United States Patent

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[54] **AERATION APPARATUS**
24 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **261/91,** 210/219, 259/108
[51] **Int. Cl.** **B01f 7/18**
[50] **Field of Search** 209/169; 210/219; 259/108; 261/91, 93

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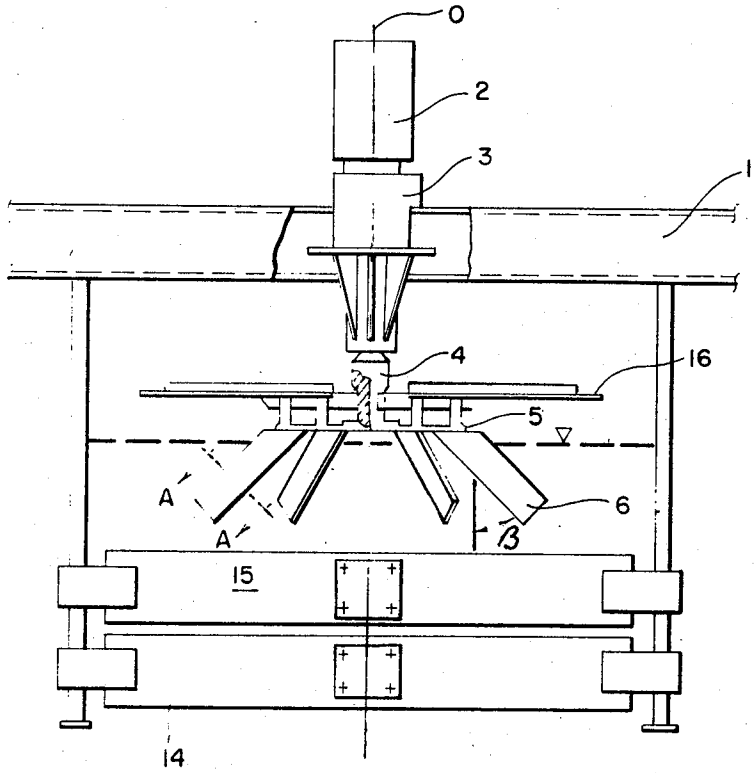
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ABSTRACT: Apparatus for introducing a gas into a liquid by rotating about a vertical shaft a set of long, narrow blades, which extend downwardly and outwardly into the liquid in a radial direction, and which blades are inclined relative to a vertical radial plane passing through the blades. Air is drawn into the liquid on the rear side of the blades and liquid is caused to flow upwardly across the blades.



