PNEUMATIC CIRCUIT OF UNDERWATER EQUIPMENT FOR INTERVENTIONS IN CONTAMINATED WATERS

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Abstract: The Research Laboratory of the Diving Center has homologated an experimental model of the underwater equipment for interventions in contaminated waters, to assure the total protection of the diver in these interventions.

This paper presents the pneumatic circuit of the underwater equipment for interventions in contaminated waters:

1. The first stage pressure regulator of the main reservoir
2. The distributor
3. The first stage pressure regulator of the second reservoir
4. Two ways valve
5. The super flow demand regulator

1. INTRODUCTION

Contaminated water is defined as water which contains any chemical or biological substance which poses a chronic or acute health risk to exposed personnel. The contamination may be naturally occurring or come from a variety of sources including terrorist acts, leaking of hydrocarbons and industrial discharges.

For the divers, it is necessary to intervene often in these waters. Therefore it imposed the innovation of specific equipment which, after the evaluation of the causes, permits the rapid diving in contaminated water and a maximum protection of the divers. These interventions have following characteristics: diver's protection by a perfect tightness, small diving descent, large duration and the possibility to permanently communicate by the surface.

The Research Laboratory of the Diving Center has homologated an experimental model of the underwater equipment for interventions in contaminated waters, to assure the total protection of the diver in these interventions. In this paper is presented the pneumatic circuit of the equipment.

2. THE COMPOSE OF THE PNEUMATIC CIRCUIT

The pneumatic circuit of the equipment consists in:

- The first stage pressure regulator of the main reservoir from the surface
- The distributor for the air supply
- The first stage pressure regulator of the emergency reservoir
- The two ways valve
- The super flow demand regulator

2.1. THE FIRST STAGE PRESSURE REGULATOR OF THE MAIN RESERVOIR FROM THE SURFACE

The supply of the diving equipment is on the surface from a large compressed air cylinder, were the stock pressure is 150-200 bar. Before the diving, this pressure is reduced on a middle value, setting by the adjustment screw of the first stage pressure regulator.

2.2. THE DISTRIBUTOR FOR THE AIR SUPPLY

A middle pressure hose (umbilical) assure the link with the T distributor. The distributor is designed to operate, even if the main supply from the surface is accidental stopped. In this case, the access unto the super flow demand regulator is blocked (tightness on ball) and it is opened the access from the hose of the second reservoir. The second reservoir has a first stage regulator, guided by the hydrostatic pressure and the air flows to the distributor at the same value of the middle pressure assured from the surface. The distributor prevents the risk of water's penetration into the super flow demand regulator and the diver receives from the second reservoir a quantity of air necessary for his security.

2.3. THE FIRST STAGE PRESSURE REGULATOR OF THE EMERGENCY RESERVOIR

This is a regulator piloted by the hydrostatic pressure; it is permanently in contact with the water and provides the emergency breathing gas. The regulator is balanced, with piston. It reduces the high pressure (150 bar) from the emergency reservoir on the middle value, pressure assured by the first stage regulator of the surface supply too, for the distributor.

2.4. THE TWO WAYS VALVE

This valve was designed to supply with air the super flow demand regulator at demand and free flow too, if it is necessary. The valve provides an additional flow of air into the helmet for ventilation and defogging.

2.5. THE SUPER FLOW DEMAND REGULATOR

The regulator receives air at middle pressure and provides at demand, to the diver, super flow breathing gas (5 cm water). This super flow into the helmet don't permit the intrusion of the contaminated water, it is safety.

3. THE FUNCTION OF THE GEARS

3.1. THE REGULATOR OF THE MAIN RESERVOIR FROM THE SURFACE

The regulator receives air at the pressure p_s from the compressed air cylinder and reduces this pressure to a middle value p_m:

$$p_m = p_h + 10bar \qquad (1)$$

Where p_h – the absolute hydrostatic pressure at depth h

p_m – the middle pressure from the umbilical.

Because the regulator isn't at hydrostatic pressure, it sets the correspondent pressure p_h for the depth h.

$$p_h = 1bar + \rho gh \qquad (2)$$

Usually it approximates $10 mcol.water \approx 1bar$.

