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Experimental Researches Regarding the Obtaining of Fine Air Bubbles

Zaid Abulghanam, Nicolae Băran, Sayel M. Fayyad, Sameh Abu-Dalo

***Abstract:** In this paper the authors present the constructive solution of a new type of fine air bubbles generator. As the air output holes are located on a single row, the bubble columns that appear in the water mass generate a planar jet similar to a bubble curtain. This bubble curtain can be used to depurate residual waters or to enrich basins or lakes with oxygen. This fine bubble generator has Ø0.5mm holes, practiced by electro-erosion using an AG55L type machine that ensures the location of the holes in xoy coordinates as demanded by the designer. Images and results of experimental researches made on the fine bubbles generator, at different working levels, are exposed.*

***Keywords:** Fine Bubbles Generator, Processing by Electro-Erosion, Bubble Curtain.*

I. INTRODUCTION

In order to increase the efficiency of aeration systems, it is necessary to increase the quantity of oxygen transferred to the water; for this purpose three methods can be used:

1. Increase of the transfer area of the oxygen to water and of the contact period between the air bubble and water;
2. Increase of the moving force (the gradient of the concentration);
3. Increase of the diffusibility of the environment by using the intensity and structure of the flow.

With respect to point 1, it is known that the ratio between the volume of the sphere (*V*) and area of the sphere (*A*) is *d*/6, where *d* is the diameter of the sphere; in order to have this ratio as smaller as possible (meaning a greater *A*) the diameter of the sphere has to be as small as possible. In the presented case the diameter of the sphere becomes the diameter of the air bubble that interferes with the water mass. To obtain air bubbles with very small diameters, porous diffusers made by porous ceramic materials, syntherised glass, other porous materials are used; these porous diffusers have the disadvantage of not ensuring a uniform distribution of air bubbles in the diffuser's output section and present a great pressure loss [1, 2]. This work proposes the obtaining of fine bubbles generators (FBG) that guarantee a uniform distribution of the air in the water mass. Moreover, this distribution follows the pattern desired by the designer of the oxygenation plant. The process proposed for the obtaining of the new type of FBG is based on a non-conventional technology, namely electro-erosion processing.

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***** Correspondence Author (s)

Zaid Abulghanam*, Al-Balqa Applied University-Faculty of Engineering Technology" Jordan.

Nicolae Băran, Politehnica" University of Bucharest, Department of Mechanical Engineering and Mechatronics, 313, Splaiul Independenţei, Bucharest, Romania.

Sayel M. Fayyad, Al-Balqa Applied University-Faculty of Engineering Technology" Jordan.

Sameh Abu-Dalo, Al-Balqa Applied University-Faculty of Engineering Technology" Jordan.

This process allows the obtaining of holes of ∅=0.2 mm, ∅= 0.3mm, ∅ = 0.5 mm, that can be drilled in a plane board, placed on a square, rectangular, chess-like net etc. and obtaining the desired distance between the holes. This is possible because the electro-erosion working machine works in XOY coordinates with a very high accuracy (0.0001 mm) [3].

Nicolae B. et al. (2017) presented the theoretical and experimental researches results on the use of air filtration cartridges to the achievement of micro air bubbles. **Mihaela C. Et al. (2017)** calculated the pressure loss that appears when the compressed air circulates from the input of the fine bubble generator to the output of the air bubble in the water layer. They also exposed the sketch of the experimental plant and the sketch of a new fine bubble generator type.

The mass transfer between the oxygen contained in the air and the water mass has applications in the following domains:

- Aeration of the residual waters from the depuration stations;
- Aeration of the waters from fountains and basins;
- Aeration of the basins from the fish breeding stations, stock ponds etc.;

In the following are exposed:

- the fine bubbles generator ;
- the experimental plant developed for the study of the working FBG;

II. THE CONSTRUCTIVE SOLUTION OF THE FINE BUBBLES GENERATOR.

The FBG is made from a board endowed with holes, fixed to the body of the generator by using screws. A row of 19 Ø0.5mm equidistant holes, having the step of 10mm, were practiced in the board (fig.1) by electro-erosion.

