Researches on the Constructive Solutions of Fine, Fixed Bubble Generators

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Abstract: *The paper presents the constructive solutions and the operation of fine, fixed bubble generators, used for aeration / oxygenation of stationary waters. By the scheme, the components and the operation of four installations for water treatment are revealed; the advantages of using fine bubble generators in water aeration processes are indicated.*

Keywords: *Fine bubble generator, water aeration installations.*

1. Introduction

Stationary water aeration is important and has many technological applications.
One of the ways to improve the mass transfer from air to water is by moving the fine bubble generators; this operation can be done through a variety of systems depending on the geometry and size of the tank, the lake where aeration is desired.
This aeration by moving the fine bubble generator is thought of as a local aeration, or as a series of local aerations.
Under normal conditions for a more efficient oxygenation of stationary water, with free surface, it is necessary that the air bubble that is emitted by a generator of fine bubbles describes a trajectory as long as possible in the water.
This trajectory practically influences the amount of oxygen that dissolves in the water, and is optimal for aerations where the height of the water layer above the fine bubble generator is not high, this height being practically determined by the amount of oxygen in the air bubble; above this height, the air bubble no longer provides a transfer of O_2 to the water even if it is still in contact with water.
The dynamics of gas bubbles in a liquid are treated extensively in fluid mechanics, especially the problem of rising bubbles having important applications in biochemistry, medicine, etc.
It also raises interesting mathematical problems; in this sense many studies have been conducted to study the rise of gas bubbles emitted from submerged orifices.
Aeration of water is achieved by introducing atmospheric air into the water as follows [1]:
1. By mechanical aeration;
2. By pneumatic aeration.
- In the case of mechanical aeration, the air is introduced into the water under the action of rotors, pallets, etc. performing surface aeration.
- In the case of pneumatic aeration, the air is sent to diffusers made of plastics, ceramics, etc.; these diffusers are located below the water level, thus aerating the water with air bubbles. Recently, fine bubble generators (FBG) have also been used [2].
From the literature [4][5] it is known that the rate of oxygen transfer to water increases as the diameter of the air bubble decreases; the diameter of the air bubble is a function of the diameter of the orifices in the perforated plate of the FBG.

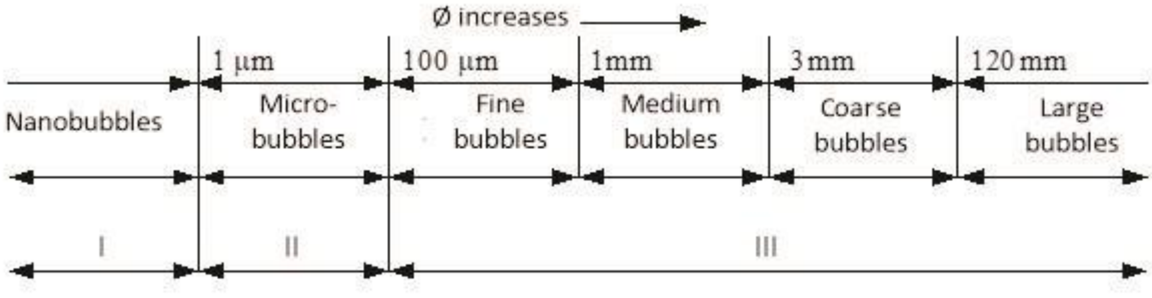

Fig. 1. Classification of gas bubbles according to their diameter
I - the area where the gas bubbles can be observed under the microscope;
II - the area where gas bubbles can be observed with difficulty;
III - the area where gas bubbles can be observed with the naked eye.

Gas bubbles (atmospheric air or a mixture of gases) can be classified according to the data in figure 1.

2. Constructive solutions and operation of fine, fixed bubble generators, which are used for water aeration

2.1 Classification of air bubble generators

The classification of fine bubble generators (FBG) is based on the following criteria [6]:
I. By placing the orifices in the perforated plate:
- Circular FBG;
- Rectangular FBG.

