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# An Efficient Solution for Water Oxygenation

***Tănase Elena Beatrice[1*] --- Nicolae Băran[2] --- Mlisan Rasha[3]***

[1,2,3]Faculty of Mechanical and Mechatronics Engineering, Politehnica University of Bucharest, Bucharest, Romania

## Abstract

The paper presents a new constructive solution for fine bubble generator, used for water oxygenation. The novelty is the fact that the air entering nozzles in water (Ø$0.5\cdot10^{-3}$ m) were performed by spark erosion. The advantages of this constructive solution that generate a pressure loss much lower than that which appears at porous diffusers, are revealed. Therefore, there is an economy of electricity at the compressor station that provides the compressed air required for water oxygenation.

**Keywords:** Water oxygenation, Porous diffusers, Spark erosion, Fine bubble generator, Pressure loss, Energy economy.



## Contents



** Corresponding Author*

## 1. Introduction

Currently, water oxygenation equipment's for are classified according to several criteria; following the constructive solution, it are divided into three categories [1]:

1. Pneumatic equipment's with porous diffusers;
2. Mechanical surface equipment's of medium or large depth, with rotor, with brush;
3. Mixed oxygenation equipment's.

Within the water treatment plants two types of pneumatic equipment's are used:

a. with large bubbles, the air bubble diameter is 6 ... 13 mm and are made of perforated pipes;
b. with fine bubbles the air bubble diameter is 1 ... 3 mm and are made of porous diffusers, porous tubes, elastic membranes.

Depending on the constructive solution, pneumatic equipment's are divided into three classes:

1) Fine bubbles generators (FBG) of ceramic, called porous diffusers (Figure 1);

The shape of porous diffusers can be circular, rectangular etc.; the diameter of circular diffusers can be of Ø50, Ø100 or Ø150 [1]. The manufacturing process can lead to various porosity values, the pore diameter being in the range of 4 ÷ 500μm. Figure 1 presents a photograph of an Ø150 mm porous diffuser.

**Fig-1.** Aspect of Ø150 ceramic porous diffuser (CPD)

2) Fine bubbles generators of porous plastic materials;
3) Rubber membrane, perforated.

## 2. The Analysis of Fine Bubbles Generators Functioning Existing in Water Treatment Plants

For fine bubble generators which include porous diffusers, there have been investigated in order to determine the loss of pressure that occurs when air passes through it. Thus, the pressure losses are determined depending on the flow rate for two types of ceramic porous diffusers (CPD) with Ø100 mm diffusers (fig.2.) [1].

