

"Device for agitating a liquid in a reactor and for injecting a gas into this liquid."

The subject of the present invention is a device for agitating a liquid in a reactor and for injecting a gas into this liquid, comprising a drive device arranged above the reactor, provided with a vertical output shaft equipped at its end with at least one axial-flow mobile assembly immersed in the liquid.

The gas injected into the liquid can be either an oxygenated gas with a proportion of oxygen varying from 20 to 100%, or carbon dioxide, or an ozonized gas, or a biogas etc. The liquid into which the gas is to be injected is arranged in reactors used in particular for the biological treatment of industrial effluents and whose height generally varies from 2 to 10 metres in depth.

In what follows "reactor" signifies both a natural "basin" (lagoon, pond, lake etc.) and also an enclosed or open headspace "tank" whose walls may be relatively close together or far apart.

The reactors into which these systems enable gases to be injected generally contain activated sludges. These reactors may therefore be either natural basins, or open headspace reactors with closely spaced walls, or enclosed reactors, which may or may not be pressurized.

In the field of the biological treatment of water, various types of systems are known depending on whether the gas is injected at the surface, or at the bottom of the basin. For example, there are surface turbines, brushes enabling air to be transferred into the liquid by creating agitation. Such devices can only be used for small heights of water and have limited oxygenation capacities.

Thus Patent EP-0 583 509 from PRAXAIR Technology Inc. describes a system characterized chiefly by a propeller situated in a hollow shaft and entraining, during its rotation and by vortex effect from the surface of the liquid, gas and liquid located under an immersed cover. The gas/liquid mixture thus formed is propelled downwards. The gas bubbles being undissolved rise within a radius of action

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corresponding overall to that of the cover where they are collected so as to be reinjected again. The inputting of feed gas and venting, as well as the optimal level of the liquid in the cover, are regulated
5 by the pressure prevailing under the cover.

Although the stated transfer efficiencies are very good, the limits of this system are chiefly:

- the zone of action limited to a radius much like that of the cover and to a relatively small depth of water,
- 10 - the enrichment of the gaseous phase with CO₂, N₂ and other gases arising from the biological activity, in the case of activated sludge applications, and the need to carry out venting causing losses of O₂,
- the complexity of the pressure regulation under the
15 cover,
- use of a gas at high pressure: need to use a booster following a VSA or MPSA (on-site production unit operating by adsorption under pressure or with vacuum regeneration).

20 Porous "bottom" systems with injection of gas and agitation means are also known. These systems have a fixed and limited oxygenation capacity, and tend to clog. Finally, there are other "bottom" devices comprising jets or the device known by the brand name
25 "Ventoxal" with injection of gas (oxygen-enriched air, or pure oxygen). The "Ventoxal" system developed by the applicant consists of a pump, a Venturi type injection system, a flow distributor and an ejector/nozzle pair, for which the gas injection pressure depends on the
30 height of water and remains chiefly greater than 1.5 bar absolute. The agitation obtained is satisfactory in the bottom of the basin but may be average in the remainder of the volume.

The purpose of the invention is to propose a
35 device for agitating a liquid and for injecting a gas into this liquid, of the type mentioned above, making it possible efficiently to transfer a gas into a liquid and to ensure agitation enabling particles to be placed in suspension and held there.

In accordance with the invention, the output shaft of the drive device also carries an auto-suction turbine immersed in the liquid and drivable by the output shaft, and the latter is enveloped coaxially by a cylinder linked at its upper end to the drive device and whose lower end opens out into the turbine; in the upper end of the cylinder is drilled an aperture for injecting a gas into an annular gap delimited by the shaft and the cylinder.

10 The output shaft of the drive device drives the turbine and the propeller at the same speed.

 The rotation of the turbine causes gas to be sucked through the hollow cylinder enveloping the output shaft of the drive device. This turbine propels the gas/liquid dispersion radially.

