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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Apparatus for Agitating a Body of Fluid

We, SCHAUBERGER BIOTECHNIK AG., a body corporate organised and existing under the laws of Switzerland, of Pfäffikerstrasse 78, Wetzikon, Switzerland, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to methods and apparatus for agitating a body of fluid, in particular for the purpose of making a mixture, solution, emulsion, suspension and the like, from a plurality of fluids or from a quantity of material and one or more fluids, or for the purpose of incorporating air into the body of fluid.

In some industrial and chemical processes it is often necessary to mix a fluid and another material to form a solution, emulsion, suspension or the like. Such mixing operations are required for example in the preparation of mineral drinks, fluid mixtures containing a small amount of a particular substance, mixtures of carbon dioxide with a fluid, and also in the purification of bodies of water.

In the latter connection, it has been found that the self-purifying capacity of still or relatively slowly flowing water is less than that of more rapidly flowing water. In relatively rapidly flowing water, for example, flowing at 20 centimetres per second or more, light particles of organic material have little tendency to settle to the bottom. In contrast, such particles tend to settle to the botom of still water or water flowing relatively slowly, for example at less than 20 centimetres per second. The greater self-purifying capacity of rapidly flowing water is due to the fact that, owing to turbulence produced in the water, oxygen has a greater tendency to be incorporated into the water and decompose the organic substances before they settle. The relativly rapid flow causes the oxygen consumed in the decomposition process to be quickly replaced. In still or relatively slowly flowing water, such as lakes or reservoirs, however, settling of the organic substances not only results in the lower regions of the water becoming saturated with such substances, but in addition, causes an oxygen deficit in the upper layers of the water, for the reason that oxygen consumed in the decomposition of the settling substances is not replaced, owing to the slower flow or complete stagnation not producing turbulence to cause oxygen from the adjacent atmosphere to be incorporated into the water. As a result, the organic substances are not consumed by oxygen and the water becomes impure or polluted. It is possible to overcome such pollution by agitating the water to reduce the settlement of organic substances and in particular, to increase the amount of oxygen absorbed into the water at its surface from the adjacent atmosphere, so that a greater amount of oxygen is available to decompose the organic substances and thereby purify the water.

According to the present invention, there is provided apparatus for agitating a body of fluid, for the purpose of mixing a quantity of material or incorporating air into the fluid, comprising a vessel to contain the fluid and having an upwardly facing opening, and a rotatable shaft extending upwardly into the vessel from the bottom thereof and carrying at least one stirring blade, the configuration of the vessel being such that in a portion adjacent the shaft, the walls of the vessel diverge upwardly in a continuous curve from the location of the shaft, in the form of an end portion of an egg-shape.

[*Price 5s. 0d.*]

Embodiments of an apparatus according to the present invention will now be described by way of example with reference to the accompanying drawings, in which:—

Figure 1 is a vertical cross-section of one embodiment of the apparatus;

Figure 1a is a cross-section of the apparatus shown in Figure 1, taken along line A—A;

Figure 2 is a vertical cross-section of a second embodiment of the apparatus;

Figure 3 is a vertical cross-section of a third embodiment of the apparatus;

Figure 4 is a partial vertical cross-section of a fourth embodiment of the apparatus, showing a vessel within a larger container; and

Figure 5 is a vertical cross-section of a fifth embodiment of the apparatus, showing a vessel within a larger body of fluid.

Referring firstly to Figure 1, the embodiment shown comprises a vertically arranged closed egg-shaped vessel 1 containing a fluid F to be mixed. The larger end of the vessel 1 is disposed upwardly, while the configuration of a substantial portion of the body of the vessel 1 lying between the larger and smaller ends thereof is defined by an exponential function which is represented in polar coordinates by the general equations $r=a\theta$ and $r=a\theta+b$, and in a specific case by the equation $r=e\theta+b$, where r is the radius vector, a and b designate any constant, and e is the base of the natural logarithm.

At the larger end of the vessel 1, an opening 2 is provided on the axis of symmetry of the vessel 1 for introducing materials M into the body of fluid F The materials to be mixed with the fluid may include air or other matter in solid, liquid or gaseous form. Depending on the nature of the material to be mixed with the fluid F, pressurised injection into the vessel may be required, particularly if the material is in the form of a powder or small particles.

