.

Conveniently, mixer **20** has a base **93** wherein a pedestal **94** supports the drive assembly (motor **88**, shaft **90**, transmission **89** and clutch **91**) while leg assemblies **95** and **96** together support housing **21**, paddle assembly **66** and their associated elements.

FIGS. 3–7 illustrate bulk mixing principles for a highly viscous fluid **97** in a mixer **98** of this invention, the level of such fluid **97** in mixer **98** being such as to only partially fill mixer **98**. In the vertical transverse views of FIGS. **3**, **4**, and **5**, the broad surfaces of a paddle assembly **99** assure a good shear field (as in regions **101**, **102** and **103**). As paddle assembly **99** rotates, gravitational forces cooperate to produce effective fluid randomization (as in region **106**) via fluid extension (as in regions **104** and **105**) and fold-over action (as in region **107**).

FIG. **7** is a view similar to FIG. 4 but using, in place of the radially curved paddle blade configuration shown in FIG. **4**, a flattened blade configuration and a fluid of differing viscosity from that shown in FIG. 4. If radially curved, the curvature may be convex or concave with respect to the direction of paddle assembly **99** rotation.

Concurrently with the type of mixing activity illustrated in FIGS. 3–5 and 7, fluid **97** is being mixed through axial recirculation in mixer **98** by means of the slot openings **108** and **109** in paddle assembly **99** (see FIG. 6). Fluid **97** flows through slot openings **108** and **109** as paddle assembly **99** rotates on its axis in mixer **98** as diagrammed. The openings **108** and **109** give rise to equal and opposite mass gradients and paddle nip pressures which function to produce remarkably rapid axial recirculation.

Preferably, though not necessarily, a mixer **98** is not completely filled with fluid **97** in a mixing operation. A generally constant large exposed surface area on fluid **97** in mixer **98**, and a generally continuously fresh surface regeneration rate, provide a maximum initial distribution of a material **110** being fed into mixer **98** for mixing with fluid **97**, especially when such an input material **110** is fed into mixer **98** in a spray form, as from a spray head **111**. In FIG. **6**, the solid line configuration illustrates approximate fluid **97** surface position with the paddle assembly **99** in the vertical position shown and the spirally looped arrow indicates generally the pattern of axial fluid flow. The dotted line and dotted arrow illustrate approximate fluid **97** surface position and flow pattern when the paddle assembly **99** has subsequently revolved through 180°.

As shown, for example, in FIGS. 3–7, the paddle assembly **99** sweeps out substantially the entire mixer **98** interior volume with each revolution (except for slots **108** and **109**), thereby eliminating the possibility of low-turnover stagnation regions in a mixer **98**, and assuring a good cross-sectional shear field throughout fluid **97**. It will be appreciated by those familiar with fluid mechanics that in, for example, a mixer **98** of this invention, which is filled to about 10 to 90 percent by volume with a fluid or liquid, during revolutions of a paddle assembly **99** therein, three distinct types of mixing (agitation or flow patterns) may be discerned occurring simultaneously. One type may be termed cyclical vertical displacement; another, rolling action; and the third, horizontal displacement.

The cyclical vertical displacement occurs typically at a cycle rate in the range from about ½ to 60 times per minute. First, liquid in the mixer is subjected to a vertical lifting force (exerted by a paddle blade in a paddle assembly) which force is greater than that exerted downwardly by gravity, yet is at least sufficient to move vertically a portion of the total volume of liquid in the mixer from a gravitationally lower region to a gravitationally higher region in the mixer. Secondly, such so displaced liquid is subjected to a gravitational falling force by effective removal of such lifting force therefrom (as the paddle blade continues to rotate). The total gravitational falling force applied to the liquid is at least sufficient to return substantially all of such so displaced liquid to the gravitationally lower region before a vertical displacement cycle is repeated on such so displaced liquid.