15 The device comprises means for directing towards the propeller the gas/liquid dispersion expelled radially by the turbine.

 According to one embodiment of the invention, the said means comprise an annular box forming a deflector, enveloping the turbine and profiled so as to direct towards the propeller the stream issuing radially from the turbine, and a set of substantially vertical plates forming counter-blades, arranged radially and fixed to the deflector.

20 Advantageously, the said means may comprise an additional agitation mobile assembly preferably driven in rotation by the output shaft, or any other means, preferably at the same speed of rotation as the shaft.

30 The deflector which envelopes the turbine pushes the gas/liquid dispersion down towards the propeller which propels gas bubbles towards the bottom, and creates a stream of pumping liquid allowing agitation of the basin. The counter-blades make it possible to direct the various liquid and gaseous streams so as to maximize the performance in terms of transfer and agitation.

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The invention will now be described with reference to the appended drawing which illustrates an embodiment thereof by way of nonlimiting example.

Figure 1 is a vertical axial sectional view of
5 an embodiment of the device for agitating liquid and injecting gas into this liquid in accordance with the invention.

Figure 2 is an elevational view of the device
of Figure 1 showing in particular the deflector con-
10 taining the turbine, as well as, chain-dotted, a variant embodiment.

Figure 3 is a perspective view representing the auto-suction turbine arranged in the deflector of the device of Figures 1 and 2.

15 The device represented in the drawings is intended to allow the agitation of a liquid L in a reactor as well as the injection of a gas into this liquid, this gas being preferably, but not exclusively, oxygenated.

20 The device comprises a drive device 1, for example a motor, arranged above the surface of the liquid L, provided with a rotary output shaft 2 extending vertically and partially immersed in the liquid L. The output shaft 2 is equipped at its lower
25 end 3 with a propeller 4 immersed in the liquid L. The shaft 2 also carries, arranged between the propeller 4 and the surface of the liquid L, an auto-suction turbine 5 which is consequently immersed in the reactor and can be driven by the output shaft 2 at the same
30 speed as the propeller 4. The output shaft 2 is enveloped coaxially by a cylinder 6 linked at its upper end to the drive device 1, with interposition of a leakproofing device 7 known per se, and whose lower end
35 6a opens out into the turbine 5 coaxially with the shaft 2.

The auto-suction turbine 5 consists of two superposed discs 8, 9 placed horizontally, and of a set of radial vanes 11 placed between the discs 8, 9 and fixed to them. Made in the upper disc 8 is a central

hole 12 delimited by a projecting collar, and into which hole the lower end 6a of the cylinder 6 penetrates, hence delimiting together with the edge of the said hole 12 an annular space 13.

5 In the upper end of the cylinder 6 is drilled an aperture 14 for injecting a gas into the annular gap 15 delimited by the shaft 2 and by the cylinder 6. The system for injecting gas into the orifice 14 is known per se and not represented.

10 The output shaft 2 passes axially through the discs 8 and 9 while being fixed to the lower disc 9, so that when the drive device 1 is actuated, the shaft 2 drives the turbine 5 and the propeller 4 in rotation at the same speed. The rotation of the turbine 5 creates
15 the suction of the gas arriving through the orifice 14, by way of the cylinder 6, as well as the suction of part of the liquid which is introduced through the annular gap 13 left free between the turbine 5 and the cylinder 6. This gas/liquid dispersion is manifested as
20 a population of bubbles whose size is mainly between 100 μ m and 2 mm.

The device also comprises means for directing towards the propeller 4 the gas/liquid dispersion expelled radially by the turbine 5 between its vanes
25 11. In the embodiment described, these means comprise an annular box 16 forming a deflector, drilled with two superposed central apertures 17, 18 coaxial with the shaft 2, the diameter of the lower aperture 18 being substantially greater than that of the upper aperture
30 17 and substantially equal to that (d) of the turbine 5.