II. According to the nature of the gas introduced into the water, there are:
- FBG at which atmospheric air is introduced into the water;
- FBG in which a gaseous mixture consisting of:

- atmospheric air + oxygen from a cylinder;
- atmospheric air with low nitrogen content;
- atmospheric air + ozone.

III. According to the operation principle, fine bubble generators (FBG) are divided into two classes:
1. Fixed FBG;
2. Mobile FBGs, which may be in one of the following situations:

- performs a rotational movement in the water tank;
- performs a translational movement in the water tank.

It is useful to make a division of expressions, as follows:
I. Water aeration refers only to the introduction of atmospheric air into water (21% O_2 + 79% N_2).
II. Oxygenation of water refers to the introduction of gaseous mixtures in which the oxygen exceeds 21%.
Obviously, I + II have the same purpose, namely to increase the concentration of dissolved oxygen in water. Increasing the percentage of O_2 introduced into the water by more than 21% reduces the time in which water oxygenation takes place.

2.2 Fine, fixed, circular bubble generators

Fine, circular bubble generators are the best known and most used due to their constructive advantages; they are either with elastomer membranes, or made of ceramic materials or perforated plates.
Membrane fine bubble generators, unlike ceramic ones, are suitable for intermittent operations, as the air release perforations will open and close depending on the air inlet, while preventing waste water from entering the aeration system.
Membrane fine bubble generators are therefore a standard component in both nitrogen removal (simultaneous denitrification, circular) and biological phosphate removal (aerobic / anaerobic alternatives, also circular).

Membrane fine bubble generators have a supporting structure (FRP, PVC or PPE) in their construction, on which the perforated rubber membrane and the air supply are fixed. Having adequate perforations and constructed of a quality material, the characteristics of the bubbles will depend on the distribution of the discharge along the effective surface of the fine bubble generator.
The orifices open after a certain deformation of the diaphragm, deformation that depends on the air flow rate and pressure in the fine bubble generator, the fastening element of the diaphragm and the constructive shape of the body of the fine bubble generator.
With the increase of the air flow rate in the fine bubble generator, all the above factors no longer influence the formation of air bubbles, because all the openings will open at a certain flow rate.
Because the design is circular (cylindrical), and after deformation takes the form of a dome, a large part of the air flow rate will pass through the central part of the membrane into larger bubbles, while the marginal areas are not representative.
These areas lead to a significant decrease in the active area of air bubble formation in the case of circular fine bubble generators.
For the experimental study, a circular bubble generator was designed and built, with a perforated plate as an element of air dispersion in the water mass, because in this constructive version no problems are encountered with membrane equipment or porous materials.
A constructive version of a plate with 37 orifices was designed, having a diameter of 0.5 mm which were arranged so that they create, as a whole, a column of "circular" bubbles; the distribution of the orifices in the circular plate can be seen in figure 2, they being arranged linearly and comprised in a circle with a diameter of 35 mm, at a distance equal to each other 5 mm.