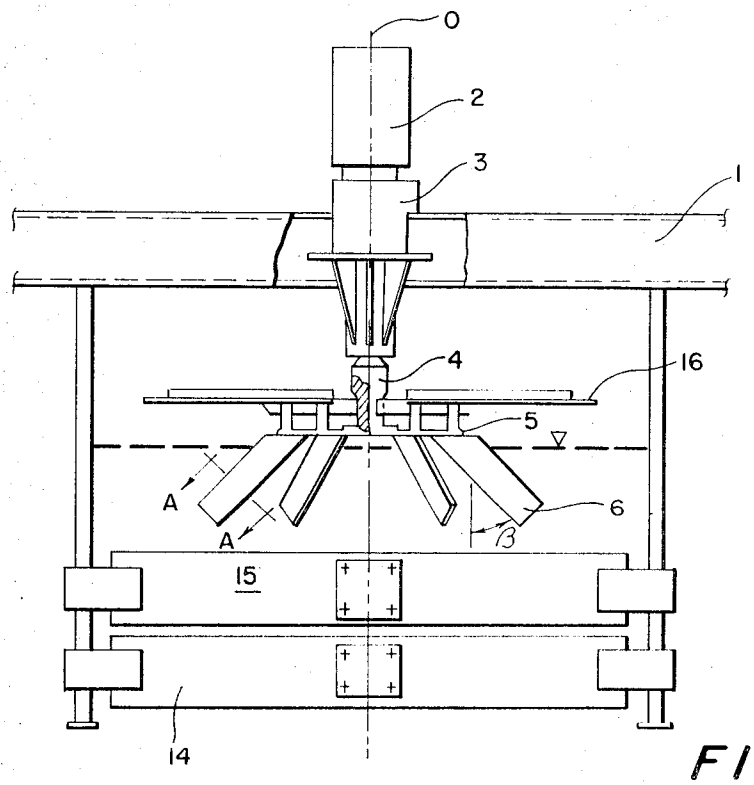


FIG. 1

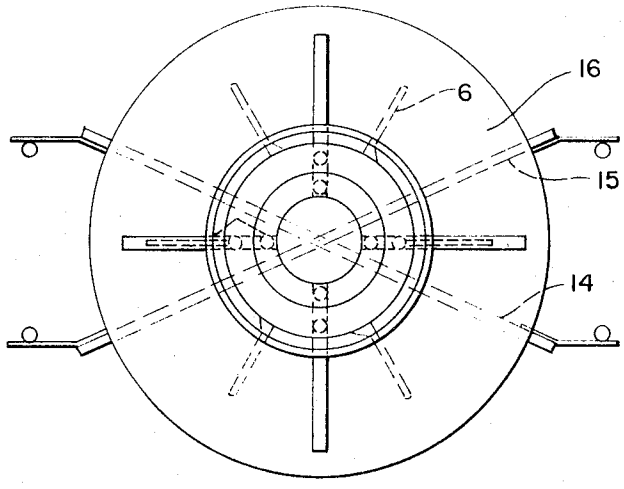


FIG. 2

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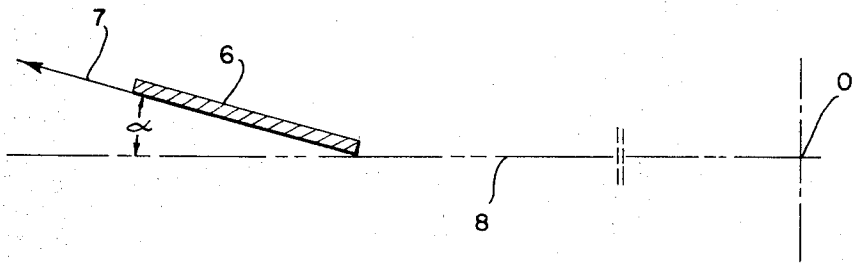