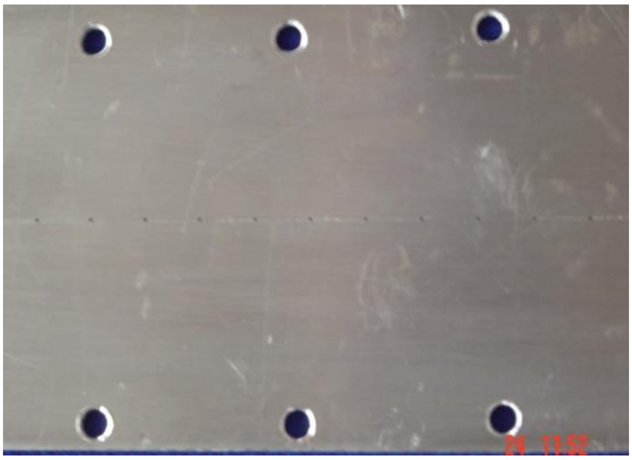

Fig. 1 Detail of the Hole Board.

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The FBG body is connected to the compressed air pipe (fig.2), allowing the pass from the circular section of the pipe to the rectangular section of the hole board.

Fig. 2 Fine Bubble Generator, of Rectangular Shape.

The distance between the holes (d), need to be of the order $(3/4)r_o$ in order to avoid the coalescence of the bubbles when exiting the holes.

The initial radius of the air bubbles (r_o) is obtained from the equilibrium equation on the oy axis between the Archimedean force (F_{arh}), the weight of the air bubble (G_{aer}) and the superficial tension force (F_{ts}) [4].

$$F_{arh} = G_{aer} + F_{ts} \qquad (1)$$

$$\rho_{H2O} \cdot \frac{4}{3}\pi r_0^3 \cdot g = \rho_{aer} \cdot \frac{4}{3}\pi r_0^3 g + \sigma \cdot \pi \cdot d_0$$

$$\frac{4}{3} r_0^3 \cdot g(\rho_{H2O} - \rho_{aer}) = \sigma \cdot d_0 \qquad (2)$$

$$r_0 = \sqrt[3]{\frac{3}{4} \cdot \frac{\sigma \cdot d_0}{g(\rho_{H2O} - \rho_{aer})}} \qquad (3)$$

The following values are given:

- the superficial tension coefficient: $\sigma = 8 \cdot 10^{-2}\, N/m^2$
- the diameter of the hole : $d_0 = 0.5 \cdot 10^{-3} m$
- the density of the water : $\rho_{H2O} = 10^3 kg/m^3$
-the density of the air: $\rho_{aer} = 1.2 kg/m^3$

$$r_0 = \sqrt[3]{\frac{3}{4} \cdot \frac{8 \cdot 10^{-2} \cdot 0.5 \cdot 10^{-3}}{9.81(1000 - 1.2)}} = 1.44mm \qquad (4)$$

The chosen value: $d = 20d_0 = 20 \cdot 0.5mm = 10mm$ can be explained by experimental researches published in [5] where r_0 has greater values that the ones obtained by the relation (3).

The ascensional velocity of the air bubbles in water [5]

$$w = 0.162\sqrt{r_0} = 0{,}162\sqrt{1.44}\ m/s, \text{with } r_0 \text{ in } mm \qquad (5)$$

$$w = 0.1948 m/s \qquad (6)$$

The contact period between the air bubble and water will be much higher as the initial radius of the air bubbles (r_0) will be smaller. From relation (3) can be remarked that $\sigma, g, \rho_{H2O}, \rho_{aer}$ cannot be modified, thus

$$r_0 = ct\sqrt[3]{d_0} \qquad (7)$$

As the diameter of the hole is smaller, the radius r_0 will be smaller, so that the ascensional velocity of the air bubble will be smaller; as consequent the contact period between the air bubble and the water mass will increase, fact that leads to a more efficient oxygenation of the water.

III. EXPERIMENTAL PLANT FOR THE STUDY OF THE FBG FUNCTIONING

To avoid the transmissions of vibrations from the compressor to the FBG the stand is composed by two independent units (fig.3). The stand contains:

* A compressor (1) with the following parameters:

-maximal pressure at overflow: p = 8 bar;

- intake air flow rate : $\dot{V}$ = 200 dm ^{3}/ min;
- working temperature: t = -10 ^{0}C -100 ^{0}C;
- power of the electric motor: P = 1,1 kW;
- number of turns: n = 2850 rpm;
- volume of the tank : V = 24 dm^3.

The compressor is endowed with a manometer (3) and a pressure reducer (4) that assures the needed working pressure.

* A Plexiglas tank containing water, having the following dimensions 0.5×0.5×1.5 m^3

Two compressed air pipes were made in order to supply the needed flow rate for the FBG:

-A pipe through the valves (15) feeds the FBG;

-A pipe through the valves (16) and (17) allows the discharge of the air excess delivered by the compressor.