Located at the lower end of the vessel 1 and also on its axis of symmetry is a rotatable shaft 3 carrying at its upper end a single-bladed stirring element 4 for stirring the fluid F and imparting to it a whirling and vertical motion, as shown by the arrows of Figure 1. Thus the flow of the whirling body of fluid in the vessel 1 comprises an upwardly flowing spiral at the outer periphery of the whirling body, extending substantially to the surface of the fluid F, and then a reversal of direction, producing a downward flow in the centre of the body of fluid F. Inside the upwardly flowing spiral there is also a vertically upward flow to the surface, which then turns inwardly, also mixing with the downward flow resulting from the upward spiral. The vortex or whirling action created by the stirring element 4 and the walls of the vessel 1 is similar to the eddy or whirlpool phenomena occurring in a flowing stream of water. The vortex in the fluid F creates a lower pressure region along the axis of the vortex, while has a suction effect so drawing fluid downwardly at the centre and also drawing in air from the region adjacent the surface of the fluid F. In Figures 1 and 1a, the path followed by an individual fluid particle *p* is shown as it passes in an upwardly flowing spiral within the body of fluid F. Any materials introduced into the vessel 1 through the opening 2 are pulled or sucked into the body of fluid F by its vortex action, which also provides a mixing effect.

Referring now to Figure 2, the apparatus comprises a vessel 5 of the same general configuration as the vessel 1 shown in Figure 1, but which is in an inverted position, that is, its larger end is downwards. Located at the lower end of the vessel 5 is a rotatable shaft 3 having a double-bladed stirring element 4′ at its upper end The vessel 5 contains a fluid F, the level of which is such as to leave a space as shown between the fluid F and the upper end of the vessel 5. An inlet pipe 6 opens into the vessels 5 by way of an inlet opening 6′ such that material is injected tangentially into, and below the surface of, the whirling volume of fluid F.

Axially arranged in the upper end of the vessel 5 is a short tubular member 7 containing a lens or filter 8. Aligned above the filter 8 is an irradiation source 9 for directing radiation, such as ultra-violet rays, downwardly through the filter 8 into the fluid F. The direction of the rays from the source 9 is along the axis of the vortex created in the body of fluid F by the stirring element 4′.

The shape of the vessel 5 is, as shown, similar to that of the vessel in Figure 1, the configuration of a substantial portion between the ends of the vessel 1 being defined by the equations set forth hereinbefore with reference to Figure 1.

In both vessels 1 and 5, the stirring elements 4, 4′ combine with the vessel walls to create a vortex in the body of fluid F. In Figure 2, materials to be mixed are injected tangentially into the vessel 5 and are picked up by the upwardly flowing spiral at the vessel wall, which then carries them into the centre of the vessel 5 and downwardly, so that they become intimately mixed by the vortex action. The rays from the source 9, which pass through the filter 8, are absorbed into the whirling body of the fluid F and, due to the continuous mixing effect, irradiate the fluid F and any additional matter it contains.

Figure 3 shows a vessel 10 similar to that shown in Figure 2 except that its upper end is open, giving it a goblet-like shape. Carried at its lower end, the vessel 10 has a rotatable shaft 3 with a single-bladed stirring element 4″ at its upper end for whirling the fluid F. As the upper end of the vessel 10

is open, it can be used in various processes for the treating and mixing of liquids. Materials to be mixed are introduced through the opening in the upper end of the vessel 10, while the vessel 10 could be used by itself or within a larger tank for mixing a fluid.

Where a vessel is to be positioned within a larger tank of fluid to be mixed, or within a natural body of water, into which oxygen is to be absorbed to decompose any organic matter therein and thereby purify the water, the embodiments shown in Figure 4 and 5 are preferred.

In Figure 4, the fluid F′ is contained within a large tank or container 25. Extending upwardly from the base of the tank are support members 21 which carry a dome-shaped vessel 20 which is of a configuration similar to the lower portion of the vessels 5 and 10 shown in Figures 2 and 3, thus forming an open bowl-type container. Extending through the lower end of the vessel 20 is a rotatable shaft 23 carrying at its upper end a single-bladed stirring element 24 located in the bottom of the vessel 20. Disposed below the vessel 20 is a motor 22 for driving the shaft 23 and its stirring element 24. In operation, the stirring element 24 creates a whirling action within a body of fluid *f* shown in dash-dotted lines in Figure 4. The container 25 may be a collecting tank, settling tank, water reservoir or similar fluid-holding device in which a mixing action is to be produced.