The rolling action occurs in a generally peripherally located and generally horizontally extending region which extends generally circumferentially about the entire internal periphery of the mixer. This region is continuously moving in a direction which is generally normal to the horizontal. This rolling action is produced by a similarly so moving band of pressure (created by the paddle blades in a paddle assembly) which is located adjacent to but following behind said region. The region of rolling action may be considered to be discontinuous in slot regions depending upon the slot design in any given mixer. The paddle blades create a zone of pressure which exerts a force on the liquid in this region of rolling action at least sufficient to cause movement of a portion of such liquid in such region along (or in) a roughly cross-sectionally circular path. This path moves (or extends) normally away from the adjacent internal periphery of the mixer housing adjacent to such band of pressure (e.g., adjacent to a paddle blade) towards the interior of the mixer a distance which is generally less than the internal diameter across the mixer housing at a given peripheral position, then back towards such internal periphery forwardly of said band of pressure, and then towards the band of pressure adjacent such internal periphery. Between the blade tips and the mixer housing wall at and in the zone of pressure, there generally exists a shear rate of at least about $2,000^{sec^{-1}}$, the exact value of this shear rate depending on this clearance and the blade tip speed in any given mixer. This shear rate can be as great as $10,000^{sec^{-1}}$, or even greater if desired, but it is presently preferred that such rate be lower than $10,000^{sec^{-1}}$ to avoid application of excessive force to a given liquid which could deteriorate same.

The horizontal displacement occurs in a longitudinal, circulatory manner in a mixer at a cycle rate such that the actual volume of the liquid moved from one end region of the mixer to the opposite end region thereof within one minute is equivalent to from about 1/10 to 30 times the total volume of the liquid in the mixer. Such equivalent volume, and the horizontal circulation rate for such liquid so moved, respectively, are each approximately proportional to said cyclical vertical displacement cycle rate in any given instance. Such horizontal displacement is produced by the slots in the blades of the paddle assembly.

The cyclical vertical displacement, the rolling action, and the horizontal displacement take place while continuously maintaining substantially the total volume of the liquid in the mixer under laminar flow conditions. Preferably, the cyclical vertical displacement in combination with the rolling action produces fold-over action in the liquid in the mixer.

FIGS. **3–6** illustrate a type of preferred paddle blade construction wherein the radially outermost, axially extending edge portions of each paddle blade are equipped with an adjustable, radially extensible or retractable knife member **113.** Such adjustability is achieved by bolting knift **113** to each adjoining paddle by nut and bolt assemblies **114** which fit through slots **115** in each knife **113** and extend through mating holes (not shown) in each paddle. By means of a knife member **113,** the distance between the tip of each paddle

blade and the interior wall surface of a mixer may be conveniently adjusted, and in addition, the total effective land area in a given paddle assembly may be adjusted as desired. For present purposes, the land area of an individual paddle blade may be considered to refer to that part of a paddle blade edge which lies on the radially outermost peripheral outside longitudinally axially extending edge portion thereof and is thus approximately adjacent to mixer interior side wall surfaces.

It is preferred that a paddle blade not actually engage or scrape the interior wall surfaces of a mixer **98** during rotation of a paddle assembly **99** therein, and that there be a relatively small finite clearance between blade tips and interior wall surfaces of a mixer, as indicated above, which clearance is generally too small to show in, for example FIGS. **3–7,** though, for example, in FIG. **8,** a relatively large clearance **116** for an embodiment of blade assembly **99** is shown in a mixer **98.**

Turning to FIGS. **9** and **10,** there is seen a diagrammatic view of another embodiment of the invention which is herein designated in its entirety by the numeral **119.** Mixer **119** is similar to mixer **98** (see, for example, FIG. **6**) but differs therefrom in that a pair of spray heads **120** and **121** are employed for feeding material into such mixer **119** instead of the single spray head **111** of the FIG. **6** embodiment. Each spray head **120** and **121** is mounted in a vent port **122** and **123,** respectively; such a configuration is particularly advantageous where the input material can be used to condense materials in a vapor phase above a fluid in mixer **119,** as when one is using a mixer of this invention in combination with a reflux condenser to conduct a polymerization reaction (see FIG. **12** below).

Observe that vents **122** and **123** in mixer **119** are angularly displaced from the vertical so that a higher fill level can be achieved in a mixer **119** during operation thereof without plugging vents **122** and **123.** Observe that, as the paddle assembly in mixer **119** normally operates, the fluid level tends to shift from a normal position to one where the fluid level is offset from the vertical and would, if vents **122** and **123** were not so offset, tend to plug such vents **122** and **123** at high fills.