The air flow rate introduced in the FBG is measured with the rotameter (5) that will be changed depending of the value range of the air flow rates.

When entering the FBG the air temperature is measured with a digital thermometer (6) and the pressure is measured using a digital manometer (7).

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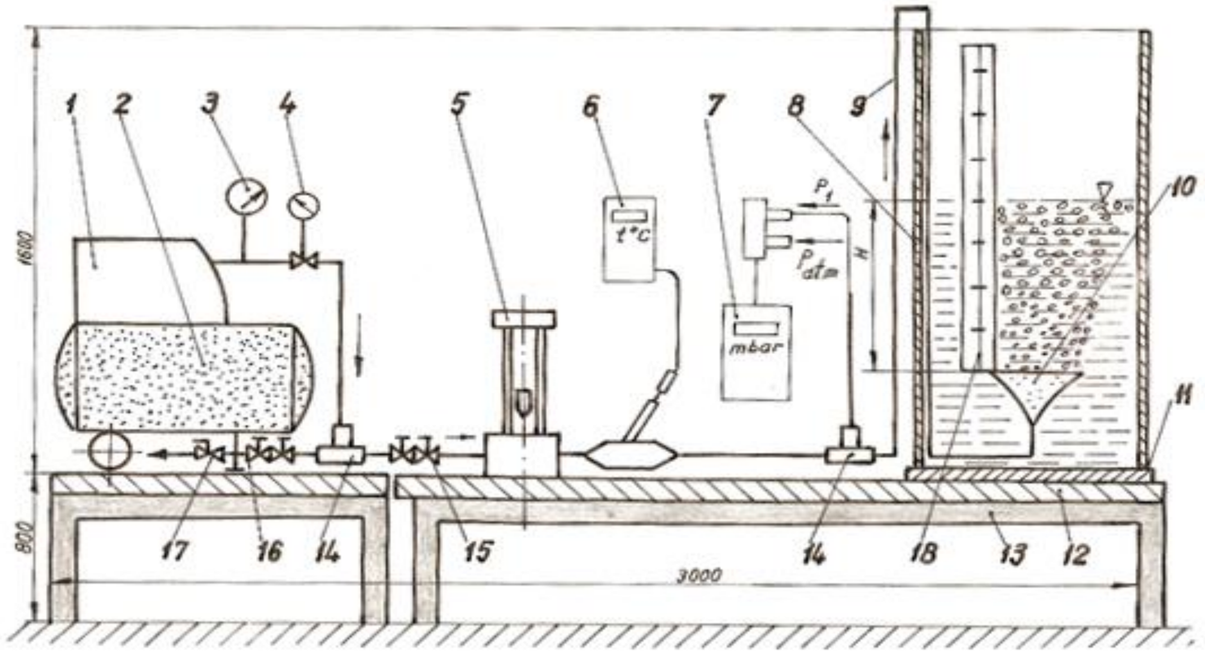

Fig. 3 Sketch for the Experimental Stand of the FBG

1- air compressor; 2- compressed air tank; 3- manometer; 4- pressure reducer; 5- rotameter; 6- digital thermometer; 7- digital manometer; 8- water tank; 9- compressed air pipe; 10- FBG; 11- base plate of the tank; 12- base plate of the stand; 13- metallic bearings; 14 – tee; 15 – valves for the regulation of the air feed to the FBG; 16 – valves for the air feed discharged to the exterior; 17- shutting-off valve; 18- graded scale.

IV. RESULTS AND DISCUSSION

A. Experimental Researches Regarding the FBG

Water was introduced in the tank (8) presented in figure 3, so that a water bed of height H = 500mm was obtained over the hole board. Per assembly , the bubble columns generate a planar jet of bubbles, which develop in different ways when the static pressure of the air entering the FBG increases (fig.4, 5, 6, 7, 8, 9, 10) .