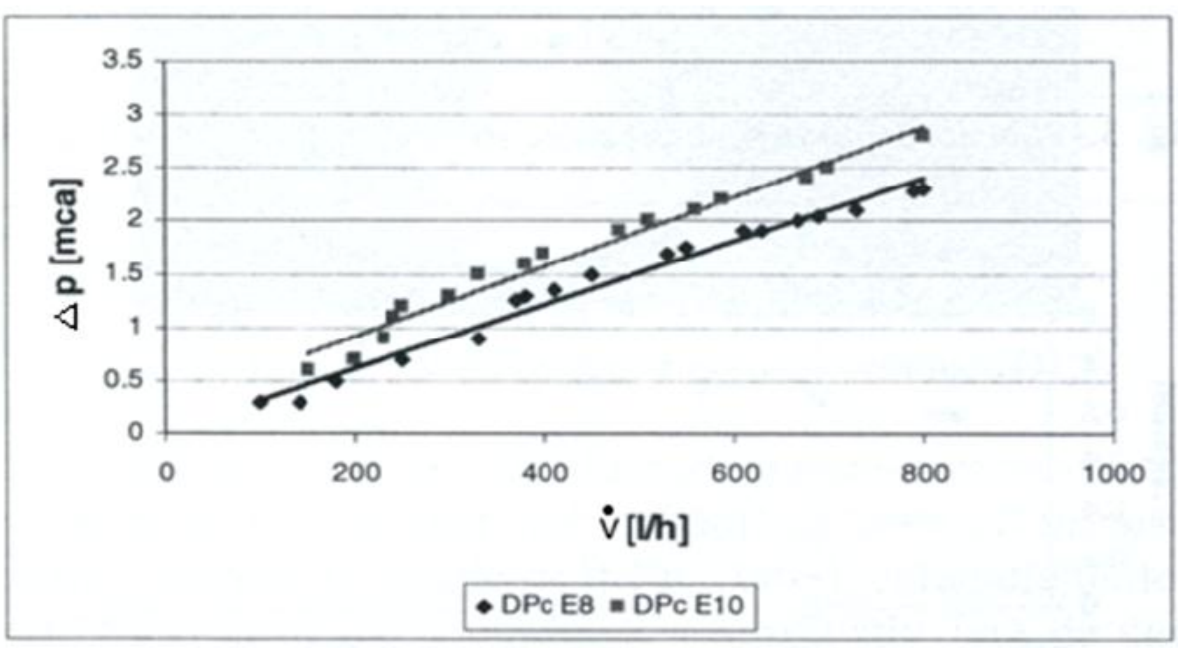


**Fig-2.** The variation of pressure loss depending on the flow rate for CPD Ø100 mm

From Figure 2 is observed that for $\dot{V} = 600\ dm^3/h$, the pressure loss through the G.B.F. is 1.7÷2.3 $mH_2O$.

For another type of FBG Ø150 mm diffuser, three different lots of ceramic porous diffusers with different volumetric porosity were tested.

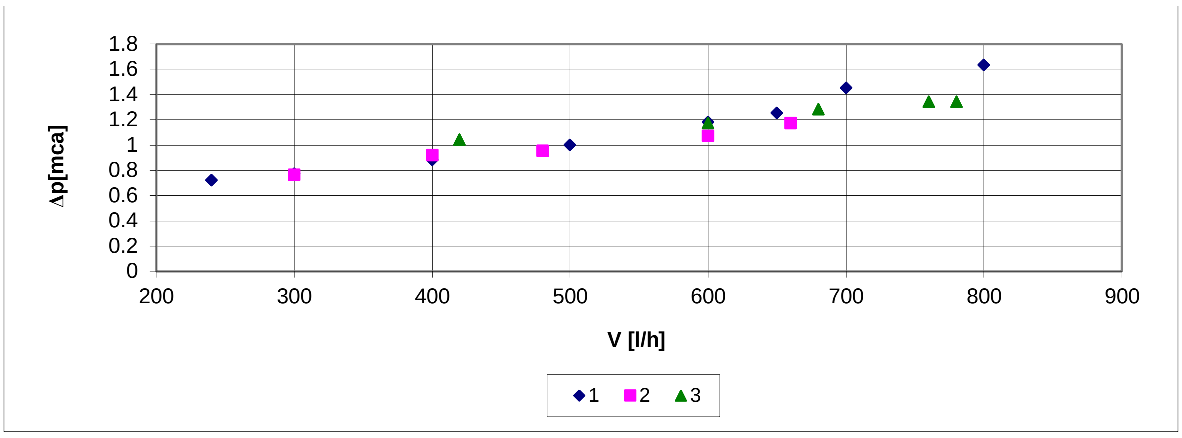


**Fig-3.** Variation of pressure loss in function of the air flow rate for CPD Ø150 mm

It can be noticed from figure 3 that a pressure loss of 1.0 ÷ 1.2 $H_2O$ occurs for $\dot{V} = 600\ dm^3/h$.

In conclusion, for the same air flow rate $\dot{V} = 600\ dm^3/h$, the pressure loss for Ø100 and Ø150 porous diffusers is in the range of 1.1÷2.3 $mH_2O$. Besides the fact that the pressure loss is large, porous diffusers have other disadvantages:

- When issuing air bubbles there is no uniformity diffusion in the water layer;
- The input air pressure in the FBG body must be high because it must overcome the hydrostatic load, the surface tension and the pressure losses occurring at the air passage through the FBG.

## 3. The Presentation of a New Type of FBG

Therefore, in addition to the three classes (1,2,3) mentioned above, the authors propose a new generation of FBG, namely:

FBG at which, the air release nozzles in the water are processed by spark erosion [2], [3]. This new type of FBG has the advantages:

- It ensures a uniform distribution of air into the mass of water; the spark erosion machine works in xOy coordinates and performs the nozzles following a network indicated by the designer.
- The nozzles have the same diameter (Ø 0.2 or 0.3 or 0.5 mm) and thus provide an air flow rate control in the water.
- The pressure loss at the air passage is much smaller than at porous diffusers.

Figure 4 presents a new type of FBG where the porous plate is built from an aluminum plate with Ø0.5 mm nozzles manufactured by spark erosion. The nozzles size establishes the size of the gas bubble [1].