FIG. 5

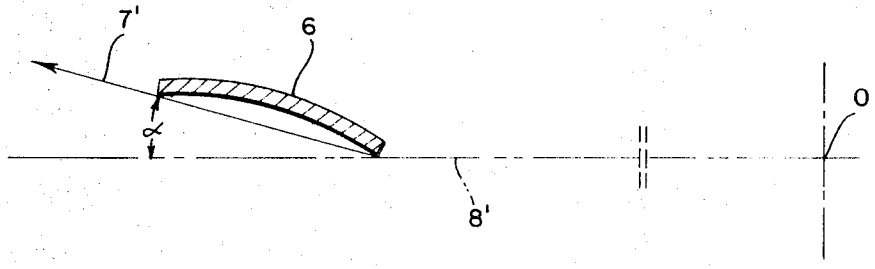


FIG. 6

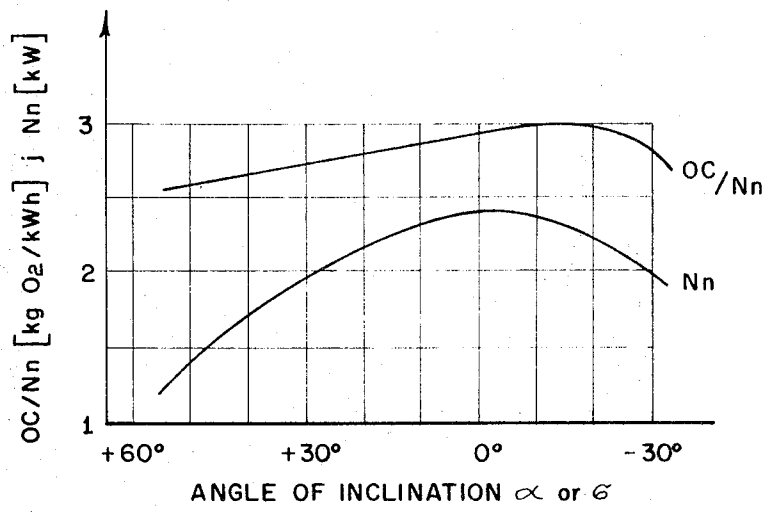


FIG. 7

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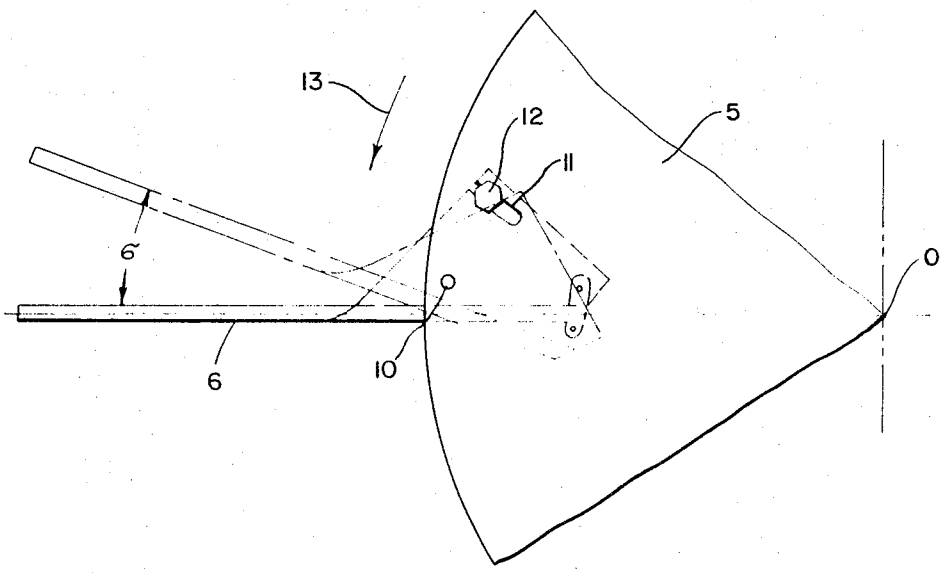


FIG. 3

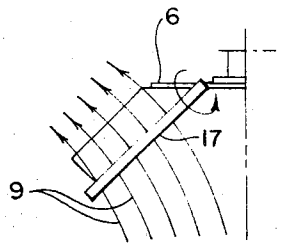


FIG. 4

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AERATION APPARATUS

BACKGROUND OF THE INVENTION

This invention relates generally to the subject of introducing gases into liquids, and more particularly, to an apparatus for aerating waste water such as sewerage. In known equipment for introducing a gas into a liquid, the gas in introduced to the liquid through hollow elements having openings arranged at zones in the liquid whereat a subatmospheric pressure is created as the hollow elements are passed through the liquid. These known hollow elements are designed with a streamlined profile for providing favorable flow characteristics as the hollow elements move through the liquid. However, the disadvantage of this apparatus is that it is quite uneconomical since it provides only a very small volume of gas to be introduced into the liquid, without a corresponding reduction in the power demand required to operate the apparatus.

It is also known to provide surface rotors with short wide blades, which blades cut into the surface of the liquid and produce strong turbulent whirls, which whirls serve as a means for introducing gas into the liquid. The absolute volume of gas introduction is considerably higher than that which is provided with the hollow elements. However, in this arrangement the power requirement increases even more than the increase in gas introduction so that the ratio of power to gas introduction remains low, and consequently, this type of apparatus is also uneconomical.

Thus, there exists a continuing need for a new, improved and more economical arrangement for introducing a gas into a liquid.

SUMMARY OF THE INVENTION

Thus, it is a purpose of this invention to provide a new and improved aeration apparatus which is more efficient, and hence more economical than aeration apparatus known heretofore.

In accordance with the present invention, the gas introduction elements are in the form of long, narrow blades mounted for rotation about a vertical axis and extending downwardly and outwardly, relative to the rotational axis, such that at least the lower ends of the blades are immersed into the liquid. Preferably each blade is inclined, relative to a vertical radial plane passing through the blade such that the upper part of the blade forms with said plane an angle between 15° in front of the said radial plane to 30° on the rear side of the radial plane, wherein the terms "front" and "rear" refer to the direction of rotation of the blades about the vertical axis. The optimum portion of the range appears to be from 5° to 30° on the rear side of the said radial plane, and the optimum value within this range appears to be approximately 15° on the rear side of the plane. Unlike the short blades discussed above, the blades of the present invention have a ratio of length to width which is preferably greater than 2:1 and up to approximately 5:1. The optimum range appears to be 3:1 to 4:1 and the optimum value appears to be 3.5:1.