The means for directing towards the propeller 4 the gas/liquid dispersion also comprise a set of substantially vertical plates 19 forming counter-
35 blades, arranged radially around a deflector box 16 and fixed to the latter. For this purpose, each counter-blade 19 penetrates radially over a certain distance inside the deflector box 16, to which it is fixed by appropriate means known per se, for example welding or

riveting. The counter-blades 19 can be arranged around the turbine 5 and the propeller 4 in appropriate number at specified angular intervals. A notch 21 into which may penetrate ends of the blades of the propeller 4 is cut into the interior edge of each counter-blade 19, at the level of the propeller 4.

The counter-blades 19 extend vertically from a level corresponding substantially to that of the liquid L, over a total height H of between 0.7 times and 12 times the diameter d of the turbine 5 (Figure 1).

The device for agitating the liquid and for injecting gas into this liquid which has just been described operates as follows.

Once the drive device 1 has been switched on, the output shaft 2 drives the auto-suction turbine 5 and the terminal propeller 4 in rotation at the same speed. The gas is injected or sucked through the aperture 14 into the annular gap 15 from where it is sucked towards the turbine 5, as is part of the liquid L in the annular gap 13 between the upper plate 8 and the cylinder 6 (as indicated by the arrow in Figure 1). At least 90% of the dispersion of bubbles is recovered by virtue of the presence of the counter-blades 19 and of the deflector 16 which directs the stream towards the propeller 4, as indicated by the two lateral arrows in Figure 1. The propeller 4, consisting of at least two blades 4a, propels the dispersion of bubbles at a speed of between for example 1 and 5 m/second towards the bottom of the basin. The dimensioning and the operating conditions applied may enable the bubbles to be propelled to a depth of 10 metres whilst preserving a horizontal speed at the floor which is sufficient (that is to say greater than 0.1 m/s) to prevent or warn of the formation of zones of deposits or of solid particles on the bottom of the basin.

The bubbles thrown to the bottom of the basin subsequently rise at the periphery of the agitation mobile assembly (4, 5) around the central axis 2. The residence time of the gas bubbles in the liquid is

sufficient to ensure the transfer of oxygen from the gas phase (if the gas injected is oxygenated) to the liquid phase. The oxygen can thus be used for the purposes of biomass respiration or oxygenation of certain compounds.

The pumping flow induced by the presence of the recouping propeller 4 and of the counter-blades 19 makes it possible to ensure the churning of the liquid volume around the agitation mobile assembly 4 within a radius which depends on the power dissipated by the propeller 4 (power of between 40 and 90% of the power applied to the motor shaft 2). This churning enables the sludges and/or solid particles to be placed in suspension so as to ensure that the concentration of sludges and/or of particles in all the volumes churned by the propeller 4 is rendered homogeneous.

When the gas injected through the orifice 14 is oxygenated, the device described above makes it possible to carry out biological treatment of industrial or urban effluents, by transferring the oxygen to the activated sludge and by agitating the biomass so as to render the concentration of sludges homogeneous. The deflector 16 which envelopes the turbine 5 pushes the gas/liquid dispersion down towards the propeller 4 which propels the gas bubbles towards the bottom of the reactor, and creates a liquid pumping flow allowing agitation of the reactor. The counter-blades 19 make it possible to direct the various liquid and gaseous streams so as to maximize the performance in terms of transfer and agitation.

