Dec. 1, 1959 Y. LE MASSON 2,915,059

AUTONOMOUS CLOSED-CYCLE DIVING APPARATUS

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FIG.1

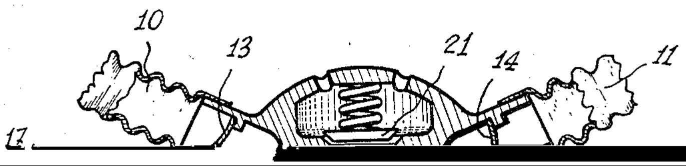

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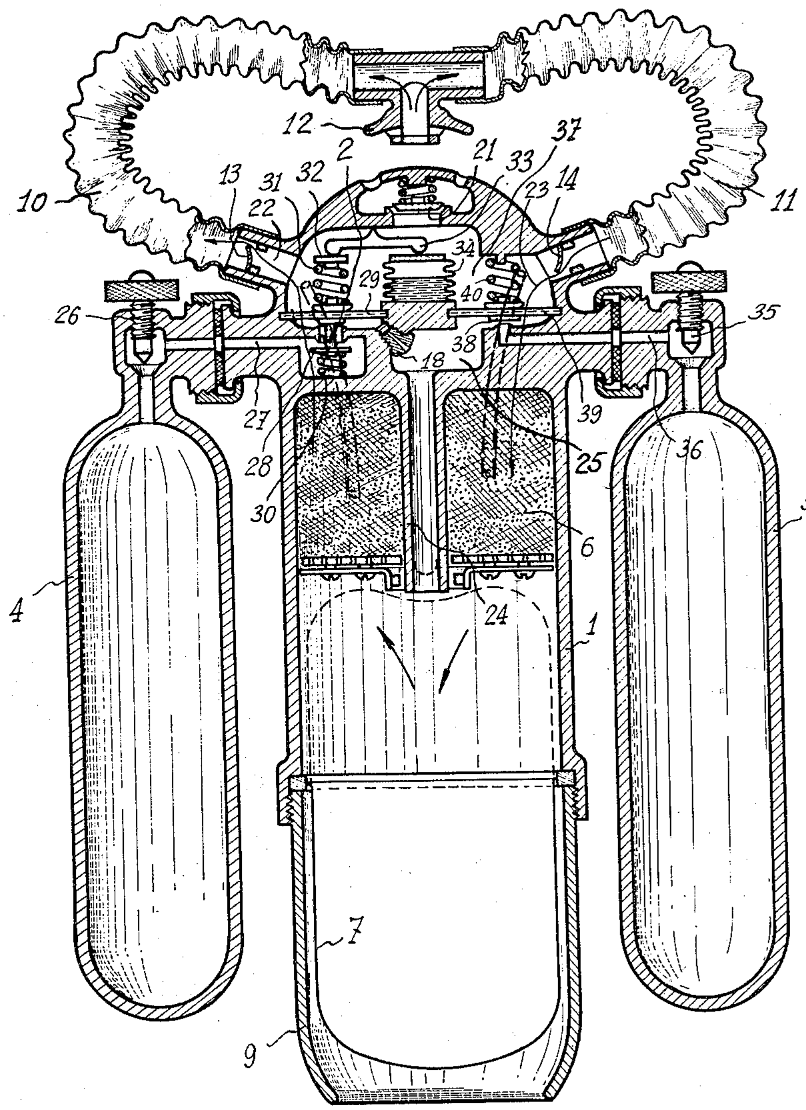
FIG. 2



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AUTONOMOUS CLOSED-CYCLE DIVING APPARATUS

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10 Claims. (Cl. 128—142)

This invention relates to diving apparatus. The objects of the invention include providing an improved diving apparatus or suit of the autonomous type operating on a closed-cycle principle. More particularly, the device should be lightweight, usable at comparatively great diving depths and for long diving periods, and should provide the diver with the possibility of normal breathing regardless of the depth at which he is positioned and without requiring him to effect manual adjustments during the dive.

A feature of the invention is that the artificial breathing mixture or atmosphere in the closed cycle is contained in a "false lungs" device, i.e. a variable storage tank de-

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For a given mass of blood in the body, there corresponds a predetermined oxygen concentration necessary for maintaining life. It follows from the foregoing that this oxygen consumption rate is of the order of 1 cg. per second and corresponds to what will hereinafter be termed "concentration 1." This is a constant independent of ambient pressure.

The problem therefore is to control, with an increasing pressure of the medium, the mass of oxygen consumed per second in such a way that it will be at least equal to the required quantity (concentration 1) while remaining less than the lethal limit (concentration 9 or 10).

The principle on which the autonomous closed-cycle diving apparatus of the invention is based, resides in the recognition of the above disclosed physiological phenomena and laws, and in the provision of an automatic oxygen-regulating mechanism operative to satisfy, at all times, the requirements set thereby.