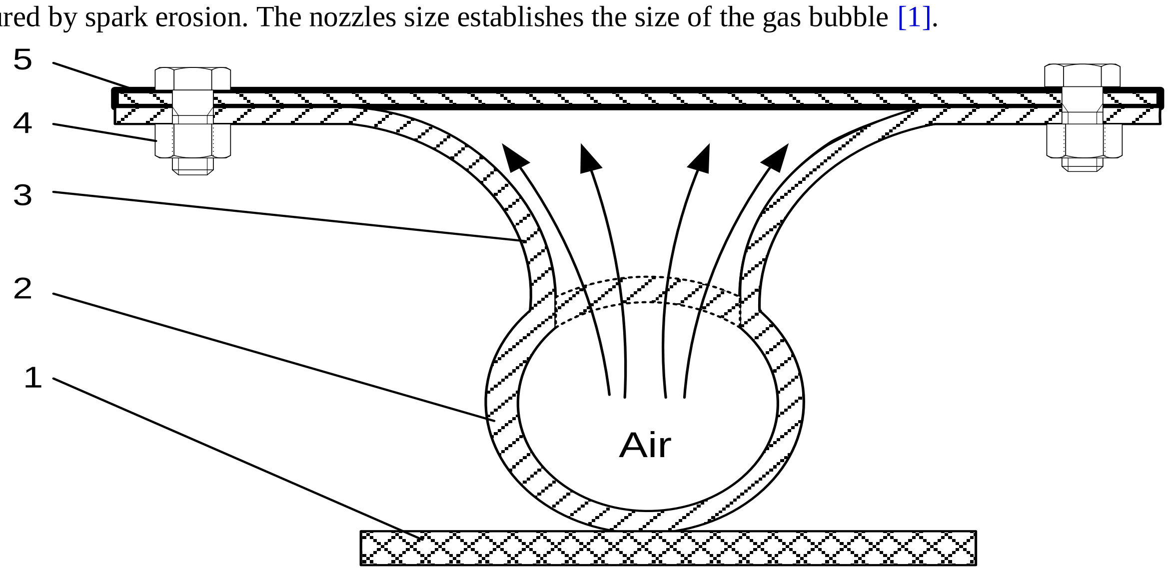


**Fig-4.** Section through a rectangular shape FBG

1- holder; 2- compressed air supply pipe; 3 – FBG body; 4 – screw for fastening the plate to the body; 5- nozzle plate

This type of FBG was put to tests using an experimental plant built in the laboratories of POLITEHNICA University of Bucharest. Other types of FBG with nozzles manufactured by spark erosion are presented in Căluşaru, et al. [4], Pătulea [5].

The authors proposed a new type of bubble generator whose orifices diameter of 0.3 mm or 0.5 mm was obtained by spark erosion. For $r_0 = 0.15$ mm in relation [1]:

$$R_0 = \left(\frac{3}{2}\cdot\frac{r_0\cdot\sigma}{\rho\cdot g}\right)^{\frac{1}{3}} \quad (1)$$

where:

σ-surface tension coefficient; $\sigma = 7.3 \cdot 10^{-2}$ N/m; ρ- water density; $\rho_l = \rho_{H2O} = 1000$ kg/m$^3$.

Is obtained: $R_0 = \left(\frac{3}{2}\cdot\frac{0.15\cdot 10^{-3}\cdot 7.3\cdot 10^{-2}}{1000\cdot 9.81}\right)^{\frac{1}{3}} = 1.185\cdot 10^{-3} m = 1.18\ mm$

This value classifies the generator in the class of generators that emit fine bubbles.