Mixer **119** employs, instead of the two-bladed paddle assembly shown, for example, in FIGS. **1–8,** a four-bladed paddle assembly which is herein designated in its entirety by the numeral **124.** As isometric view of such a paddle assembly **124** is seen in FIG. **11,** wherein, as a matter of convenience in drawing, the end edges of the paddle blades **125, 125', 126,** and **126'** are shown to be perpendicular to the shaft **127,** though it will be appreciated that, in the embodiments shown in FIGS. **9** and **10,** the corresponding blade end edges are curved so as to have a close tolerance with the inside walls of the housing **129** of mixer **119.** Observe that paddle blades **125** and **125'** and **126** and **126'** are, respectively, generally diametrically opposed to one another on shaft **127**; that such blades are slotted at their diagonally opposite corners; and that such blades are diametrically opposed to one another on shaft **127.** Slot patterns in pairs of radially adjacent blades are symmetrically located. Each paddle blade **125, 125', 126,** and **126'** is equipped with an adjustable knife **130** similar in construction details to the kinfe **113** described above in mixer **98.**

In each of the mixers **98** and **119,** an outlet port **131** and **132,** respectively, is provided in order to permit material to be withdrawn from respective mixer **98** or **119** in a continuous or discontinuous manner depending upon the mode of operation selected. Input to each of mixers **98** and **119**, respectively, is had through respective inlet ports **133** and **134**, respectively.

In FIG. **12** is shown a mixer which is herein designated in its entirety by the numeral **98'** and which is simlar in constructional details to the embodiments shown in FIGS. **6** through **8.** Mixer **98'** employs a paddle assembly **135** having radially curved blades (pair), and is equipped with a reflux condenser **136.** Mixer **98'** with reflux condenser **136** is suitable for operation as a reactor in the manufacture, as by continuous mass polymerization, of such polymers as, for examples, homopolystyrene or styrene acrylonitrile copolymer. The interior mixing action achieved in a mixer **98'** with a paddle assembly **135** can maintain a viscous polymer melt therein in a substantially isothermal condition. Appropriate jacketing (not shown) on mixer **98'** helps avoid heat losses. Monomer vapors evolved from the polymer melt (not shown in FIG. **12**) pass upwardly through a vapor space maintained over the viscous fluid melt within the lower part of mixer **98'** past spray head **137** into a vent port **139** through which the vapors are fed to the reflux condenser **136.** In condenser **136,** the vapors are condensed and then are allowed to be fed back to the interior of mixer **98'**, as through a suitable piping and pump arrangement herein designated in its entirety by the numeral **138.** In the case of, for example, homopolystyrene manufacture, the vapors evolved from a mixer **98'** during continuous mass polymerization operation comprise styrene monomer for the most part.

In this description, for convenience, it will be appreciated that in a figure wherein there is used a numeral with one or two prime marks, thereafter, such so primed numeral designates a second or a third embodiment of this invention, respectively, wherein the part or element so designated is like or similar to a corresponding part or element identically numbered, but without prime marks in the embodiment of FIGS. **1** and **2.**

Referring to FIGS. **13** through **15,** there is seen an illustration of one preferred paddle assembly embodiment of the present invention herein designated in its entirety by the numeral **150.** Paddle assembly **150** is seen to employ a shaft **151** which has affixed thereto, as by welding or the like, a pair of diametrically opposed blade members **152** and **153.** Formed in paddle assembly **15** in diagonally opposite corner regions of respective paddle blades **152** and **153** are slots **154** and **155** which extend from the axial side edge of each such paddle blade **152** and **153** to shaft **151.** The paddle assembly **150** has blade members **152** and **153** which are similarly both radially and convexly curved with respect to the direction of shaft rotation. To provide rigidity and support for blades **152** and **153,** a plurality of axially spaced but radially extending gussets **156** are provided. Each gusset **156** extends from shaft **151** radially outwardly along the concave surface of each blade member **152** and **153,** respectively, and is conveniently secured to the adjoining shaft **151** and blade member **152** (or member **153,** as the case may be) by means of welding or the like. The added rigidity provided by gussets **156** permits one to use the paddle assembly **151** in a relatively large sized mixer and/or in one in which a relatively highly viscous fluid is to be mixed or agitated. Along the radially outwardly axially extending tip portions of each blade **152** and **153,** respectively, there is mounted a knife or a doctor blade **156.** Knife blade **156** is mounted, for example (see FIG. **15**), through each paddle blade **152** and **153** by means of appropriate nut and bolt assemblies **157.** A slot **160** is formed in doctor blade **159** for each nut and bolt assembly **157** to provide for adjustment in a radial direction of the blade. A slot **158** is formed in blade **152** and in blade **153** so that when paddle assembly **150** is mounted functionally in a mixer housing (not shown), a sensor, such as a pressure sensor or level sensor, can be inserted into the mixer from a side wall into the mixer interior without interferring with rotational movements of paddle assembly **150.**

It is preferred to use a paddle assembly, such as assembly **150,** with solid blades (except in slot regions); however, small drain holes, or the like (not shown) for draining fluid from a paddle assembly when it stops rotating may be provided, if desired, without adversely affecting this invention, particularly when the holes are small and the viscosity of the fluid being operated upon in the mixer is high.