As the blades are rotated through the liquid, strong turbulent whirls on the rear side of the blades cause air to be drawn into the liquid. Concurrently, the downward and outward orientation of the blades, together with the angle of inclination of the blades relative to the vertical radial plane, causes the liquid to flow from below and from the center of the apparatus upwardly across the blades. Consequently, the movement of the liquid is across the path of the incoming gas bubbles and this causes a thorough mixing of the liquid and gas. Further, it to be noted that the flow of liquid, which is quite large, is from the lower central part of the liquid where the gas content is particularly low, and that this flow is across the gas-enriched portion of the blades.

The angle of inclination of the blades, relative to the vertical radial plane, can be varied over a range, and of course the power demand for operating the apparatus varies with the said angle of inclination. It has been found that the flow of gas into the liquid is considerably increased relative to that attained with the same power demand with previously known apparatus. Further, although the maximum power demand is required when the blades lie in the said vertical radial plane, it has been found that the absolute volume of gas introduction reaches a maximum when the blades are inclined approximately 15° to the rear of the said vertical radial plane. At this angle, of course, the power demand is less than maximum.

A number of arrangements are possible for providing the said inclination of the blades relative to the said vertical, radial planes. For describing this angle, it is convenient to refer to the "profile chords" which are the shortest straight lines perpendicular to the longitudinal axis of the blades connecting opposite longitudinal edges of the blades. One way to set the angle of inclination is to turn the blades such that the profile chords turn about the longitudinal axis of the blade. Moreover, a blade can be twisted by different amounts along its length such that different inclination angles are provided along the length of the blade. Further, the said angle of inclination of a blade can be provided by displacing the profile chords about a vertical axis parallel to the vertical axis of rotation such that the outer, lower ends of the blades follow the inner upper parts of the blades. This turning of the blades about a vertical axis can be provided in addition to, or in lieu of the turning of the blades about their longitudinal axes. Moreover, this turning of the blades about a vertical axis can be variable along the length of the blades so that the longitudinal axes of the blades appear curved in the plan view.

Regardless of which method is chosen for providing the angle of inclination between the profile chords and the vertical radial plane, it is normally preferable, at least for purposes of economics, to construct the blades with the longitudinal axes straight and with the profile chords at a constant angle along the length of the blade. However, in some fields of application, an increase of gas introduction readily justifies the cost of the more complex shape.

According to another feature of the invention, the upper, inner ends of the blades are mounted in a vertical plane for pivotal movement about an axis parallel to the rotation axis. With this arrangement, it is possible to vary the inclination angle of the blades by simply rotating the blade about the said vertical, pivotal axes.

The longitudinal axes of the blades preferably form an angle of 30° to 60° with the vertical. In a preferred embodiment of the invention, this angle is approximately 45°.

Although the exact shape of the blades can be varied within a considerable range, it must be observed that on the one hand a suitably directed flow of liquid is created, and on the other hand a turbulence is created for introducing the gas bubbles into the liquid. Therefore, the blades are advantageously provided, at least at their lower ends, with substantially planar surfaces. This is especially true adjacent the forward longitudinal edge of the blade (in the direction of flow). However, the advantageous results of the invention may also be achieved by using surfaces of other shapes such as convex or concave. For purpose of economics, it is normally preferable to design the blades as plane plates having a constant width along their length. Similarly, it is economically advantageous that the blades be made from a single piece of material and that the upper, inner ends of the blades be provided with right-angle portions for mounting the blades on the apparatus.