Example of implementation of the device

Dimensioning of the turbine 5

The extrapolation and dimensioning criteria for the turbine 5, after optimization trials, are the following (Fig. 1):

$H1 = 0.1 \text{ to } 5d$ (d being the diameter of the turbine 5)

$H2 = 0.5 \text{ to } 2d$

$H3 = 0.1 \text{ to } 5d$

$d_1 = 0.01$ to $0.1 \cdot d$ (d_1 is the radial distance between the turbine 5 and each counter-blade 19)

$d_2 = 0.01$ to $0.1 \cdot d$ (d_2 is the radial distance between the bottom of a notch 21 and the ends of the blades 4a)

5 $L_{cp} = 0.5$ to $2 \cdot d$ (L_{cp} is the width of each counter-blade)

$D_h = 1$ to $2 \cdot d$ (D_h = diameter of the propeller 4)

The counter-blades 19, four in number in the example illustrated in the drawings, are oriented
10 radially with respect to the axis of the turbine. They are at least two, the contour of which hugs the geometrical shape of the rotor (propeller).

The counter-blades have been added so as to transform the tangential stream into an axial stream
15 oriented towards the bottom of the vessel. Their number has been defined experimentally with the aim of distributing over the entire circumference the zones of Gas/Liquid dispersion rising towards the surface.

These counter-blades start from the surface of
20 the liquid, and may advantageously descend down to a depth equal to at most 12 times the diameter of the turbine. Their positioning with respect to the surface is necessary so as to avoid the formation of a vortex which would lead to the shutting down of the turbine.

25 In respect of the propeller for recovering the Gas/Liquid dispersion, the number of blades 4a varies from 2 to 12. It is defined in such a way as to limit the risks of choking with respect to the operating range of the turbine in terms of Gas/Liquid ratio.

30 The rate of recovery of the gas/liquid dispersion can advantageously be increased by adding an additional mobile assembly 22 (Figure 2), for example a propeller with two or more blades. This mobile assembly 22 can be fixed to the output shaft 2 as represented,
35 and makes it possible to increase the peripheral speed of the liquid in the annular box.

The operating parameters of the turbine are:

- the immersion I which is the distance between the level of the liquid and the upper disc of the turbine.

- the speed of rotation N
- the gas flow rate Q_g
- the gas injection pressure P_g

The extrapolation criteria for these operating
5 parameters are the following:

- I/d from 0.01 to 5: nominal value = 0.4
- Modified Froude number = $Fr^* = N^2 \cdot d^2 / g \cdot I$ = inertial forces/gravity forces
 - $Fr^* =$ from 0.1 to 25: nominal value = 1.1 to 2.5
- 10 $Fr^* < 0.1 \Rightarrow$ very weak gas suction
- $Fr^* > 24 \Rightarrow$ risk of choking
- Power consumed = $N^3 \cdot d^5 \cdot N_p$ with N_p power number = $f(Fr^*)$

The modes for running the device which are
15 addressed by the invention may be the following:

- Continuous operation:
 - operation at fixed speed of rotation, regulation of the gas flow rate being effected by a flow rate control member placed on the fluid line,
- 20 - operation at variable speed and variable gas flow rate so that the optimal conditions of operation of the turbine always hold.
- Alternating/sequenced operation:

Operating in cycles by alternating phases of
25 agitation with injection of gas and phases of agitation without injection of gas, and/or alternating phases of agitation with variable speeds. Such operation finds its full justification and interest in particular in respect of single-basin nitrification/denitrification.

30 The ranges of operating conditions are the following:

- The net specific inputs (NSI) measured in KgO_2/kWh absorbed may vary from 0.5 to 8.
- The suction capacity of the turbine 5 may reach 50 Nm^3/h of gas per kWh consumed by this turbine.

35 The agitation speeds are from around 50 to 1000 rev/min.

The immersion/diameter ratio of the turbine 5 varies from 0.01 to 5.

The modified Froude number is between substantially 0.1 and 25

The height of water in the basin may conventionally be between 2 and 10 m.

- 5 - The dissipated power ratio between the propeller 4 and the turbine 5 may vary from 40/60 to 90/10.

10 The liquid may be one of the following: activated sludges, industrial or urban waste effluents, "process" water, sea water, concentrated sludges.

The system described above can be included

- 15 - either within an enclosed or open biological or/and chemical reactor which may or may not operate under pressure, coupled with physico-chemical separation processes (settling tank, flotation agent, membranes, filters etc.)

