

[54] **FLUID DIFFUSION APPARATUS**

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[52] U.S. Cl. 261/87

[51] Int. Cl. B01f 3/04

[58] Field of Search 261/87

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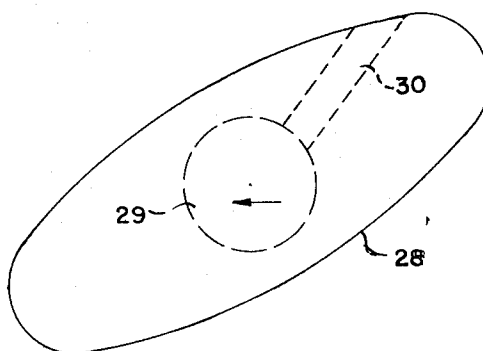
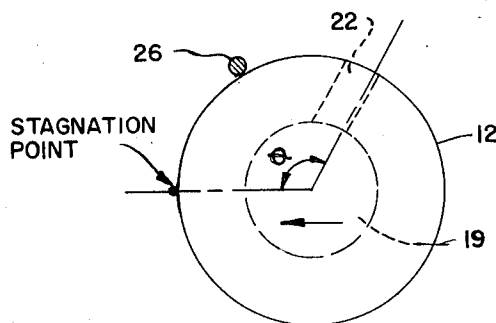
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[57]

ABSTRACT

Apparatus for entraining a light fluid into a denser fluid. A substantially hollow vessel is provided which is adapted to contain therein the denser fluid. A rotatable drive shaft having impeller means arranged at its lower end is disposed within the vessel. Both the drive shaft and the impeller means have interconnecting passageway means. The drive shaft passageway means includes light fluid inlet means whereas the impeller means passageway means includes aperture means transverse to and in communication with both its passageway means and the interior of the vessel. The aperture means are also spaced radially outwardly of the drive shaft. As the impeller means is rotated by means of the drive shaft, the lighter fluid is passed from the fluid inlet means through the drive shaft and out of the aperture means whereby the lighter fluid is entrained in the denser fluid within the vessel.

