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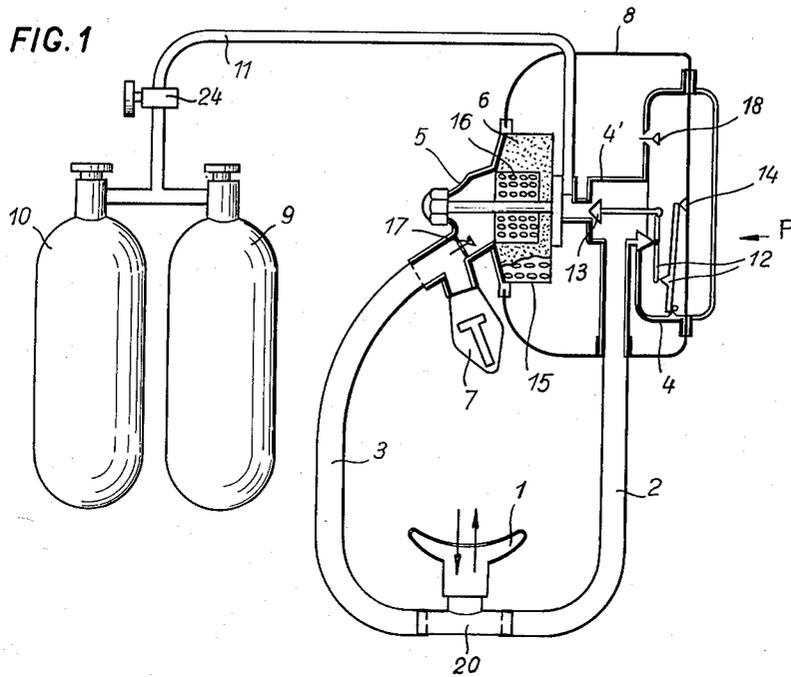
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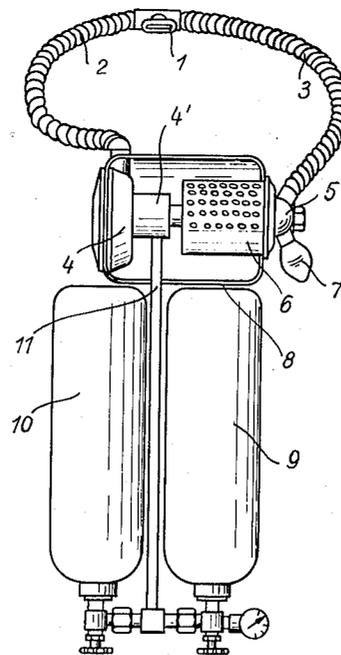
SUBAQUEOUS BREATHING APPARATUS

Filed June 28, 1954

3 Sheets-Sheet 1



**FIG. 2**



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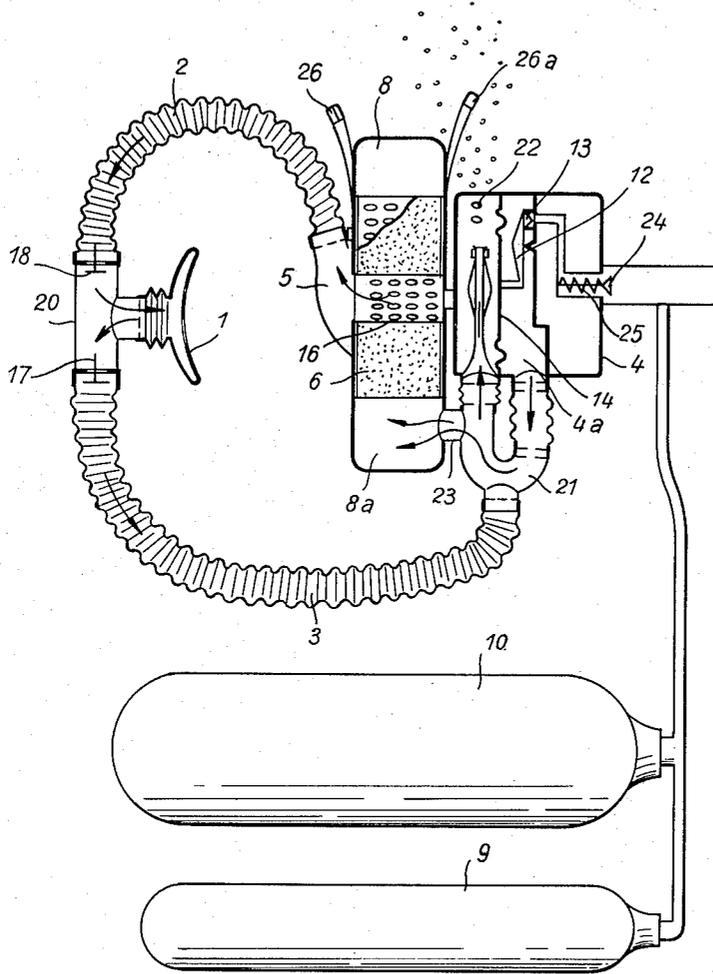
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FIG. 3