The other embodiment of a mixing vessel positioned within a body of fluid F′, shown in Figure 5, comprises a vessel 30 of a cup-shaped configuration which is similar to the lower portion of the vessel 1 shown in Figure 1. Mounted at the lower end of the vessel 30 is a hollow rotatable shaft 33 with a single-bladed stirring element 34 located at its upper end. Fluid, or any material S′, below the vessel 30 may also be drawn into the vessel 30 through the hollow shaft 33 so that such fluid may be incorporated upwardly into the whirling volume of fluid *f*. Additionally, it should be noted that the irradiation source 9 shown in Figure 2 could be used in either of the embodiments shown in Figures 4 or 5 to provide radiation treatment of the fluid.

In Figures 4 and 5, a vortex or whirling movement is produced in the fluid F′ to be mixed, whether it is a natural body of water, such as the water of a lake, or a large container holding some other fluid, by the stirring elements 24, 34 disposed in the lower portion of vessels 20, 30 respectively. The general outline of the body of fluid *f* to which the whirling movement is imparted is shown by the dash-dotted line in Figures 4 and 5. additionally, in Figure 4, the flow pattern within the body of fluid *f* is shown by a number of solid lines bearing directional arrows. The flow pattern is the same as previously described for Figure 1, the outer layer of the body of fluid *f* moving in an upwardly flowing spiral to the surface of the fluid. Similarly, inwardly of the upwardly spiraling layer is an upwardly flowing layer which reverses direction in the upper region of the whirling body of fluid *f*, then passing inwardly and downwardly at S along the axis of the vortex. The suction effect developed by the vortex produced in the body of fluid *f* tends to suck in any materials to be mixed with the fluid; this suction effect may be used in the case of water to draw oxygen into the water to provide a biochemical purification action. In both the embodiments shown in Figures 4 and 5, as the vessel 20, 30 extends only a short distance above the stirring element 24, 34, it does not interfere with any mixing at the interface of the main body of fluid F′ and the fluid *f* in the whirling volume.

In the mixing operation, whether in the closed vessels shown in Figures 1 and 2 or in the open vessels of Figures 3, 4 and 5, a relatively small amount of energy is needed to rotate the stirring elements and create the vortex in the fluid. Moreover, where an open vessel is used, as in Figures 4 and 5, not only is it possible to produce circulation of fluid within the boundaries of the whirling body of fluid *f*, but the fluid F′ is also drawn into that whirling body so that a complete mixing action can be achieved. Additionally, when either the open or closed vessels are used, the whirling body of fluid will show resonance phenomenon when a relatively high speed stirring element is employed; under such conditions the intensity of fluid circulation produced by the stirring element can be increased by increasing the speed of the elements, with only a relatively small additional energy consumption.

WHAT WE CLAIM IS:—

1. Apparatus for agitating a body of fluid, for the purpose of mixing a quantity of material or incorporating air into the fluid, comprising a vessel to contain the fluid and having an upwardly facing opening, and a rotatable shaft extending upwardly into the vessel from the bottom thereof and carrying at least one stirring blade, the configuration of the vessel being such that in a portion adjacent the shaft, the walls of the vessel diverge upwardly in a continuous curve from the location of the shaft, in the form of an end portion of an egg-shape.

2. Apparatus according to claim 1 wherein said walls are formed substantially completely by said end portion of an egg-shape.

3. Apparatus according to claim 1 wherein said vessel is substantially completely egg-shaped with its axis of symmetry arranged vertically.

4. Apparatus according to claim 3 wherein the larger curved end of said egg-shape forms the upper end of said vessel.

5. Apparatus according to claim 3 or claim 4 wherein a substantial portion of the walls of said vesel, lying between the curved ends thereof, is defined by the polar equation $r = a\theta$.

6. Apparatus according to claim 3 or claim 4 wherein a substantial portion of the walls of said vessel, lying between the curved ends thereof, is defined by the polar equation $r = a\theta + b$.

7. Apparatus according to claim 3 wherein an inlet opening lying on the axis of symmetry of said vessel is formed in the upper end thereof.

8. Apparatus according to claim 3 wherein an inlet conduit opens into said vessel substantially tangentially to the wall thereof.

9. Apparatus according to claim 8 wherein said inlet conduit opens into said vessel below the surface of said body of fluid which is contained within said vessel in use.

10. Apparatus according to claim 3 wherein irradiation means is disposed above and in alignment with an opening in the upper end of said vessel.

11. Apparatus according to claim 10 wherein a radiation filter is disposed within said opening.

12. Apparatus according to claim 10 or claim 11 wherein a lens is disposed within said opening.

13. A tank or the like container for containing a body of fluid to be agitated, including an apparatus according to claim 2 arranged within the tank such that the body of fluid in the tank is in communication with the fluid in said vessel.