2 Claims, 6 Drawing Figures



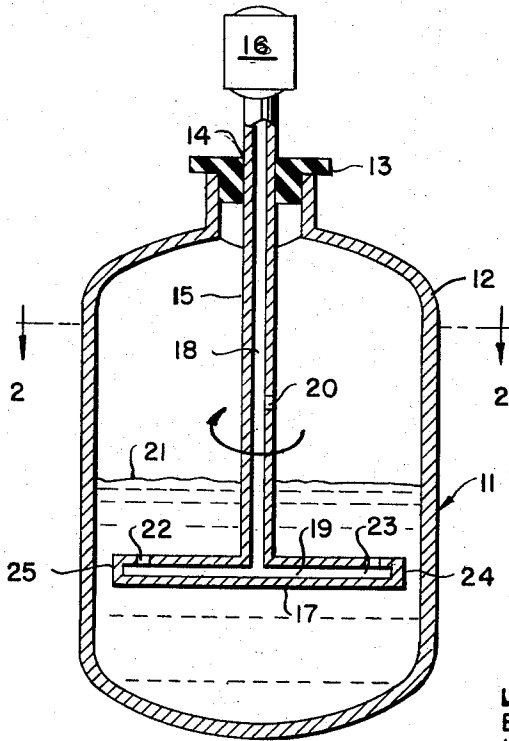


FIG. 1

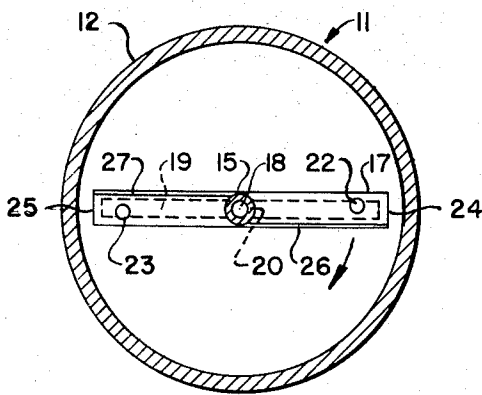


FIG. 2

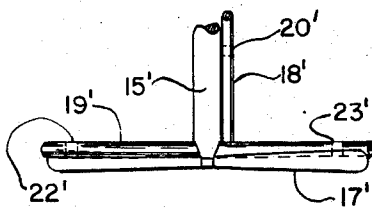


FIG. 1a

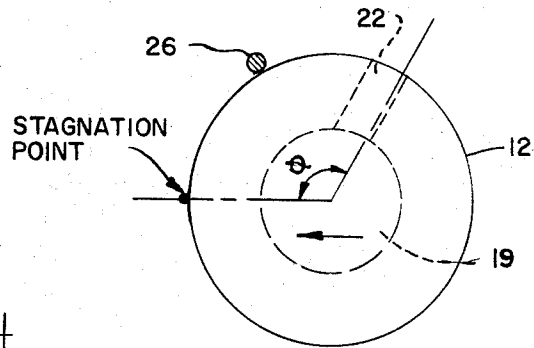


FIG. 3

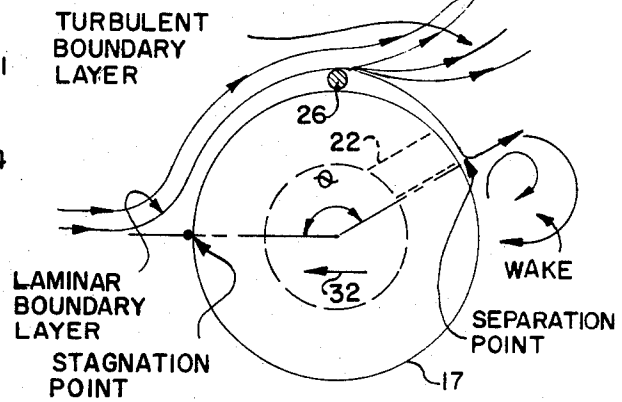


FIG. 4

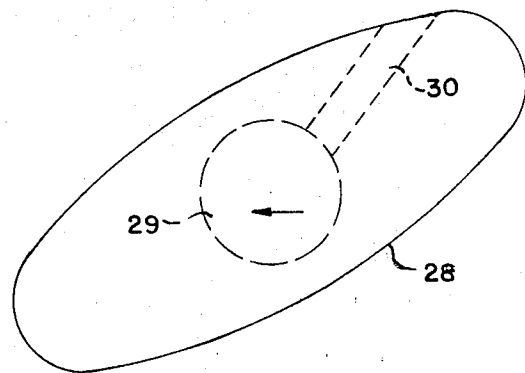


FIG. 5

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FLUID DIFFUSION APPARATUS

REFERENCE TO RELATED APPLICATION

This application is a continuation of application Ser. No. 724,043, filed April 25, 1968.

BACKGROUND OF THE INVENTION

1. Field of the Invention and,

This invention relates to fluid diffusion apparatus, and, more particularly, to apparatus for rapidly diffusing a light fluid into a heavier fluid, such as a gas into a liquid, by agitation.

2. Description of the Prior Art

Stirring devices for diffusing a light fluid into a heavier fluid are well known in the prior art. In the past, when one desired to entrain a light fluid into a denser fluid, such as a gas into a liquid, the compressed gas was merely blown into a liquid or blown into the liquid under a strong conventional stirrer. Recently, it has been proposed to introduce the gas into the liquid through a hollow stirrer which sucks the gas into the liquid. These devices, on turning, automatically suck up the gas above the liquid and very finely distribute it in the liquid without creating a vortex. The suction effect of these stirrers is caused by the acceleration of the fluid which causes a diminished pressure arising around the stirrer edges. For gas transport, these low-pressure regions are connected to the gas volume above the liquid by cavities or channels in the stirrer and by a hollow stirrer shaft. Thus, hollow stirrers are useful in those cases in which it is difficult to bring the gas into the liquid. This is the case with toxic or aggressive gases, at high pressures, or when the liquid to be gassed contains finely granular solids (as, for example, in catalysis with a suspended contact, the processing of sewage effluents, etc.) which easily clogs up the apertures of gas distributors.

The more unfavorably constructed such a stirrer is from a hydrodynamic point of view, the lower the partial vacuum, that is, the greater the suction effect, at the same circumferential speed, which can be produced with it. Various examples of such prior art hollow stirrers are discussed in an article entitled, "Auslegung von Holtrührern zur Flüssigkeitsbegasung" (Design of Hollow Stirrers for Gassing of Liquids) by M. Zlokarnik which appeared in the March 1966 issue of *Chemie-Ing.-Techn.* 38, No. 3, pp. 357-66 (1966). One example discussed is the so-called "tube stirrer" having hollow tubes forming an impeller, the outer tube ends being obliquely cut off and open so that a large suction-producing edge is formed. However, very little is known of the efficiency and economy of such prior art stirrers, especially when used in the closed containers required for diffusing gases into liquids.