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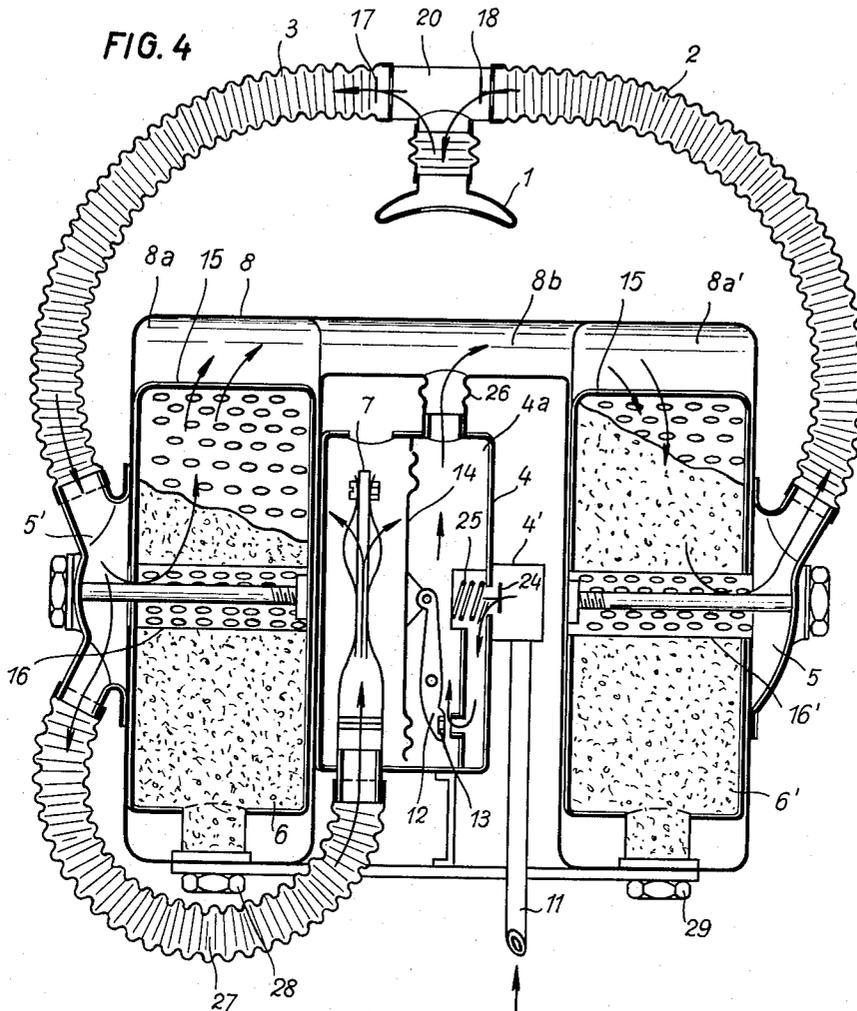
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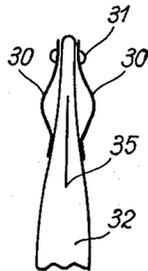
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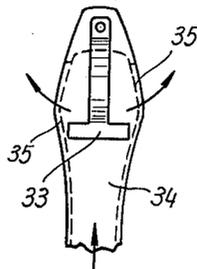
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**FIG. 5**



**FIG. 6**



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## SUBAQUEOUS BREATHING APPARATUS

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Application June 28, 1954, Serial No. 439,817

Claims priority, application Italy June 27, 1953

4 Claims. (Cl. 128—142)

Subaqueous breathing apparatus operating on either oxygen or air supply bottles, or both, are known. The drawbacks inherent to these types of breathing apparatus are the impossibility of safe diving below depths exceeding 14 to 18 meters, and a limited diving range as compared with their clumsiness, respectively.