In figure 4, the digital manometer displays 52.8mbar = 538.22mmH_2O, a smaller value than 563mmH_2O. This fact proves that not all the holes are emitting air bubbles. The explanation is the following:

-in the experimental plant, the drilled board supports a water bed of height H=500mmH_2O; the pressure due to the superficial tension [3] is of:

$$p_{ts} = \frac{2\sigma}{r_0} = \frac{2 \cdot 8 \cdot 10^{-2}}{0.25 \cdot 10^{-3}} = 620\, N/m^2 \qquad (8)$$

$$\Delta h_{ts} = \frac{p_{ts}}{\rho_{H2O} \cdot g} = \frac{620}{10^3 \cdot 9.81} = 0.063 mH_2O \qquad (9)$$

Therefore, the first gas bubbles will appear if the digital manometer displays:

$$\Delta h_1 > H + \Delta h_{ts} \,,\, \Delta h_1 > 563 mmH_2O \qquad (10)$$

Fig. 4. A Part of the FBG Emits Disparate Air Bubbles

In figure 5 the FBG works normally, every hole emits a bubble column. If the static pressure of the air entering the FBG is increased to Δh_1 = 62.4 mbar = 636mm H2O, the planar bubble jet looks like in figure 7.

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The use of the pressure reducer (picture 4, fig. 3) allows the increase of the static pressure of the air to Δh_1 = 80.5 mbar = 820.59mm H_2O; the planar jet on the upper side disintegrates (fig.8) .

If the pressure of the compressed air is increased to Δh_1 = 120 mbar = 1223mm H_2O, the image of figure 9 is obtained.

If the pressure of the compressed air continues to increase to Δh_1 = 165 mbar = 1681.9mm H_2O, the image of figure 10 is obtained.

Figures 5-9 prove that this type of fine bubbles generator gives birth to a planar jet of air bubbles, namely a bubble curtain, of dimensions 20×50 cm^2 .

Following the experimental researches practiced previously [6] , [7] the dependence $\dot{V}$ = f(Δh_1) presented in figure 11 was established.

Fig. 5 Working FBG; Δh_1 = 60 mbar = 611mm H_2O, Fig. 6 Bubble columns that generate a planar jet; picture made from a lateral side for the figure 5 .