SUMMARY OF THE INVENTION

It is an object of this invention to provide improved diffusion apparatus for continuously entraining a light fluid into a denser fluid.

It is a further object of this invention to provide fluid diffusion apparatus which requires no external pumping means.

It is a still further object of this invention to provide fluid diffusion apparatus which entrains light fluids into denser fluids without the necessity for extremely high entraining impeller velocities.

The objects of this invention are carried out by providing a substantially hollow vessel containing a light fluid and a denser fluid. A rotatable drive shaft carrying an impeller at its lower end is disposed in the denser fluid and below the light fluid. Both the drive shaft and the impeller are in fluid communication through interconnecting passageway means and both passageway means include aperture means for introducing the light fluid into the drive shaft passageway means and out of the impeller passageway means wherein the light fluid is diffused in the dense fluid. The aperture means arranged in the impeller passageway means are spaced radially outwardly of the drive shaft and are transverse to the passageway means of the impeller. Thus, the impeller itself, normally a part of the stir-

ring system, is used to sparge the liquids so that capital costs are saved.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a vertical sectional view of preferred apparatus for carrying out the invention;

FIG. 1a is a vertical view of a modification of a portion of the apparatus of FIG. 1;

FIG. 2 is a view taken along lines 2-2 of FIG. 1;

FIG. 3 is an end view of a portion of the apparatus of FIG. 2 taken in the direction of the arrow;

FIG. 4 is a diagrammatic view of the flow lines caused by the apparatus of FIG. 1; and

FIG. 5 is a modification of a portion of the apparatus of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings, FIG. 1 shows preferred apparatus 11 for carrying out the invention. An imperforate, substantially hollow tank or vessel 12 is shown adapted to contain a gas-liquid mixture therein. Although the invention will be described with reference to a gas-liquid mixture, obviously it is applicable to any mixture of fluids whereby it is desired to diffuse a light fluid into a denser fluid. Also, although a closed vessel will be described in accordance with the teachings of the invention, obviously the lighter fluid may be introduced into the vessel from an outside source, particularly when the lighter fluid is not a gas or the vessel may be open with a light fluid, such as oxygen, sparged into a denser fluid.

Vessel 12 is preferably closed at its upper end by a suitable closure means 13. Closure means 13 is provided with a preferably centrally located opening 14 for the passage therethrough of a drive shaft 15. Drive shaft 15 is coupled at its upper end, i.e., outside of vessel 12, to suitable motive means, such as a motor 16. Obviously the motive means could be hydraulic or pneumatic, electrical or mechanical. If desired, shaft 15 may be turned manually by providing suitable handle means at its upper end.

Drive shaft 15 passes through opening 14 in fluid-tight relationship thereto. Shaft 15 has a substantially preferably cylindrical impeller 17 disposed at its lower end. In FIG. 1, impeller 17 is shown as being integral with drive shaft 15. Obviously, impeller 17 may be a separate component of the apparatus 11, screw-threaded or otherwise fastened in fluid-tight engagement to the lower end of shaft 15.

Both drive shaft 15 and impeller 17 include intercommunicating passageway means. As shown in FIG. 1, passageway means 18 and 19, respectively, extend along the longitudinal axes of drive shaft 15 and impeller 17. At least one aperture 20 interconnects passageway 18 with the gas disposed in the upper portion of vessel 12 and above interface 21. Although passageway means extending through the drive shaft 15 and impeller 17 have been disclosed, for convenience of illustration, obviously other types of interconnecting passageway means may occur to one skilled in the art such as a hollow tube or rod fastened to a solid drive shaft and interconnecting with a similar tube or rod fastened to a solid impeller such as shown in FIG. 1a. Here, a solid drive shaft 15' is shown having a propeller-like solid impeller 17' fastened to or integral with its lower end. A hollow rod 18' integral with or otherwise fastened to shaft 15' intercommunicates with a like hollow rod 19' on impeller 17'. Apertures 20', 22' and 23' are disposed in rod 19' in the manner discussed herein with respect to the embodiment of FIG. 1. The preferred arrangement of the passageways and apertures, as discussed hereinbelow with respect to the embodiment of FIG. 1, are also deemed applicable to the embodiment of FIG. 1a. Further, although hollow rods have been disclosed in the embodiment of FIG. 1a, obviously the "rods" may be bluff or semi-cylindrical bodies as will also be discussed in detail hereinbelow.