It is the object of this invention to provide a self-breathing apparatus which eliminates the above drawbacks and affords with respect to known constructions the following main advantages:

1. Eliminating the risk of self-poisoning by oxygen or CO<sub>2</sub>, hence possibility of diving down to a depth of 40 to 50 meters;
2. Increase in diving range of from 3 to 6 times with respect to breathing apparatus supplied with air from bottles of the same content,
3. Possibility of varying this diving range or increasing the oxygen content of air breathed, merely by reducing or increasing depth of inspiration;
4. Lower emission of air from the discharge valve with respect to known open-cycle breathers, this being an important factor in approaching fish or in warfare;
5. No serious risk to the user should the supply of soda lime or other suitable substance placed in the filter for fixing carbon dioxide be momentarily exhausted, because the only consequence would be a decrease in diving range.

The principal object of this invention is to provide a breathing apparatus by which air with an enriched oxygen content is breathed and the percentage of oxygen in the expired gases is utilised at a given depth for inspiration, the apparatus being provided for this purpose with a hollow rubber cushion to which the inspired gases flow and are in part collected before or after passing through a CO<sub>2</sub> retaining filter, the remaining portion of the expired gases being expelled through a suitable valve in order to maintain the composition of breathed gas unaltered under operating conditions.

The compressed gas storage bottles employed are adapted to supply to the breathing apparatus provided with an automatic valve controlled by external pressure or other pressure relieving or air delivering device, air admixed with a certain oxygen percentage. On inspiration following each expiration the expired gases are in part drawn in again, after having been purified from CO<sub>2</sub>, the balance being supplied by air enriched with oxygen supplied by the storage bottles which unites with the former air, thereby re-establishing the initial composition.

The invention will be explained in detail with reference to the accompanying drawings which show by way of example some embodiments of the apparatus according to the present invention and in which:

Fig. 1 is a part sectional diagrammatic view of an apparatus according to this invention.

Fig. 2 is a part sectional side elevation of an embodiment of the apparatus shown in Fig. 1.

Fig. 3 is a longitudinal section of the apparatus according to a modification.

Fig. 4 is a longitudinal section of the apparatus according to a further modification.

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Figs. 5 and 6 are a side and plan view, respectively, of a structural detail of the apparatus.

Referring to Figure 1, 1 denotes the conventional mouth piece to which lead hoses 2, 3 made from resilient material such as rubber. The hose 2 is coupled with the inner of the self-adjusting device known per se, contained in the casing 4 of sheet metal of which the membrane 14 of resilient material such as rubber or of undulated sheet metal is subjected to the action of the water pressure and actuates through levers 12 a relief valve 13 controlling the flow of the gas mixture (air and oxygen) supplied by the bottles and supplied through the conduit 11.

On the drawing two similar bottles 9, 10, containing compressed oxygen and compressed air, respectively, are shown.

It is understood that the number of air bottles can be increased over the number of oxygen bottles.

The other hose 3 connects the mouth piece 1 with a chamber 5 externally limited by a cup shaped sheet-metal body and communicating with a filter 6 and with valve 7 for discharging to the outside.

The spring loaded discharge valve 7 is of a type known per se. The filter may contain a soda lime charge enclosed between nets or perforated sheet metal casings 15, 16, respectively, and is enclosed within the resilient hollow cushion 8 made of rubber or the like which will be referred to as a "lung" of which the "breathing capacity" is a fraction of the volume of each inspiration, for instance about 400 cm.<sup>3</sup>. Part of the expired air collects in the lung 8 after elimination of CO<sub>2</sub>, the other part being expelled through the discharge valve 7.

The construction as shown comprises two bottles 9, 10 of equal volume containing oxygen and air, respectively. Since air contains 79% nitrogen and 21% oxygen, the mixture flowing through the supply pipe 11 to the automatic device 4 is made up of 40% nitrogen and 60% oxygen.