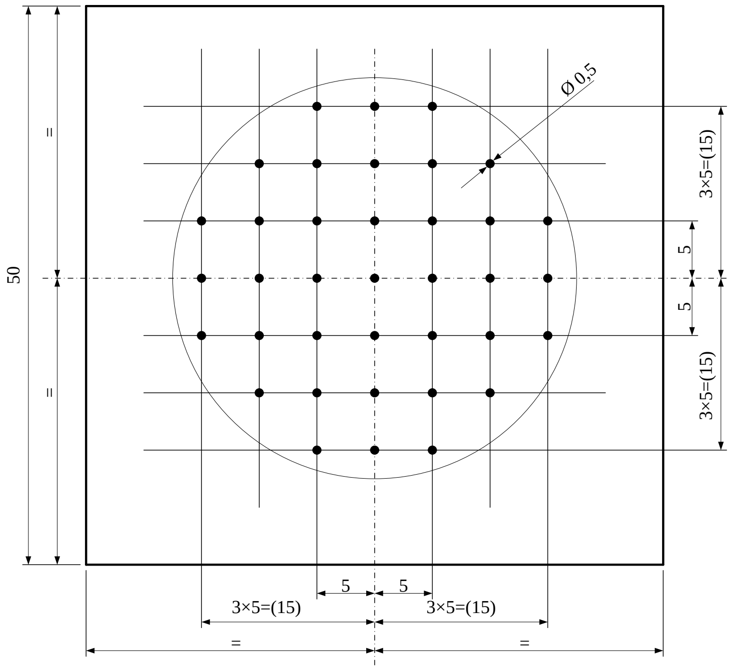

Fig. 2. Sketch of the perforated plate of the fine bubble generator

This plate has been designed and built to be an integral part of a fine bubble generator, with which experimental researches are performed in the laboratory, which will establish the operation and performance of such equipment.
The plate of figure 2 constitutes the main element of the generator of fine bubbles, of circular shape, presented in view (fig. 3) and in section (fig. 4); its orifices form fine air bubbles through which the water is oxygenated.

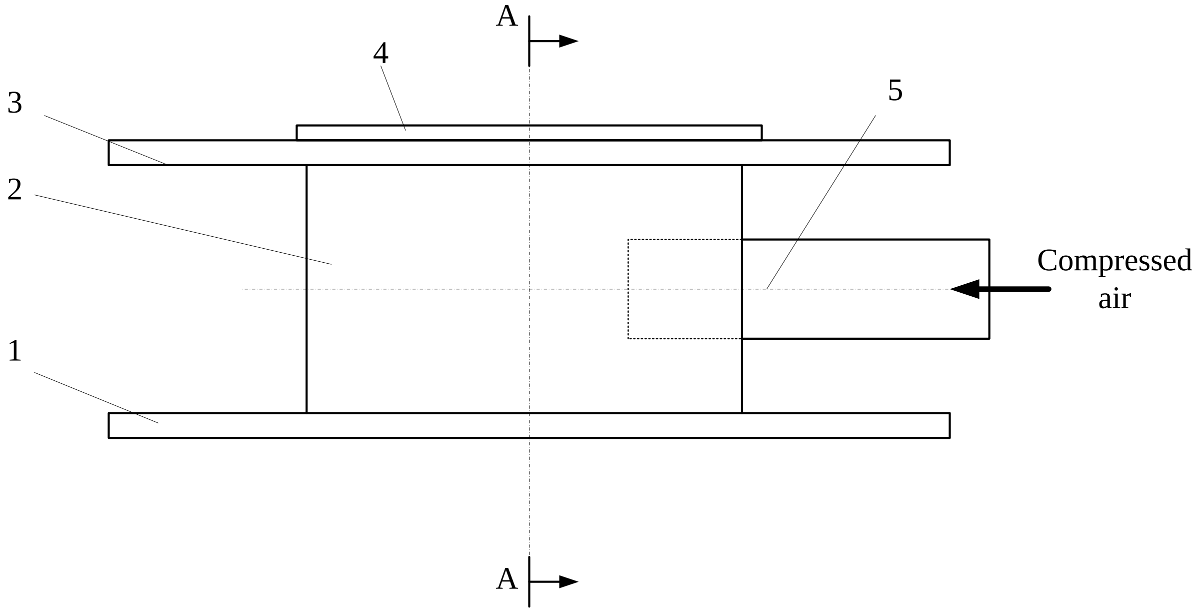

Fig. 3. Circular fine bubble generator (view):
1 - base plate; 2 - cylinder ø35; 3 - upper plate;
4 - plate with orifices; 5 - air supply pipe