It is preferred to use a paddle assembly, such as assembly **150,** wherein the blades are radially curved because such a generally cross-sectionally S-shaped configuration in a paddle blade assembly tends to retain similar geometry at different mixer fillages.

In operating a mixer of this invention using a highly viscous fluid, it is preferred to employ rotational speeds for the paddle assembly therein which produce laminar flow in such viscous fluid.

It will be appreciated that, while the embodiments of the present invention as shown and described herein are necessarily limited to a few forms of the present invention, many variations and modifications thereof are feasible and practical without departing from the spirit and scope of the present invention disclosed and claimed herein.

What is claimed is:

1. A mixer adapted for use in processing highly viscous fluids comprising:

A. a housing enclosing an interior chamber whose walls are generally radially symmetrical with respect to a longitudinal axis extending therethrough, said housing having defined therein port means adapted for input and output of material into and from said chamber,

B. a paddle assembly positioned generally within said housing and comprising:

1. a shaft rotatably mounted at its opposite end portions in said housing and extending generally longitudinally through said interior chamber parallelly to said axis, and

2. at least one pair of diametrically opposed blade members, each blade member radially projecting from said shaft, each blade member axially extending generally continuously along said shaft, each such pair of blade members being slotted in the region of their respective diagonally opposite outside corners, the effective total slot cross-sectional surface area in each blade member ranging from about 3 to 50 percent of the total effective surface area of such blade member, the diameter of each such pair of blade members at any given location along said shaft except in slot locations being not less than about **90** percent of the diameter of said interior chamber measured at about the same location,

C. bearing means functionally located between said housing and said shaft and adapting said shaft for rotational movements, and

D. sealing means for said shaft adapted to prevent fluid leakage between said shaft and said housing.

2. The mixer of claim **1** wherein said paddle assembly has one pair of said blade members with generally equally sized slots in each individual blade.

3. The mixer of claim **2** wherein each of said blade members is substantially flat and planar.

4. The mixer of claim **2** wherein each of said blade members is similarly radially and convexly curved with respect to the direction of shaft rotation.

5. The mixer of claim **1** wherein said chamber has dimensions such that the ratio of the length of said chamber along said axis to the maximum diameter of said chamber ranges from about 0.5 to 3.5.

6. The mixer of claim **1** wherein said shaft is substantially coaxial with said axis.

7. The mixer of claim **1** wherein the ratio of the clearance between blade tips and said chamber walls at substantially all locations in said chamber along said axis except opposite slot locations ranges from about 0.01 to 0.0001.

8. The mixer of claim **1** wherein the effective total slot cross-sectional surface area in each blade ranges from about 4 to 20 percent of the total effective surface area thereof, and wherein the slot in each respective blade of such a pair of blades is substantially equally sized and similarly located at respective diagonally opposite outside ends thereof.

9. The mixer of claim **1** further equipped with drive means for revolvably driving said shaft including a power head and power transfer means.

10. The mixer of claim **1** wherein there is an input port equipped with a spray head adapted to spray input materials delivered into said mixer.

11. A paddle assembly adapted for use in a mixer chamber whose walls are generally radially symmetrical with respect to a longitudinal axis extending therethrough, said paddle assembly comprising:

A. a shaft, and

B. at least one pair of diametrically opposed blade members,

C. each blade member radially projecting from said shaft to near engagement with interior wall surfaces of said chamber,

D. each blade member axially extending generally continuously along said shaft,

E. each such pair of blade members having its individual blade members slotted in the region of their respective diametrically opposite outside ends, the effective total slot cross-sectional surface area in each blade ranging from about 3 to 50 percent of the total effective surface area of such blade.

12. A paddle assembly of claim **11** wherein the effective total cross-sectional surface area in each blade ranges from about 4 to 20 percent of the total effective surface area thereof, and wherein the slot in each respective blade of such a pair of blades is substantially equally sized and similarly located at respective diametrically opposed outside ends thereof.

13. The paddle assembly of claim **11** wherein each of said blade members is substantially flat and planar.

14. The paddle assembly of claim **11** wherein each blade member is similarly radially and convexly curved with respect to the direction of shaft rotation between said shaft and said interior wall surfaces.

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