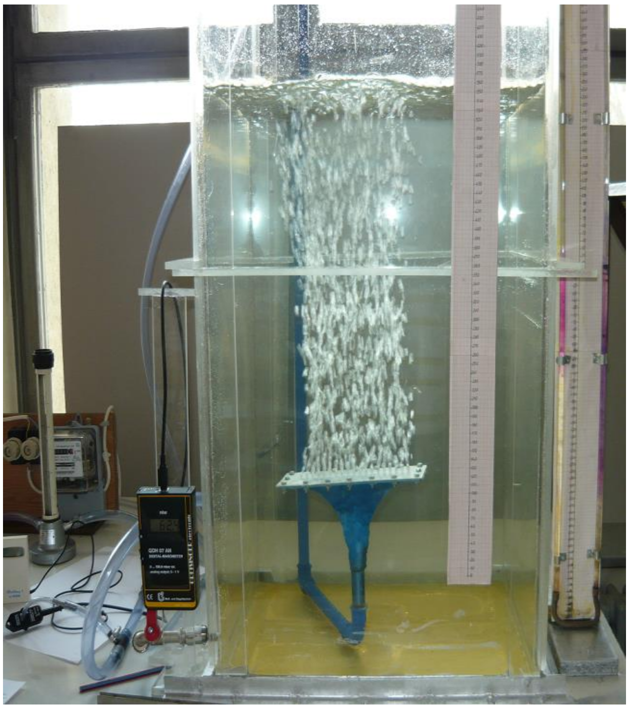

Fig. 7 Working FBG; $\Delta h_1 = 636 mmH_2O$

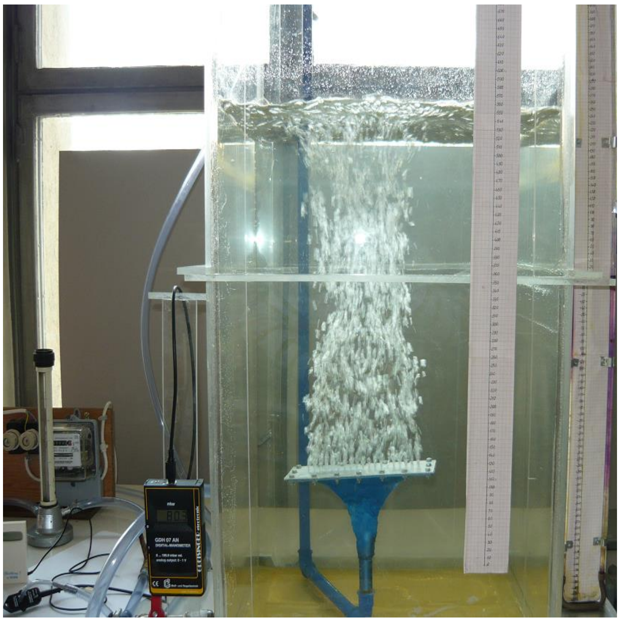

Fig. 8 Working FBG; $\Delta h_1 = 820.59 mmH_2O$

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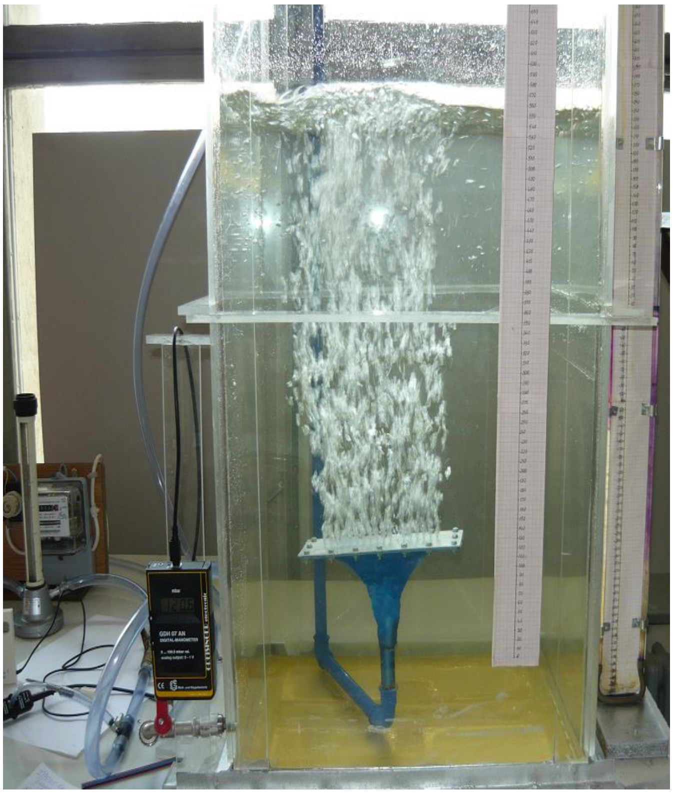

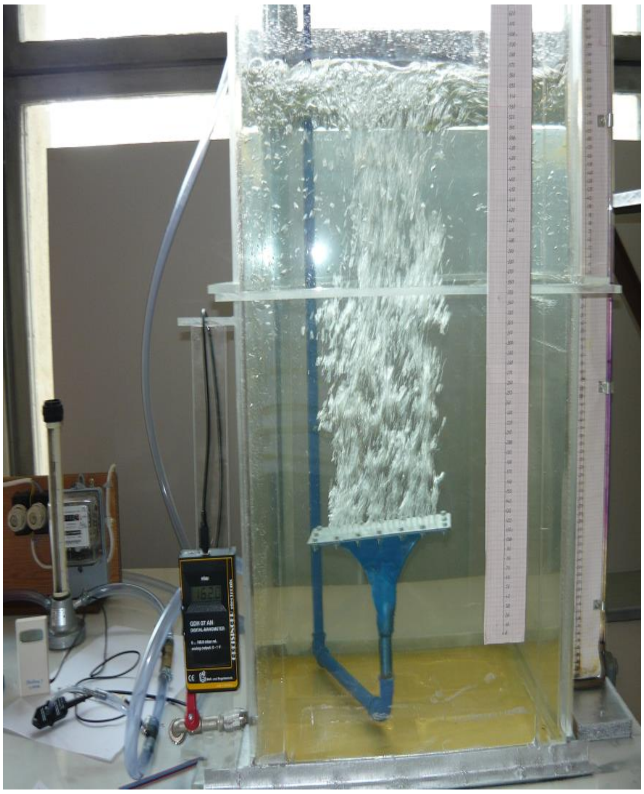

Fig. 9 Working FBG; the air columns are distorted; $\Delta h_1 = 1223 mmH_2O$ **, Fig. 10 FBG working in turbulent conditions;** $\Delta h_1 = 1681.9 mmH_2O$