According to this invention a mixed gas is inspired the volume of which is derived, for the sake of doubling economy, by 50% from the cushion 8 and by 50% from the bottles, this proportion being, however, variable.

Assuming the expired volume is referred to as 100, and the apparatus is adjusted so that sixty parts by volume are caught by the lung 8 and forty parts are expelled through the valve 7 and assuming, merely hypothetically, the composition of the expelled air is the same as that of normal air, the consequence is a loss through the valve 7 of 31.5 parts nitrogen, 6.4 parts oxygen and 2 parts CO<sub>2</sub>.

The lung 8 retains 47.5 parts nitrogen and 9.6 parts oxygen, while 3 parts CO<sub>2</sub> are eliminated through absorption by the lime soda charge contained in the filter 6.

Considering 700 cm.<sup>3</sup> to be the actual expired volume, out of this amount 279 cm.<sup>3</sup> are eliminated through the valve 7 and 421 cm.<sup>3</sup> flow to the chamber 5; however, 23 cm.<sup>3</sup> out of the latter, represented by CO<sub>2</sub>, are retained by the soda lime charge in the filter 6, 398 cm.<sup>3</sup> flowing to the lung 8, the latter quantity being made up of 330 cm.<sup>3</sup> nitrogen and 68 cm.<sup>3</sup> oxygen and being intended for recovery.

On the next inspiration the last mentioned 330 cm.<sup>3</sup> nitrogen and 68 cm.<sup>3</sup> oxygen as well as 160 cm.<sup>3</sup> nitrogen and 250 cm.<sup>3</sup> oxygen from the bottles are therefore supplied to the lung 8. Consequently, total inspiration is 490 cm.<sup>3</sup> nitrogen and 318 cm.<sup>3</sup> oxygen, which is a still very oxygen-rich composition that is convenient in every respect.

With my novel apparatus and in accordance with the example just described, out of 808 cm.<sup>3</sup> inspired air, 398 cm.<sup>3</sup> have been recovered, which means a considerable saving in bottles and, the bottle volume being the same, an important saving in gas.

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The inspired recovered air from the lung 8 can flow through the pipe 3 through which expired gases have flowed at the previous stage. In order to eliminate the necessity for inspiration of the small quantity of carbon dioxide left in the tube 3 at the end of expiration, this carbon dioxide not having passed through the filter, non-return valves 17, 18 can be provided for controlling the air flow from the tube 3 to the chamber 5 and from the lung 8 to the device 4 for the recovered purified air.

To insure satisfactory operation of the apparatus the external water pressure acting on the unit 4, should be the same as that acting on the lung 8, while the pressure acting on the valve 7 should be appreciably greater or said valve should be suitably pre-set.

Referring to Figure 2 showing diagrammatically a construction of the apparatus, the tube 11 opens into the casing 4' enclosing the automatic valve 13 and fast with the unit 4; the filter 6 can be provided with a nipple adapted to be connected, such as by screwing to the casing 4 and can be arranged within the rubber lined lung 8.

It is thereby possible to supply the chamber 5, together with the filter 6, the lung 8 and valve 7 for replacement or adaptation of the present system to existing apparatus of other types.

The chamber 5 is secured by means of a screw to the device 4 and is coaxial therewith, the eccentric position of the valve 7 being adjustable at will by acting on the screwed connection in order to vary the water pressure acting on said valve, thereby automatically controlling the quantity of discharged gases.

A modified construction of the apparatus according to this invention is shown in Figure 3.

The uni-directional valves 17 and 18 controlling the connection between the mouth piece 1 and the inlet into the lung 8 and the chamber 5 at the outlet from the filter 6 containing soda lime are arranged at the opposite ends of the sheet metal connection 20 supporting mouth piece 1 of rubber or the like and having connected thereto the rubber hoses 2, 3, respectively.

The tube 2 is connected by its other end with the inside of the chamber 5 which communicates with the inner chamber confined by the perforated inner wall 16 of the filter 6 containing soda lime. The tube 3 is connected to a sheet metal connection 21 having two branch pipes one of which leads within the chamber 4a situated past the valve 12 controlled by the membrane 14. The other branch pipe connects with the valve 7 discharging excess exhaust air, and situated in a chamber 4b of which walls are integral with the casing 4 and are connected through openings 22 with the outside.