The liquid flow is produced by means of the blades alone, without additional elements such as effluent channels, etc. This minimizes the risk of jamming or hooking of the apparatus because of solids carried by the liquid. The possibility does exist, however, that the liquid, after flowing past the blades, will very quickly return to the bottom and flow once again across the blades. However, it is preferable that this liquid remain away from the apparatus so that new unaerated liquid can flow from the lower central portion of the apparatus up across the blades. To provide this result, the present invention also includes a set of vertical, downwardly extending stationary baffle plates which cross below the rotational axis and

are located one above the other. Such an arrangement assures that the blades are loaded uniformly about the circumference of the apparatus. With this arrangement, an unbalanced off-centered loading of the blades is prevented, and consequently the durability of the apparatus is considerably increased.

In apparatus of the present type, the motor which provides rotational movement of the blades is often arranged just slightly above the rotor on which the blades are mounted. In order to protect the motor from the effects of sprayed water, the rotor is provided with a disc which rotates with the apparatus and which is mounted above the blades. This disc also increases the flow of gas into the liquid. Because of the upward flow of the liquid across the blades, some of the liquid is sprayed upwardly. This liquid strikes the disc and falls back into the body of liquid, carrying with it additional air from the surrounding atmosphere. The disc is preferably opened at its center and designed as an annular ring so that the atmospheric air can pass from above to the area beneath the disc. In addition, the disc improves the flow characteristics of the liquid by receiving the liquid thrown upwardly and deflecting the same to the outer portion of the apparatus. For this purpose, the disc outer circumference is preferably bent upwardly by an angle of 10° to 20°but preferably 15°.

Thus, it is an object of this invention to provide a new and improved aeration apparatus.

It is another object of this invention to provide a new and improved apparatus for introducing a gas into a liquid wherein the liquid is moved in a path across the path of gas introduction.

It is another object of this invention to provide an aeration apparatus wherein long, narrow blades, having a predetermined inclination, and which extend downwardly and outwardly into a liquid, are rotated about a vertical axis.

It is another object of this invention to provide an aeration apparatus having a plurality of blades extending downwardly and outwardly relative to a vertical rotation axis, at an angle of 30° to 60° but preferably 45°, wherein the blades are inclined relative to vertical radial planes passing therethrough, the angle of inclination preferably being 15° to the rear of the said vertical plane, plus or minus °.

Other objects and the attendant advantages of the present invention will become apparent from the detailed description to follow together with the accompanying drawings. Brief Description of the Drawings

There follows a detailed description of preferred embodiments of the invention to be read together with the accompanying drawings. However, it is to be understood that the detailed description and the accompanying drawings are provided only for purposes of illustration and that the invention is capable of numerous modifications and variations apparent to those skilled in the art without departing from the spirit and scope of the invention.

FIG. 1 is a side elevational view of a preferred embodiment of the invention.

FIG. 2 is a plan view of the apparatus shown in FIG. 1.

FIG. 3 is an enlarged plan view corresponding to a portion of FIG. 2.

FIG. 4 is an elevational view of one blade showing also the direction of liquid flow thereacross.

FIG. 5 shows a section of blade taken along line A–A of FIG. 1, but wherein the angle of inclination of the blade is greater than in FIG. 1.

FIG. 6 is a sectional view similar to FIG. 5 but showing a modification.

FIG. 7 is a graph illustrating the relationship between gas introduction and power demand, both shown in relation to the angle of inclination of the blades. Detailed Description of the Preferred Embodiments

Referring now to the drawings, like numerals are used to represent like elements throughout the specification.

Referring to FIGS. 1 and 2 there is shown a frame 1 having a motor 2 and a gearing arrangement 3 arranged thereon. A vertical shaft 4 extends downwardly from the gearing. A plurality of blades 6 are fixed to the shaft 4 for rotation therewith through holding member 5. These blades 6 are long and narrow. In the preferred embodiment, as shown in the drawings, the ratio of width to length is approximately 1:3.5. The blades extend downwardly and outwardly forming an angle β, which is preferably 45° plus or minus 15°.

The shape of the blades can be varied, depending upon desired operating conditions. Two suitable blade shapes are shown in FIGS. 5 and 6, respectively, both of these blades having the same angle of inclination α between the profile chords, 7 and 7′ and a line representing a vertical radial plane through the blade, lines 8 and 8′, respectively. These lines are shown relative to the rotational axis 0. This angle α is illustrated in FIGS. 5 and 6 as the preferred angle of 15°. FIG. 5 shows a flat blade 6 whereas FIG. 6 shows a curved blade 6.