- 20 - or within an enclosed biological and/or chemical reactor operating under pressure with control of the gas content within the gaseous headspace by way of a vent.

In the case of deep basins (with a water height of greater than around 7 metres) or stations already kitted out, the system can operate with air or oxygen type basin bottom transfer systems such as "Ventoxal".

- 25 The device according to the invention has the following advantages:

- 30 - suction of gas at low pressure (from 0.7 bar absolute) allowing suction of atmospheric air or the use of oxygen produced on site with no recompression step or originating from other steps or processes of the site using gases,

- limiting of the problems of pH reduction attributable to the reinjection of CO₂ produced by bacteria,

- 35 - the recouping mobile assembly (4) whose power is tailored to the requirements, possesses a wide radius of action and enables the gas/liquid mixture to be propelled to the bottom of the basin whilst

achieving satisfactory levels of agitation, even for considerable depths of water (around 7 to 10 metres),

- possibility of decoupling the agitation and the injection of gas, thus allowing the various modes
5 of running set forth earlier (continuous and alternating/sequenced operation).

As compared with the Ventoxal system, the system according to the invention has the advantages of enabling gas to be injected at atmospheric or slightly
10 lower pressure, and of increasing the transfer efficiencies by at least 10% to 50% depending on the water height and the gas flow rate.

The system can be equipped with one or more axial-flow mobile assemblies such as propellers mounted
15 coaxially on the shaft 2.



1. Device for agitating a liquid (L) in a reactor
5 and for injecting a gas into this liquid, comprising a
drive device (1) arranged above the container, provided
with a vertical output shaft (2) equipped at its end
with at least one axial-flow mobile assembly (4)
10 immersed in the liquid, characterized in that the
output shaft of the drive device also carries an auto-
suction turbine (5) immersed in the reactor and
drivable by the output shaft (2), in that the latter is
enveloped coaxially by a cylinder (6) linked at its
15 upper end in a leakproof manner to the drive device and
whose lower end (6a) opens out into the turbine, and in
that in the upper end of the cylinder is drilled an
aperture (14) for injecting a gas into an annular gap
(15) delimited by the shaft and the cylinder.
2. Device according to Claim 1, characterized in
20 that the turbine (5) consists of two superposed discs
(8, 9) and of a set of radial vanes (11) arranged
between the discs and fixed to them, and in the upper
disc (8) is made a central hole (12) into which
penetrates the lower end (6a) of the cylinder (6) which
25 together with the edge of the said hole delimits an at
least partially annular space (13) through which liquid
can be sucked into the turbine.
3. Device according to one of Claims 1 and 2,
characterized in that it comprises means for directing
30 towards the axial-flow mobile assembly (4) the
gas/liquid dispersion expelled radially by the turbine
(5).
4. Device according to Claim 3, characterized in
that the said means comprise an annular box (16)
35 forming a deflector, enveloping the turbine (5) and
profiled so as to direct towards the axial-flow mobile
assembly (4) a stream issuing radially from the
turbine, a central aperture (18) being made in the
lower face of this box, and substantially vertical



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plates (19) forming counter-blades, arranged radially and fixed to the deflector (16).

5. Device according to Claim 4, characterized in that the said means furthermore comprise an additional
5 agitation mobile assembly (22).

6. Device according to one of Claims 4 or 5, characterized in that the counter-blades (19) are at least two in number and extend vertically from a level corresponding substantially to that (L) of the surface
10 of the liquid over a total height (H) of between around 0.7 times and 12 times the diameter (d) of the turbine (5).

7. Device according to one of Claims 1 to 6, characterized in that the axial-flow mobile assembly is
15 a propeller (4).

8. Device according to Claim 7, characterized in that radial notches (21) are cut into the counter-blades (19) so as to allow the blades (4a) of the propeller (4) to penetrate therein.