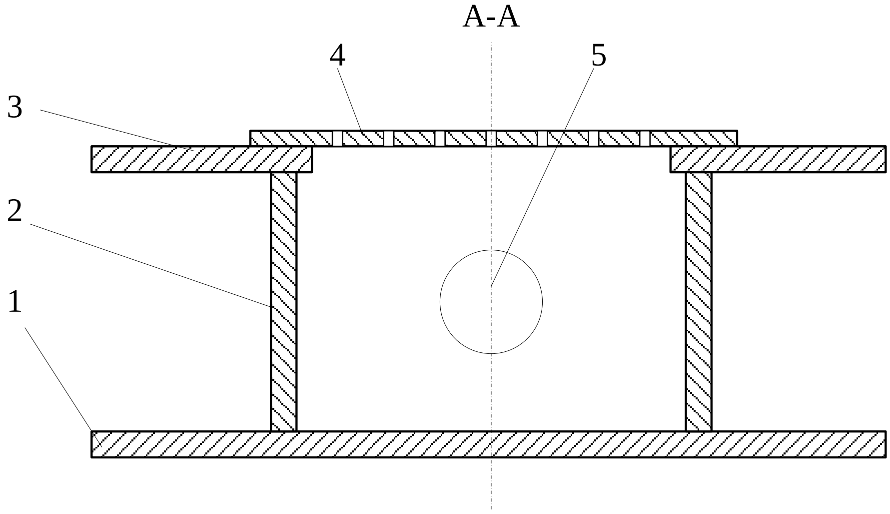

Fig. 4. Circular fine bubble generator (section):
1- base plate; 2 - cylinder Φ 35; 3 - upper plate;
4 - plate with orifices; 5 - compressed air supply pipe

Fixing the plate to the body of the fine bubble generator as well as its construction (gripping the component parts) was done by gluing, using a compound based on Acrylic.

2.3 Rectangular fine bubble generator

In the second constructive version, i.e. rectangular FBG, the plate also has 37 orifices with a diameter of 0.5 mm which were arranged in a single row, at a distance of 5 mm, so that the bubble columns as a whole, at the exit of the fine bubble generator, to create a bubble curtain similar to that of a flat jet that has a rectangular cross section [3]. The distribution of the Ø0.5mm orifices is observed in figure 5, where one can see the construction of the generator and the connection to the compressed air duct:

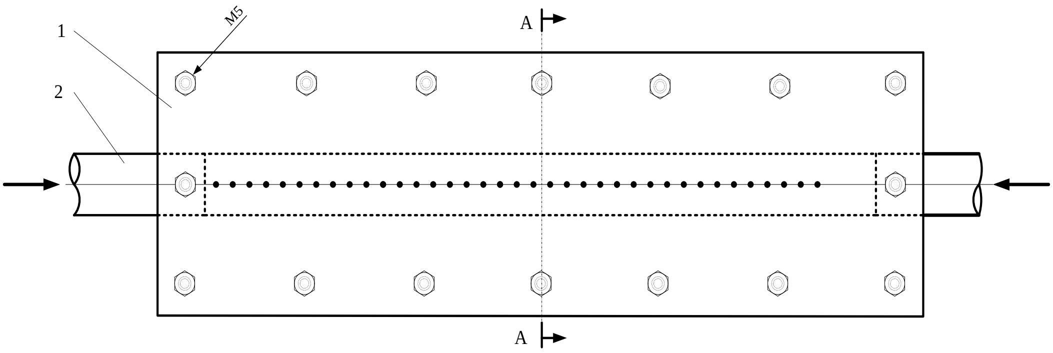

Fig. 5. FBG sketch in version II where the perforated plate can be observed:
1-plate with holes; 2- compressed air supply pipe

As one can see from the construction of this type of fine bubble generator, the air supply can be made through both ends of the generator. This facilitates the connections between the generators, when one use a series of such generators.