In the operation of the present invention, the motor 2 is operated, turning the shaft 4 through gearing 3 and hence also turning the blades 6 about the axis 0. As the blades turn, a turbulence is created in the area behind the blades, which turbulence draws in gas bubbles from the surrounding environment. Concurrently, liquid from the area below the central portion of the apparatus is passed upwardly across the surface of the blades, that is, directly across the path of the incoming gas bubbles, thereby drawing off the gas bubbles from the rear surface of the blades. In practice, the path of the liquid is directly across the blades as shown by the arrows 9 in FIG. 4. Thus, the gas suction and the directed liquid flow contribute towards considerably increasing the quantity of gas introduced into the liquid in relation to the power demanded for turning the blades. Another feature of the invention which contributes towards this considerably increased gas introduction is the dimensions of the blades. As indicated earlier, the length is at least twice, and can be up to five times as long as the blades are wide. This increases the area across which the liquid flows.

The operation of the apparatus is dependent in large part upon the selected angle of inclination. If this angle is 0°, that is, if the profile chord of the blade lies on a vertical, radial plane, then the power demand is at a maximum. As is evident from FIG. 7, with the angle α at 0°, the power demand is at a maximum of 2.4 kw. and the absolute oxygen introduction is 7 kg./h and the specific oxygen introduction is approximately 2.9 kg./kwh. However, by increasing the angle α by 15°, the power demand drops to 2.5 kw. and surprisingly, the absolute oxygen introduction increases to 7.1 kg./h and the specific oxygen introduction increases to 3.0 kg./kwh.

Various means may be provided for selecting or changing the angle of inclination. First, the blade may be designed to turn so as to change the position of its profile chords about its longitudinal axis. For example, the blade may be made to turn about the lower rod 17 in FIG. 4. The blade may be turned uniformly over the entire length of the blade, or only selected certain portions of the blade may be turned, thereby providing different angles of inclination along the length of the blade.

It is also possible to select or vary the angle of inclination by turning the blade about a vertical axis parallel to but spaced from the axis of rotation 0. Different longitudinal portions of the blade can be turned by different amounts thereby providing a blade which is curved when viewed from the plan view. However, if it is desired to turn the entire blade by the same amount, thereby maintaining the longitudinal axis straight as viewed in the plan view, then it is possible to use the means illustrated in FIG. 3. Referring to FIG. 3, the blade 6 is turned from a first position shown in solid lines to a second position shown in dotted lines, the angle between these two lines represented by the letter σ and being approximately 15°. The rotary axis 10 is placed in the foot of the blade. To provide the necessary adjustment, the holding member 5 is provided with a number of curved elongated slots 11 spaced from the axis 10. Mounting bolts 12, connected to the foot of the blade 6 pass through the slots 11 and are adapted to be tightened against the slot thereby firmly holding the blade 6 in the desired position. The arrow 13 in FIG. 3 represents the

direction of rotation; and hence the dotted line position illustrates the position whereat the angle σ is 15° on the rear side of the vertical radial plane on which the solid line blade **6** lies.

It should be understood that the two procedures for varying the angle of inclination of the blade, relative to the vertical, radial plane passing therethrough, can be carried out separately or simultaneously. Also, as illustrated in FIG. **3**, the blades are constructed in one piece, wherein the foot is formed as a bent portion of the main part of the blade.

In order to assure that the liquid which has already flowed past the blades **6** will not flow too quickly back to the suction area below the central part of the apparatus, there is provided a pair of crossed, vertical, downwardly extending baffle plates **14** and **15**, which plates cross at points beneath the axis of rotation **0**. A disc is provided above the blade to rotate therewith. This disc is designed as a guide ring **16** having an open center for permitting gas to flow from the surrounding environment to the surface of the liquid in the center of the apparatus. Further, this guide ring **16** protects the motor and the gearing against splashing liquid. In addition, it receives liquid thrown upwardly by the turbulent action of the blades and deflects the same downwardly back to the main body of liquid.

Although the invention has been described in considerable detail with respect to preferred embodiments thereof, it will be apparent that the invention is capable of numerous modifications and variations apparent to those skilled in the art without departing from the spirit and scope of the invention.