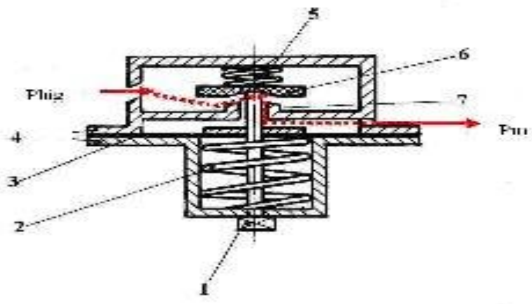

Figure 1 The regulator of the main reservoir from the surface

1. ***Adjustment screw***
2. ***Adjustment spring***
3. ***Diaphragm***
4. ***Body***
5. ***Shutting spring***
6. ***Piston***
7. ***Seat***

3.2. THE DISTRIBUTOR FOR THE AIR SUPPLY

The distributor has a simple T form. The middle pressure, which flows from the surface, presses the ball on the seat (3) and blocks the access from and unto the emergency reservoir. In case of an accidental interruption of the supply from the surface, it opens the manifold of the emergency reservoir, the air flow push the ball from the seat 3 unto the seat (1) and it stream to the two ways valve. In case of an accidental break of the umbilical, the water don't pervades into the valve, where the pressure is up 10 bar than the hydrostatic pressure.

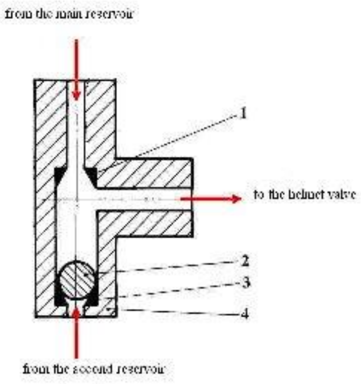

Figure 2 Distributor

1. ***Seat***
2. ***Ball***
3. ***Seat***
4. ***Body***

3.3. THE FIRST STAGE PRESSURE REGULATOR OF THE EMERGENCY RESERVOIR

Where the piston (4) is balanced closes on the seat (5) the p_{hight} air input. When the diver inspires, the middle pressure falls, the piston is pushed by the hydrostatic pressure and it opens the access of the breathing gas from the reservoir. The spring is adjusted until the middle pressure p_m allowed has 10 bar up than the hydrostatic pressure.

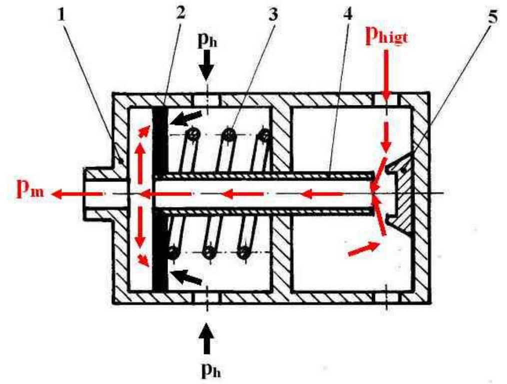

Figure 3 The first stage pressure regulator of the emergency reservoir

1. ***Body***
2. ***Diaphragm***
3. ***Spring***
4. ***Piston***
5. ***Seat***

3.4. THE TWO WAYS VALVE

The breathing air from the distributor inputs by the system ball – seat too, the middle pressure push the ball (2) and the gas flows into the valve precinct. The faucet (4) opens the valve and if is necessary, the faucet (8) opens the access into the helmet, for ventilation and defogging.

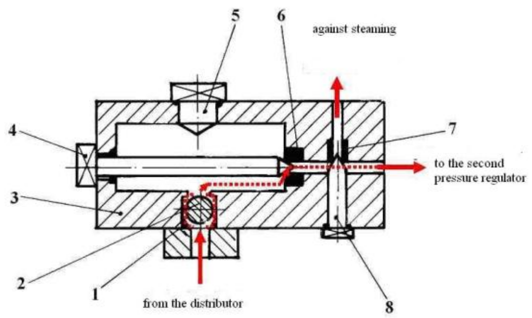

Figure 4 The two ways valve

1. ***Seat***
2. ***Ball***
3. ***Body***
4. ***Faucet***
5. ***Cork***
6. ***Gasket***
7. ***Gasket***
8. ***Defogging faucet***

3.5. THE SUPER FLOW DEMAND REGULATOR

This is a simple projection solution, by attaching of the spring (7) for super flow. The mechanism is with downstream piston. By inspiration, the lever (8), pushed by diaphragm, drags the piston and it opens the input of the breathing gas by the restrictor (2), until the pressures from upstream and downstream are balanced. In this moment, the piston closes the entrance of the air. The super flow spring (7) oppresses the diaphragm with a force which exerts 5cm col. water pressure. The respiratory gas gets out from the regulator with the pressure $p_h + 5cmcol.water$. This small differential pressure prevents the accidentally input of the contaminated water into the mask. The respiratory air is evacuated by means the valves block (9).