If a section is performed through the fine bubble generator (A-A), one can obtain the figure below, where its components are also presented (figure 6).

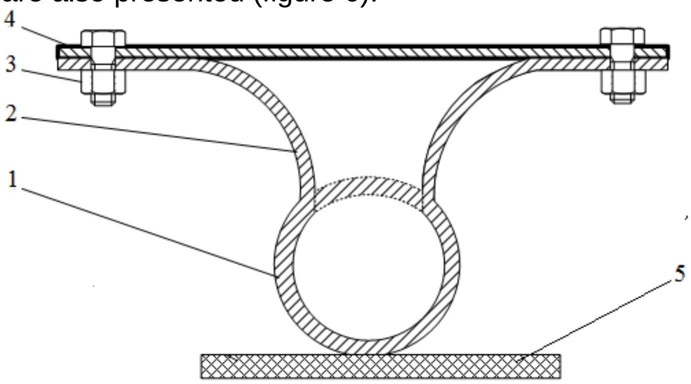

Fig. 6. Rectangular FBG section:
1- compressed air supply pipe; 2 - FBG body; 3 - body plate fixing screws; 4- plate with orifices; 5 - support

Following the calculations and the imposed conditions, this fine bubble generator was calculated, resulting in a rectangular fine bubble generator, (figure 7):

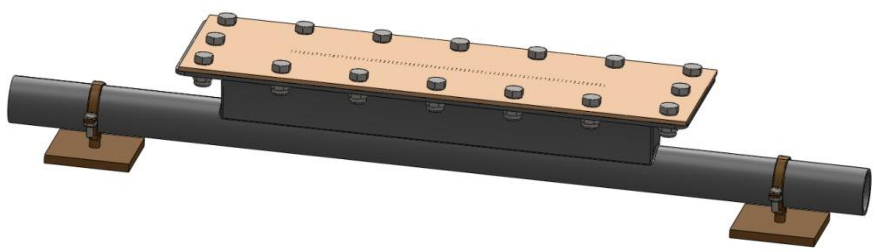

Fig. 7. Fine bubble generator - the second constructive version, rectangular shape

By its design, the physical realization of the designed model was carried out, namely the plate with orifices was also eroded, and the component parts of the body of the fine bubble generator were made of metal and joined by welding.
Figure 8 shows the built-in and assembled fine bubble generator.

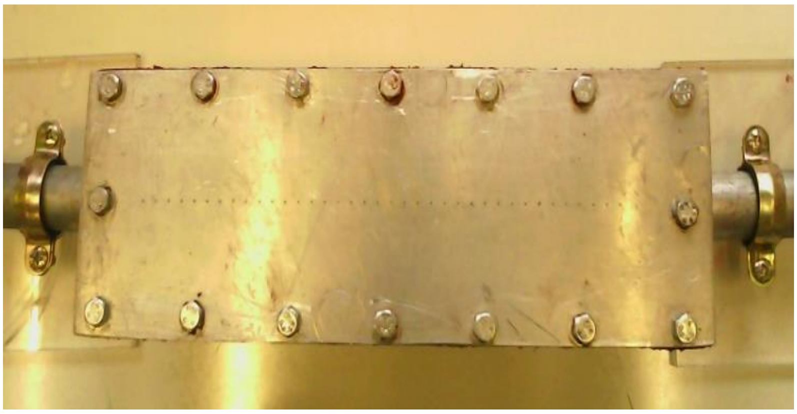

Fig. 8. FBG assembly of the fine bubble generator body and the plate fastened with screws

A sealing system is provided between the orifice plate and the flange of the fine bubble generator body to withstand the action of water consisting of a silicone gasket.