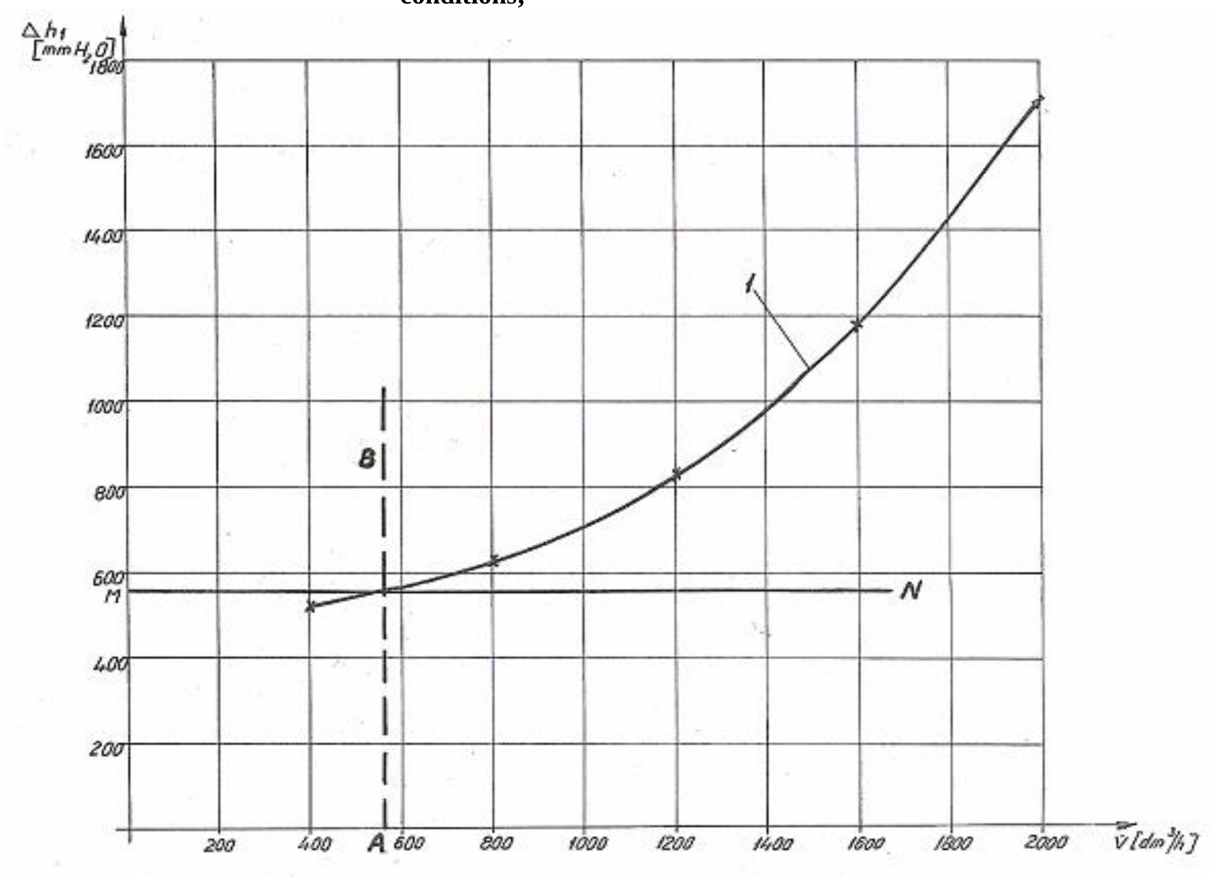

Fig. 11 Graphic representation of the function: $\dot{V}$ **= f(Δh₁)**

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The efficient working range of a FBG, for which he emits independent bubble columns, in the case of a hydrostatic load H = 500mm H_2O is delimited as follows:
- over the line MN (whose ordinate is equal to 563 mm H_2O), in the limits of Δh_1 = 565 ÷ 1200 mm H_2O
- on the right side of the line AB, (whose abscissa is equal to 545 dm^3/h), in the limits of $\dot{V}$ = 545 ÷ 1600 dm^3/h.

Figure 11 shows that, if the air flow rate is increased over 1400 dm^3/h, the value of Δh_1 exceeds 1000 mm H_2O, leading to a increase of the energy needed for the compression of the air injected in the water mass.

V. CONCLUSIONS

- This type of fine bubbles generator, multiplied five times, ensures an air bubble curtain of a width of 1 m and height given by the hydrostatic load.
- The air feed introduced through a row of holes $\phi 0.5 mm$ generates bubble air columns similar to a planar jet [8].
- The FBG can be used to aerate polluted water masses that displace with a small velocity (in the case of depurating stations of the residual waters) or to oxygenate waters that feed basins for fish breeding.
- Another use of the FBG is the following: in the case of euthrophyed lakes, a row of 20 FBG is launched at depth and displaced by a boat floating on the surface of the lake. The boat contains a moto-compressor that ensures the air needed for the oxygenation of the water mass.
- The construction of FBG is solid, resistant to water action.

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