Impeller 17 is provided with at least one aperture interconnecting passageway 19 with the liquid disposed in the lower

portion of vessel 12 and below interface 21. As can best be seen in FIG. 2, two such apertures 22 and 23 are shown interconnecting the upper portion of impeller 17 with the liquid in vessel 12. Any number of apertures may be provided; however, two such apertures are preferred arranged opposite each other in impeller 17 as best seen in FIG. 2. The first aperture 22 is preferably disposed on the side of the longitudinal axis of impeller 17 opposite the aperture 23. Further, both apertures 22 and 23 are preferably spaced radially outwardly of the longitudinal axis of drive shaft 15 and closer to the outer extremities 24 and 25 of impeller 17 than to the longitudinal axis of drive shaft 15. Thus, apertures 22 and 23 may be at any position on impeller 17. However, the further they are from drive shaft 15, the more lighter fluid that can be sparged. The closer apertures 22 and 23 are to ends 24 and 25 the better; however, too close may result in the lighter fluid slipping around the ends of impeller 17. The closer apertures 22 and 23 are to drive shaft 15, the lesser the velocity of fluid. Apertures 22 and 23 are preferably disposed on the impeller 17 such that, as impeller 17 rotates in the direction of the arrow in FIG. 2, aperture 22 is disposed on the upper portion of impeller 17 opposite the direction of rotation. Although apertures 22 and 23 are illustrated in FIG. 1 as holes having their axis parallel to the longitudinal axis of drive shaft 15, the particular configuration of these apertures is a matter of design choice.

Referring now to FIG. 3, it can be seen that aperture 22 preferably lies at a point between at least 30° from the stagnation point of impeller 17 to a point 180° with respect to the stagnation point of impeller 17. The stagnation point will be discussed further hereinbelow with respect to FIG. 4. Although aperture 23 is not illustrated in FIG. 3 for convenience of illustration, aperture 23 preferably lies at a point between at least 30° from the stagnation point of impeller 17 to a point 180° from the stagnation point similar to that of aperture 22 but taken in the opposite direction of the arrow in FIG. 2.

As discussed hereinabove and can best be seen in FIGS. 1 and 2, the outer extremities 24 and 25 of impeller 17 are closed and have their planar faces substantially parallel to the longitudinal axis of drive shaft 15. If desired, impeller 17 may be provided with a pair of tripping wires 26 and 27, respectively, welded or otherwise secured to impeller 17 along the upper face thereof. Wires 26 and 27 are disposed above the horizontal centerline of impeller 17 and before apertures 22 and 23 as best seen in FIG. 2 for creating a turbulence thus causing the laminar boundary layer to separate sooner.

In operation, impeller 17 is rotated by means of motor 16. The gas disposed above interface 21 enters the passageway 18 in drive shaft 15 through aperture 20. The gas enters the passageway 19 in impeller 17 and exits out of aperture 22 into the liquid disposed below interface 21.

As impeller 17 is moved through the liquid, the liquid is accelerated thereby causing a decrease in pressure around the substantially cylindrical impeller 17. At a critical speed, the decrease in pressure due to the acceleration of the fluid around impeller 17 just compensates for the head of liquid disposed above the apertures 22 and 23. At this point, the gas begins to be entrained in the liquid.

The actual rate of entrainment depends on numerous factors. Among these are the following: the speed of rotation of impeller 17; the radial distance between apertures 22 and 23 and the axis of rotation (i.e., the longitudinal axis of drive shaft 15); the angular distance between the apertures 22 and 23 and the stagnation point; the area of the apertures 22 and 23; the head of liquid above the impeller apertures 22 and 23; and the impeller profile.

Impeller 17 may have a variety of configurations which are sufficient to form substantially the flow patterns illustrated in FIG. 4 as will be discussed further hereinbelow. Preferably, impeller 17 is a bluff body, such as a cylinder, ellipse or hydrofoil, which, when moved through a liquid, accelerates the liquid thus causing a decrease in pressure which is used as a driving force to sparge the liquid.

FIG. 5 shows an end view of an alternate embodiment of impeller 17. In this embodiment, impeller 28 is a flattened ellipse or hydrofoil having a central cavity or passageway 29 and an aperture 30 similar in operation and function to the passageway 19 and aperture 22 of the embodiment of FIGS. 1 through 3. A tripping wire would not be necessary for an impeller of this configuration.