## 4. Experimental Research Regarding the Pressure Loss to a New Type of FBG

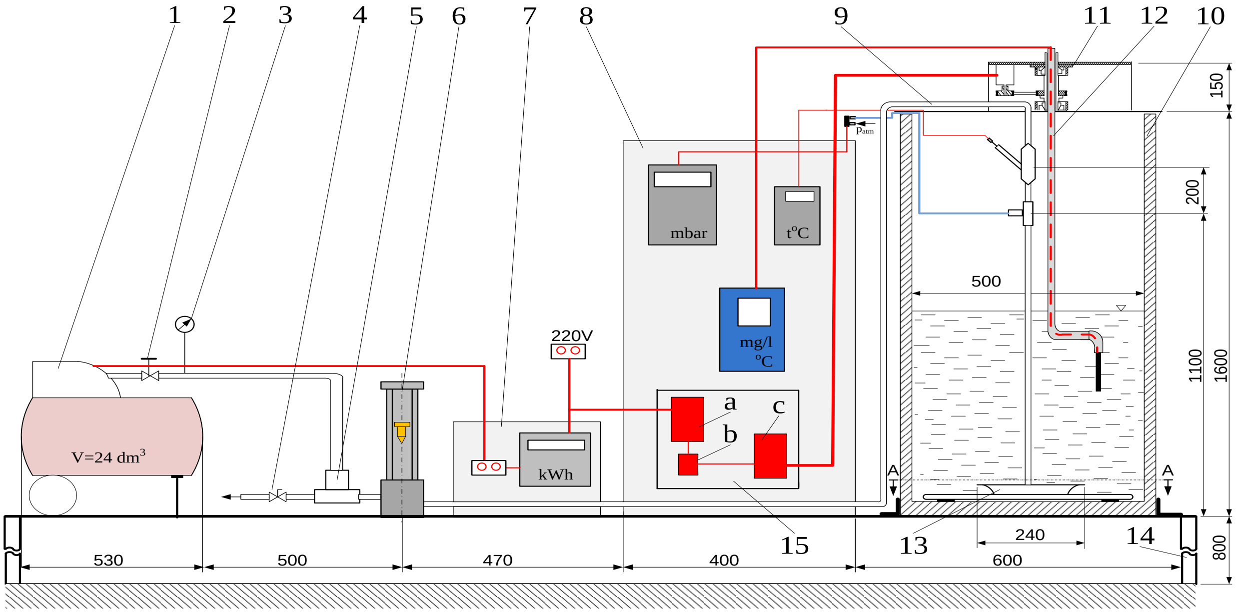


**Figure-5.**presents the principle scheme of the plant used for water oxygenation [6].

Fig.5. Sketch of the experimental setup for researches regarding water oxygenation

1– electro compressor with air tank; 2– pressure reducer; 3–manometer; 4–union for air exhaustion in the atmosphere; 5– T-joint; 6– rotameter; 7– electrical board; 8– measurement device panel; 9– pipe for the transport of the compressed air to the FBG; 10– water tank; 11– mechanism for the actuation of the probe; 12– oxygen meter probe; 13– FBG; 14– plant holder; 15–control electronics (a– supply unit, b- switch, c- control element)

The air delivered by the compressor (1) is discharged through the rotameter (6) and enters the FBG (13).Maintaining constant the pressure and the air flow rate is made using the pressure reducer (2).

The air flow rate is measured by the rotameter (6); and the pressure at the FBG input is measured by the numeric display manometer (3).

During dynamic conditions, air flows through the pipe (9) (fig.5), inflows the FBG body and enters through the nozzles in the water from the tank. The air pressure at the input of the FBG body has to surmount hydrostatic load, surface tension and pressure losses [7, 8]:

$$p_1 = \rho_{H_2O} \cdot g \cdot H + \frac{2\sigma}{r_0} + \Delta p \ [N/m^2] \qquad (2)$$

If $p_1$ is known, using this relation one can find the value of Δp:

$$\Delta p = p_1 - \rho_{H_2O} \cdot g \cdot H - \frac{2\sigma}{r_0} \ [N/m^2] \qquad (3)$$

where: H-height of the water layer above the FBG; H=0.5 m; $r_o$ –inner radius of a nozzle; $r_o=0.25\cdot10^{-3}$m; σ-surface tension coefficient of water; $\sigma = 7.3 \cdot 10^{-2}$ N/m.

Experimental measurements led to the following data:

$p_1 = 583.44 \ \text{mmH}_2\text{O} = 5723.5 \ \ \text{N}/\text{m}^2$

By replacing in (3), one obtains:

$$\Delta p = 5723.5 - 1000 \cdot 9.81 \cdot 0.5 - \frac{2 \cdot 7.3 \cdot 10^{-2}}{0.25 \cdot 10^{-3}} = 244.35 N/m^2 = 24.92 mmH_2O \qquad (4)$$

This experimentally determined value was obtained for an air flow rate of $\dot{V} = 600\, dm^3/h$.

## 5. Conclusions

1. Fine bubble generators manufactured by spark erosion represent an original solution; FBG manufactured by spark erosion provide a controlled and uniform spreading of air in water.

2. The ratio between the distance between two nozzles and their diameter is chosen [8] such as the bubble columns do not interfere, phenomenon that appears in the case of porous diffusers manufactured from ceramic materials or glass.

3. The experimental researches proved that pressure losses that appeared when air passed through FBGs with plates manufactured by spark erosion were less that in the case of FBGs called "porous diffusers".

For the studied case, *Δp=24.9 mmH$_2$O*, and for the same air flow rate of $\dot{V} = 600 \ dm^3/h$ from Oprina, et al. [1], results a pressure loss:

-*Δp=1.7 ÷ 2.3 mH$_2$O* for *CPD Ø100 mm;*

-*Δp=1.17 ÷ 1.2 mH$_2$O* for *CPD Ø150 mm.*

4. Reduced pressure losses when air passes through the FBG leads to an economy of energy used for air compression.

5. The consumption of energy needed for aeration represents about 50% from the total energy consumption of a wastewater plant. This high percentage explains the scientific researches performed in order to obtain FBGs with reduced pressure losses, so with less energy consumption.

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