I claim:

1. Apparatus for introducing a gas into a liquid comprising: a vertical shaft mounted to be rotated about a vertical axis and adapted to be positioned above the surface of the liquid, at least one elongated blade operatively connected to the shaft for rotation therewith about said vertical axis, the length of the blade being at least twice its width, the longitudinal direction of the blade extending outwardly and downwardly relative to the axis of the shaft, such that the upper, inner end of the blade is adapted to be located above the surface of the liquid and the lower, outer end of the blade is adapted to be located below the surface of the liquid, the blade angle formed at the outer end of the blade between its profile chord and a vertical radial plane passing therethrough being less than 30°, whereby as the blade is rotated about the vertical axis gas is drawn into the liquid on the rear side of the blade and liquid is caused to flow upwardly across the blade.

2. Apparatus according to claim **1** wherein the profile chord at the lower part of the blade is positioned, relative to the longitudinal axis of the blade, such that the profile chord at the lower part forms above its intersection with a vertical radial plane passing therethrough a blade angle of inclination which is between 15° on the forward side of the said vertical radial plane and 30° on the rear side of the said vertical plane, said forward and rear sides being defined with reference to the normal direction of rotation of the blade.

3. Apparatus according to claim **2** wherein the said blade angle of inclination is approximately 15° on the rear side of the said vertical radial plane.

4. Apparatus according to claim **2** including means for changing the blade angle of inclination by turning the said profile chord about the longitudinal axis of the blade.

5. Apparatus according to claim **2** wherein the longitudinal axis of the blade extends outwardly and rearwardly of a radial, vertical plane passing through the upper part of the blade.

6. Apparatus according to claim **5** including means for changing the blade angle of inclination by turning the blade about a vertical axis parallel to the said axis of rotation.

7. Apparatus according to claim **2** wherein the longitudinal axis of the blade forms an angle between 30° and 60° with the vertical axis of rotation.

8. Apparatus according to claim **1** wherein at least the lower part of the longitudinal axis of the blade extends rearwardly of a vertical radial plane passing through the upper part of the blade, and forms an angle on the outer side of its intersection with said vertical radial plane which is between 0° and 30° on the side of the said vertical radial plane rearward of the normal direction of rotation of the blade.

9. Apparatus according to claim **8** wherein the said blade angle is approximately 15° on the rear side of said vertical radial plane.

10. Apparatus according to claim **8** including means for changing the blade angle of inclination by turning the blade about a vertical axis parallel to the said axis of rotation.

11. Apparatus according to claim **10** including means for changing the blade angle by turning the profile chord of the blade about the longitudinal axis of the blade.

12. Apparatus according to claim **8** wherein the longitudinal axis of the blade forms an angle of between 30° and 60° with the said vertical axis of rotation.

13. Apparatus according to claim **1** wherein the longitudinal axis of the blade is inclined at an angle between 30° and 60° relative to the vertical rotation axis.

14. Apparatus according to claim **13** wherein the angle formed between the longitudinal axis of the blade and the vertical axis of rotation is approximately 45°.

15. Apparatus according to claim **1** wherein the length of the blade is between 2 and 5 times its width.

16. Apparatus according to claim **15** wherein the length of the blade is approximately 3.5 times its width.

17. Apparatus according to claim **1** wherein the surface of the blade, at least at its lower end, is flat.

18. Apparatus according to claim **1** wherein the blade is of substantially constant width and includes a horizontally bent portion at its upper end, said portion being adapted for mounting the blade relative to the said shaft.

19. Apparatus according to claim **1** including a pair of stationary baffles arranged below the blade.

20. Apparatus according to claim **19** wherein the baffle plates are arranged one above the other, and said baffle plates intersect on the said axis of rotation.

21. Apparatus according to claim **1** including a disc extending about the shaft and connected for rotation with the shaft, said disc being mounted above the blades.

22. Apparatus according to claim **21** wherein the center of the disc is open for the passage of gas therethrough.

23. Apparatus according to claim **16** wherein the outer circumference of the disc is inclined upwardly at an angle between 10° and 20°.

24. Apparatus according to claim **23**, wherein the outer circumference of the disc is inclined upwardly at an angle of approximately 15°.