3. Installations for the insufflation of gas mixtures in water

Depending on the nature of the gas introduced (criterion II, par. 2.1) into water, there are [7][8]:

3.1 Fine bubble generator which introduces atmospheric air into the water (figure 9)

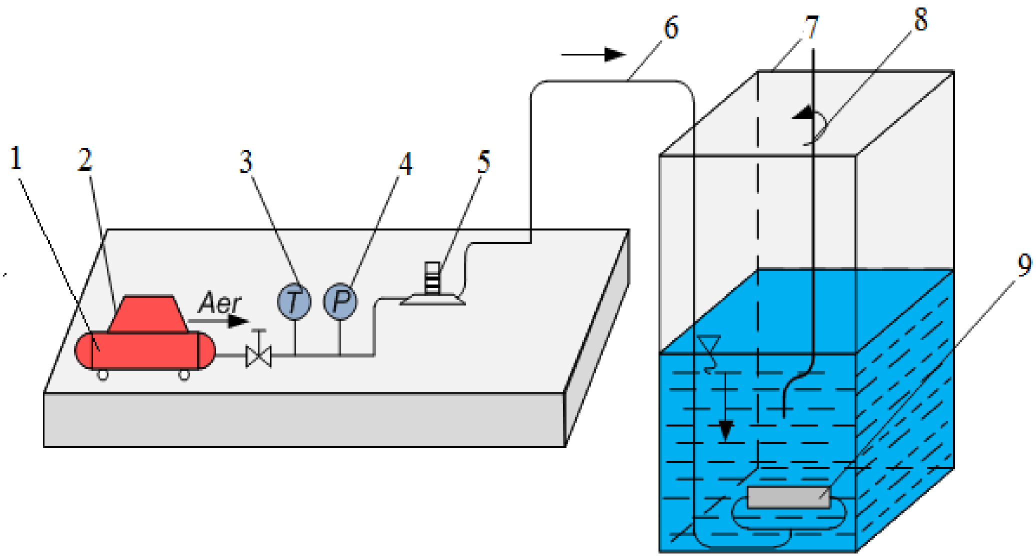

Fig. 9. Sketch of the experimental installation for introducing atmospheric air into water
1 - air compressor; 2 - compressed air tank; 3 - temperature measuring device; 4 - gas pressure measuring device; 5 - rotameter; 6 - compressed air supply pipe of the fine bubble generator; 7 - parallelepiped tank with water; 8 - oxygenometer probe; 9 - bubble generator with 152 orifices Ø 0.1 mm

From the compressor (1) the air is introduced into a compressed air tank (2) and then the rotameter (5) is used to measure the flow rate; finally the air enters the FBG (9).