The latter branch pipe further connects through a small tube 23 with the inside of the lung 8 which in this construction externally surrounds the outer wall 15 of the filter 6 containing soda lime and forms an annular chamber 8a surrounding the filter 6.

The necessary air-oxygen mixture charge required for integrating the inspired air charge from the filter 6 containing soda lime passes on each inspiration through the pipe 11, the automatic relief valve 24 loaded by the spring 25 and the valve 13 controlled by the membrane 14.

In the structure just described the valve 7 and membrane 14 are arranged at a level acted upon by the same pressure of the liquid column overlying the diver, the position of the latter being immaterial.

26, 26a denote two small belts for pre-setting the volume of the lung 8, for suiting it to the requirements of the diver, by decreasing or increasing the variations in volume of the lung 8a on inspiration and expiration by the user.

A further modified construction of the apparatus according to this invention is shown in Figure 4.

Apart from the central portion enclosing the mem-

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brane 14, valve 7 discharging excess of the exhausted air and valve 23 for the inlet of the fresh mixture from the bottles, the apparatus is substantially symmetrical in shape and comprises chiefly two annular filters 6, 6' filled with soda lime, shaped to form round the filters 6, 6' two annular chambers 8a, 8a' connected together by at least one conduit 8b which connects through a short connecting pipe 26 with the chamber 4a wherein the membrane 14 is arranged.

As will be seen from the drawing, the air expired by the user opens the valve 17 and flows through the flexible conduit 3 and chamber 5', whence part of the expired air flows through a further hose 27 to the excess air discharge valve 7 and part thereof enters through the perforated inner wall 16 the filter 6 containing soda lime and flows to the chamber 8a of the lung 8. The air next flows through the tube 8b towards the chamber 8a' of the portion of the lung 8 surrounding the second filter 6' containing soda lime. During its flow through the conduit 8b said air is admixed with a fresh charge flowing from the bottles through conduit 11, automatic relief valve 24 loaded by spring 25, valve 13 and chamber 4a.

From the second filter 6' filled with soda lime the air flows through the chamber 5', hose 2 and valve 18 back to the mouth piece 1 on the next inspiration.

28, 29 denote plugs closing below the filters 6, 6' filled with soda lime. Said plugs are operated for emptying and re-filling the filter when CO<sub>2</sub> absorbing power of the charge in the filters 6, 6' is exhausted.

The structure of the valve 7 indicated on the previous figures is clearly shown in Figures 5 and 6. 30 denotes two leaf springs connected together by a rivet 31 extending through the tapered end of the rubber hose 32. Said springs are each provided at their free end with a flattened cross member 33, said cross members pressing two opposite flat outer faces of the tube so as to shut off communication between the inside 34 of the tube and the outside through two slots 35 cut in the opposite side walls thereof.

What I claim is:

1. In a subaqueous breathing apparatus a mouth-piece, a source of compressed air-oxygen mixture, a chamber interposed between the mouth-piece and said source of air-oxygen mixture, automatic valve means responsive to the water pressure, for controlling the flow of the mixture within said chamber, an adjustable discharge valve connected to the mouth-piece for discharging part of the air expired through the mouth-piece, a hollow cushion of resilient material for storing part of the expired air connected to the mouth-piece and connected to the chamber provided with said automatic valve means, and at least one filter containing a fixing agent for retaining carbon dioxide in the circuit containing said hollow cushion.

2. Apparatus as claimed in claim 1, wherein the filter for retaining the carbon dioxide is arranged between the mouth-piece and resilient hollow cushion.

3. Apparatus as claimed in claim 1, wherein nonreturn valves are arranged, between the filter for retaining the carbon dioxide and the mouth-piece and the resilient hollow cushion and the chamber connected to the source for supplying the oxygen-air mixture under pressure, whereby the part of expired air passing through the said filter is enriched with a fresh charge of oxygen-air mixture before entering the said mouth-piece on the following inspiration.

4. Apparatus as claimed in claim 1, wherein the valve for discharging part of expired air is rotatably secured to the body of the apparatus body, whereby the water pressure acting on said valve can be varied with respect to the water pressure acting on the automatic means controlling the flow of the air-oxygen mixture to the apparatus.