14. A tank according to claim 13 wherein an inlet opening is further provided in the lower end of said vessel, to provide for upward circulation of fluid from said tank into said vessel.

15. A method of agitating a body of fluid for the purpose of mixing a quantity of matter or incorporating air into the fluid, an an apparatus according to any one of claims 1 to 12, wherein the fluid is continuously stirred within the vessel to form a vortex flow within at least a portion of the body of fluid, the vortex flow comprising an upwardly spiralling flow adjacent the walls of said vessel and a downwardly directed flow within the upwardly spiralling flow; and matter to be mixed into the fluid is directed into the upper region thereof.

16. A method according to claim 15 wherein said matter is directed downwardly along the axis of said vortex flow.

17. A method according to claim 15 wherein said matter is directed tangentially into the lateral periphery of said vortex flow.

18. A method according to claim 15 wherein said body of fluid is irradiated by radiation directed downwardly along the axis of said vortex flow.

19. Apparatus for agitating a body of fluid, substantially as hereinbefore described with reference to the accompanying drawings.

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Sheet 1

FIG.1

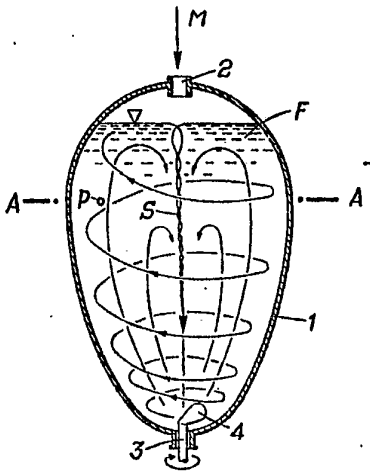


FIG.2

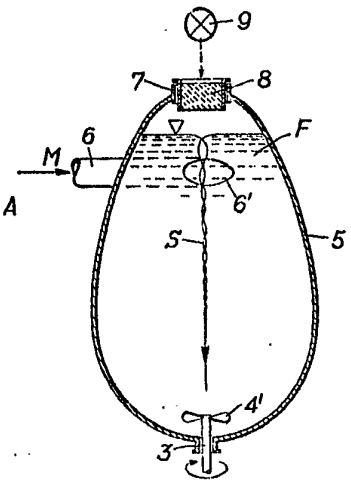


FIG.1a

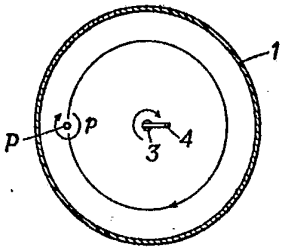
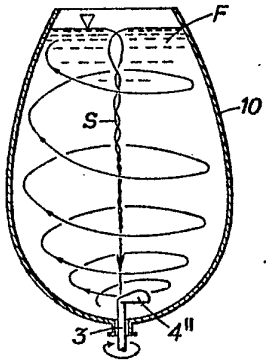


FIG.3



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Sheet 2

FIG. 4

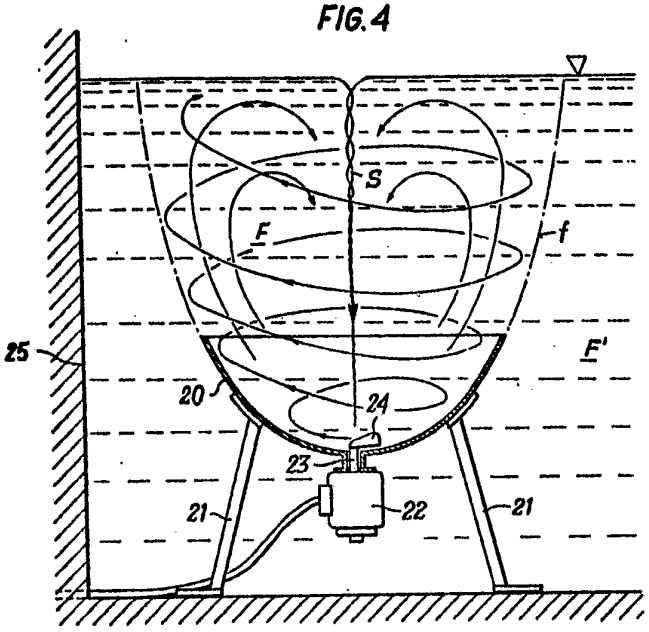

FIG. 5