3.2 Fine bubble generator which introduces a gas mixture: air + oxygen from the cylinder

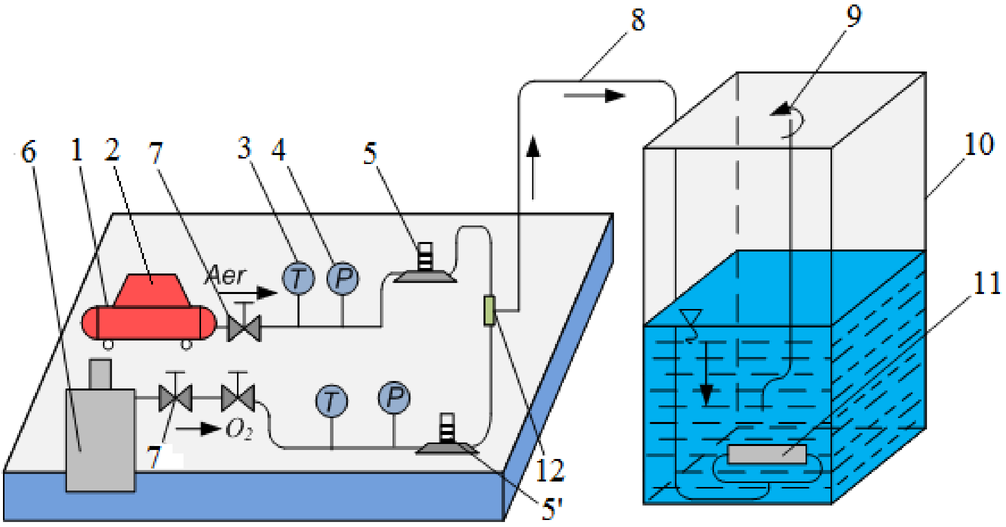

Fig. 10. Scheme of the installation that introduces a mixture of atmospheric air and oxygen into the FBG
1 - air electro compressor; 2 - compressed air tank; 3 - gas temperature measuring device with digital indication; 4 - gas pressure measuring device with digital indication; 5, 5 '- rotameters; 6 - oxygen cylinder: p = 120 bar; 7 - pressure reducer; 8 - air supply pipe + O_2 of the FBG; 9 - oxygenometer probe; 10 - water tank; 11 - fine bubble generator; 12 - mixing chamber of the two gas currents

From the compressor (1) the air is introduced into a compressed air tank (2) and subsequently into the mixing chamber (12) where it mixes with the oxygen supplied by the cylinder (6); the rotameters (5) and (5 ') are used to measure the flow rates. Finally, the mixture of atmospheric air and oxygen enters the FBG (11).

3.3 Installation using low nitrogen air

Figure 11 shows the installation scheme; the air delivered by the oxygen concentrators (1) passes through each rotameter (2) contained in the generator (1) which delivers low nitrogen content and then enters the FBG [9].

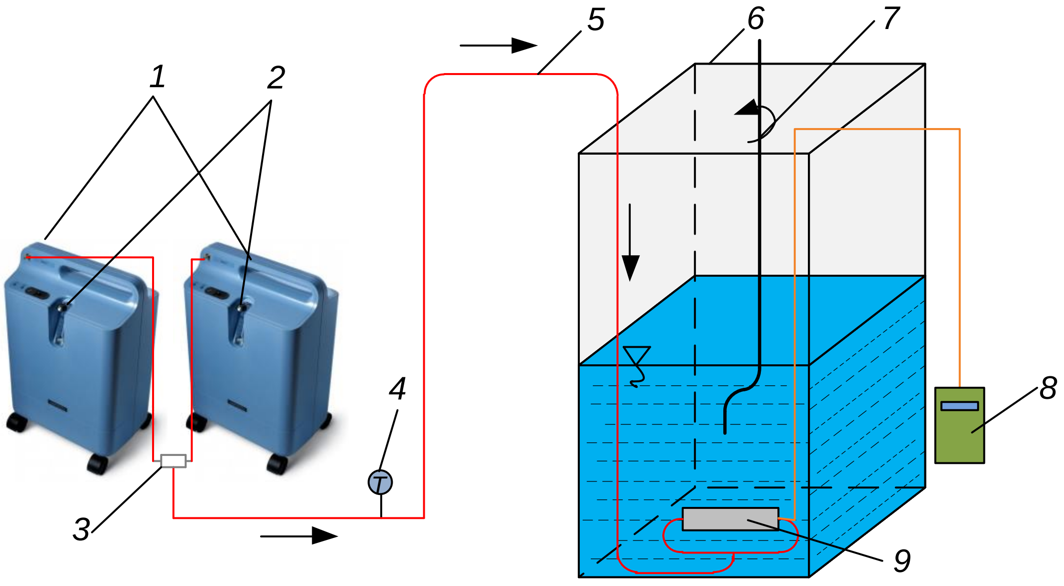

Fig. 11. Scheme of the low-nitrogen air introduction system in the FBG:
1 - oxygen concentrators; 2 - rotameters; 3 - mixing chamber of the two gas currents; 4 - gas temperature measuring device with digital indication; 5 - low nitrogen air supply pipe of FBG; 6 - parallelepiped tank with water; 7 - oxygenometer probe; 8 - gas pressure measuring device with digital indication; 9 - fine bubble generator with 152 orifices Ø 0.1 mm

Through the pipe 5 the air enters the FBG (9) which is in the water tank (6); the volume of water is 0.5 x 0.5 x 0.5 = 0.125 m^3.