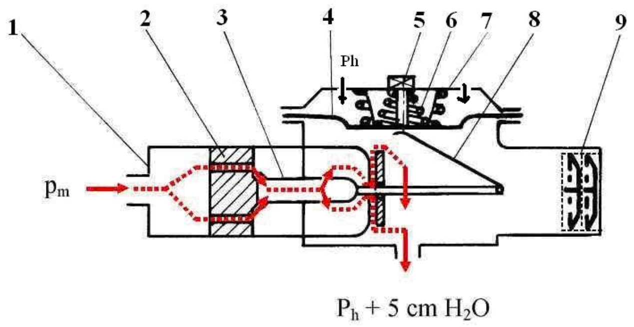

Figure 5 The super flow demand regulator

1. ***Body***
2. ***Restrictor***
3. ***Downstream piston***
4. ***Diaphragm***
5. ***Adjustment screw***
6. ***Safeguard spring***
7. ***Super flow spring***
8. ***Lever***
9. ***Valves block***

4. THE BALANCE OF FORCES WHICH ACTION THE MECHANISM OF THE SUPER FLOW DEMAND REGULATOR

The functional principle of the mechanism of the super flow demand regulator is delineated in Figure 6.

The forces which act the plug of piston push the lever by rotation with s.

The plug rotates with $\ddot{\theta}$ and displaces with x.

The diameter of plug is d.

The longer of lever is B.

When the diver inspires, the differential pressure opens the plug. The expantion wave propagates unto the first stage pressure regulator and the plug of this it’s open. This is the unbalance phase of the inspiration. As the mass flow rate becomes equal in both valves, the flow becomes balanced (stationary flow).

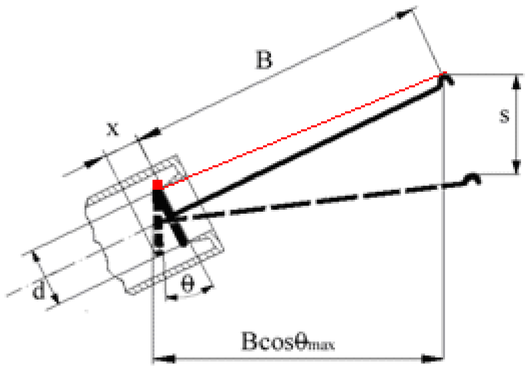

Figure 6 The tangential mechanism

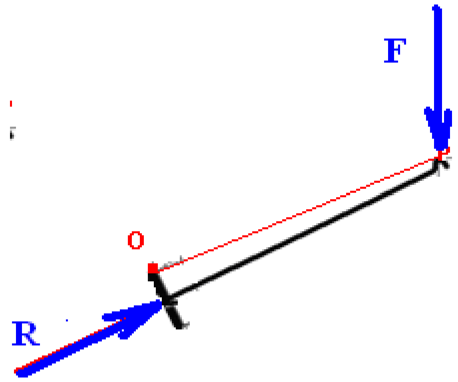

Figure 7 The forces which action on the plug in the point O
R – resistance force of the air
F – movement force
i – lever multiplication ratio
I – inertial moment of the plug

Underaction of the forces F and R, results a rotation moment M which moves the plug in the point O (fig. 7):

$$\mathrm{M} = {}^{d}\!/_{2}\left(i \cdot F - R\right) \tag{3}$$

$$\mathrm{M} = I\,\ddot{\theta} \tag{4}$$

The dynamics of the forces balance for the open of the mechanism can be wrights thus:

$$I\,\ddot{\theta} = {}^{d}\!/_{2}\left(i \cdot F - R\right) \tag{5}$$

$$i = \frac{B}{{}^{d}\!/_{2}} \tag{6}$$

$$F = \Delta p \cdot A_m \tag{7}$$

$$R = \frac{1}{2} A_p C \rho_c U_c^2 = \frac{1}{2} A_p \cdot C \cdot k \cdot p_c \tag{8}$$

C- coefficient of form

U_c- critical velocity

Δp - differential pressure

A_m- effective area of the diaphragme

ρ_c- critical density

p_c –critical pressure

The exposed area of the plug is:

$$A_p = \frac{\pi d^2}{4}\cos\theta \quad (9)$$

The displacement of the diaphragme s is made by its deformation under differential pressure $\Delta p = 3 \div 4 cmcol.water$ by inspiration and the mechanism it's open. The sensibility of the apparatus is high and the respiratory resistance is low.

The super flow mechanism (7) (fig.5) assure of the diver a facile breathing even if he sustains an intense physical effort. But the great advantage of the super flow is that the respiratory pressure p_r into the helmet is up the hydrostatic pressure and it prevents the accidental intrusion of the contaminated water.

$$p_r = p_m + 5cmH_2O \quad (10)$$

5. CONCLUSIONS

The underwater equipment for interventions in contaminated waters was tested in the simulator of the Hyperbaric laboratory and into the Black See too, like an experimental model. The equipment offers to the utilizer the diving security and respiratory comfort because of the super flow demand regulator.

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