Referring now to FIG. 4, it is assumed that impeller 17 is moving in the direction of the arrow 32. The stagnation point is the point lying along the horizontal centerline of impeller 17 where the liquid first contacts impeller 17 as it is being rotated through the liquids. As the fluid flows and is accelerated around the impeller 17 in the direction of the arrows, a laminar boundary layer builds up which then breaks up into a turbulent boundary layer which finally separates completed from impeller 17. The head of fluid pulled by aperture 22 in impeller 17 before the wake created as seen in FIG. 4 is substantially at an angle of approximately 100° to 120° from the stagnation point (i.e., angle θ). In other words, apertures 22 and 23 are preferably disposed between 30° and 180° from the stagnation point; the point of greatest efficiency lies at angle θ , or approximately 100° to 120° from the stagnation point as illustrated in FIG. 4.

Thus, a single aperture or a plurality of apertures may be disposed at any position along the periphery of impellers 17 and 28. The closer these apertures are disposed to the drive shaft 15, the less effective they become as the velocity of the shaft 15 at this point becomes less. Preferably, then, the exit apertures 22, 23 and 30 are disposed on the upper surface low-pressure areas of impellers 17 and 28, on the side of the impellers opposite the direction of rotation of the impellers, closer to the outer extremities of the respective impellers than to the drive shaft 14, and lying within an angle of approximately 30° to 180° with respect to the stagnation point. In a most preferred embodiment, the gas exit apertures are disposed at a position approximately 100° to 120° from the stagnation point. Finally, the impeller itself is preferably a bluff body so as to cause a decrease in pressure when the fluid is accelerated as the impeller is moved through the fluid.

The essential cause of the gas throughput into a liquid at a given number of revolutions of the impeller is the suction produced by the impeller. Thus, for a given shape of the impeller, the number of revolutions per unit amount of time and the distance of the orifice from the drive shaft are of importance. The material characteristics of the liquid must also be considered, such as density, kinematic velocity and surface tension. Generally, the specific characteristics of the sucked-in light fluid if it is a gas is of no importance as far as suction is concerned. The specific characteristics of the vessel may be important as will be the mounting of the impeller in the vessel. Thus, although a closed vessel has been described above, obviously similar results may be obtained with other types of vessels and various types of fluids.

It can be seen from the foregoing that the shape of the impeller and the position of the impeller aperture means exert an exceedingly strong effect on the gas throughput and on the consumed energy of the apparatus.

Although preferred embodiments of the invention have been discussed, minor variations and alterations may occur to one skilled in the art, and it is to be understood that such modifications fall within the spirit and scope of the appended claims.

I claim as my invention:

1. Apparatus for entraining a light fluid into a denser fluid comprising:

- a substantially hollow closed vessel adapted to contain therein said denser fluid;
- a rotatable drive shaft disposed within said vessel;
- said drive shaft having passageway means extending longitudinally thereof;
- light fluid inlet means in communication with said passageway means for introducing light fluid into said passageway means;

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impeller means arranged at the lower end of said drive shaft and adapted to be rotated thereby, said impeller being formed from a cylindrical body and having its outer extremities imperforate and parallel to the longitudinal axis of said drive shaft;

said impeller means having passageway means extending longitudinally thereof in communication with the first-mentioned passageway means;

aperture means arranged transverse to and in communication with the second-mentioned passageway means for introducing light fluid from the second-mentioned passageway means into the interior of said vessel;

said aperture means being spaced radially outwardly from said drive shaft and lying at an angle having its apex at the center of said cylindrical body of from approximately 100° to 120° from the initial point of contact of said cylindrical body with said denser fluid when said cylindrical body is rotated; and

fluid tripping wire means disposed along the upper surface of said body between said aperture means and the point of initial contact of said body with said fluid when said impeller means is rotated for creating a turbulence when said impeller means is rotated through said denser fluid.

2. Apparatus for entraining a light fluid into a denser fluid comprising:

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a substantially hollow vessel adapted to contain therein said denser fluid;

a rotatable drive shaft disposed within said vessel;

said drive shaft having passageway means extending longitudinally thereof;

light fluid inlet means in communication with said passageway means for introducing light fluid into said passageway means;

impeller means arranged at the lower end of said drive shaft and adapted to be rotated thereby, said impeller being formed from an elongated body of elliptical cross-section; said impeller means having passageway means extending longitudinally thereof in communication with the first-mentioned passageway means;

aperture means arranged transverse to and in communication with the second-mentioned passageway means for introducing light fluid from the second-mentioned passageway means into the interior of said vessel; and

said aperture means being spaced radially outwardly from said drive shaft and lying at an obtuse angle from the direction of rotation of the elliptically-shaped body, said obtuse angle having its apex at the center of said elliptically-shaped body.

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