3.4 Installation using a mixture of air and ozone

The scheme of the installation is shown in Figure 12 [10].

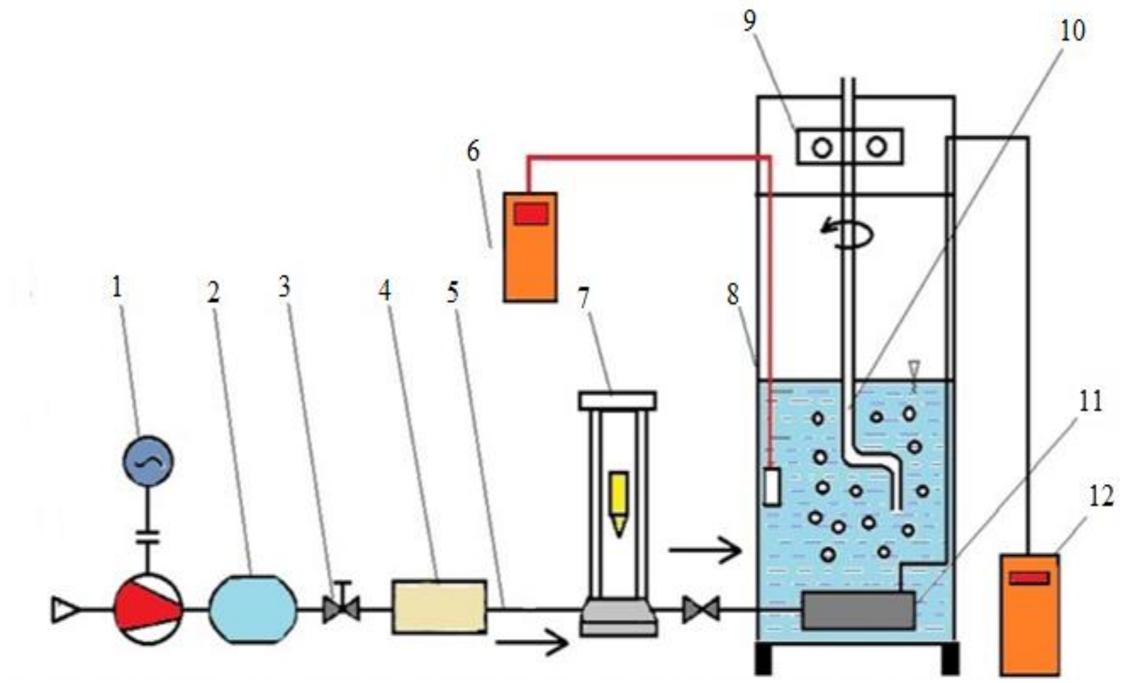

Fig. 12. Scheme of the installation for water oxygenation researches
1 - electro compressor; 2 - compressed air tank; 3 - pressure reducer; 4 - ozone generator; 5 - pipe; 6 - thermometer with digital indication; 7 - rotameter; 8 - water tank; 9 - mechanism for rotating the oxygenometer probe in water; 10 - oxygenometer probe; 11 - fine bubble generator; 12 - manometer with digital indication

The air supplied by the electro compressor (1) mixes with the ozone supplied by the generator (4) and then enters the FBG.

4. Conclusions

1. The use of FBG has the following advantages:
- Ensure a uniform distribution of air bubbles in the water volume;
- Air bubbles have the same size;
- The diameter of the air bubbles can be controlled by the size of the outlet from the perforated plate;
- The pressure losses when the air passes through FBG are much smaller than for porous diffusers made of porous materials.

2. As the diameter of the outlet of the air bubbles in the water decreases, the rate of oxygen transfer to the water will increase.

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