In addition to the above considerations, it should be noted that, underwater, the average respiratory rhythm is about one inhalation every two seconds, which corresponds to an oxygen consumption per inhalation, taking concentration 1 as a basis, equal to 2 centigrams, or a volume of 0.014 liter at atmospheric pressure. Since the average lung capacity is 2 liters, it is seen that owing to the small volume of oxygen that is required, it be-per second, the actual quantity that is required in practice at any given time varies with the muscular exertion, respiratory capacity, and like factors, so that a lack or an excess of oxygen might result. A lack of oxygen is not permissible. An excess of oxygen on the other hand will result in a regular increase in the respirable volume which, as stated above, it is desired to retain constant. Consequently, there is no satisfactory operation of the system out of water, since the unconsumed oxygen in excess will then escape through the overflow valve. In this sense, the system will not then operate in a closed cycle.

Now assuming that the apparatus thus adjusted is lowered to a depth of say 10 meters, the pressure increases to two atmospheres and the above-mentioned volume (two liters at 1 atmosphere) is reduced by half and make-up gas is automatically added to it by the means (3) to maintain the volume the same. The respirable volume therefore still remains the same, i.e. equal to the capacity of the user's lungs. But since on the other hand the oxygen absorption capacity of the user has been increased tenfold (concentration 10) the excess of oxygen which occurred at surface conditions, is now taken up. The system operates in a fully closed cycle, so long as the oxygen concentration does not exceed the user's absorption capacity.

The upper limit of concentration at moderate depths is determined by the depth. Beyond 9 meters depth the concentration may be chosen freely, provided it be selected within the range of from 1 to 10.

With the apparatus operating at constant depth, only the means (1) and (2) are operative. When the apparatus is lowered to greater depths, the means (1), (2) and (3) operate. When the apparatus is raised, the volume increases and the means (1), (2) and (4) become operative.

The means (1) for insuring constant rate of oxygen delivery may comprise a simple expansion valve followed

tional amount of the gas without any effort on the part of the diver's lung muscles.

Two alternative embodiments of diving apparatus according to this invention will now be described for purpose of illustration but not of limitation with reference to the accompanying diagrammatic drawings wherein:

Fig. 1 is a sectional view of one embodiment of the invention; and Fig. 2 is a similar view of a modification.

As shown in Fig. 1, the diving apparatus comprises a central body **1**, having secured to or integrally formed with it a pair of expansion units or valves **2** and **3** supplied with pure oxygen and neutral gas respectively from the storage containers **4** and **5**. Each expansion valve may be of a conventional kind including a diaphragm acting on a valve, one side of the diaphragm being actuated by the gas pressure on the downstream or delivery side while the other side of the diaphragm receives the combined action of the pressure of the ambient medium and of an adjustable biassing spring.

The body **1**, into which the expanded oxygen and neutral gas are delivered from the units **2** and **3**, is connected with a reservoir **6** containing a substance adapted to absorb carbon dioxide gas, such as soda lime or another suitable absorber of CO_2. The body **1** is further connected with the interior space of a "false lung" device or collapsible container **7**. This may comprise a bag or tank defined by a fluid-tight, flexible wall having a circular orifice **8** sealed between the body **1** and a protective hood **9** of generally cylindrical shape having one end screwed into the body **1**. The outer end of the hood may be hemispherical and is perforate so as to allow the surrounding medium, water, to contact the outer face of the bag **7** of the false lung during a dive.

The false lung **7** is adapted to move from the expanded full-line position to the retracted or collapsed position shown in chain lines, and in so doing the capacity of the lung changes by about 3 liters.

ciently collapsed to actuate the trigger **20**. Thus, the valve **3** remains inoperative to supply make-up gas. If the depth and pressure increase, the volume of respirable mixture decreases, and as the diver fills his lungs with the mixture, the false lung **7** collapses sufficiently to open the valve **19** and feed in an additional amount of neutral gas which will again maintain the volume of gas at a value corresponding to the capacity of the diver's lungs. If, on the other hand, the depth and external pressure decrease, the internal gas increases in volume but, since the maximum volume offered to it as determined by the fully expanded condition of the bag **7** is limited there is an excess of internal pressure over the pressure of the external medium, and the excess of mixture escapes through the valve **21**.

All of the above operation is of course fully automatic throughout the diving process which may be continued until exhaustion of the oxygen store or that of the absorbing capacity of the reservoir.

The embodiment shown in Fig. 2 also comprises a body **1** the interior of which communicates with the false lung **7** and also with the reservoir **6** containing carbon dioxide absorptive material.

Just as in the first embodiment, the reservoir **6** is connected by the conduits **22** and **23** via chamber C with the flexible tubes **10** and **11** serving respectively for the outlet and inlet of the breathing mixture, and each of which is fitted with a check valve **13** or **14**. Extending through the reservoir **6** is a conduit **24** connected at its ends with the interior of body **1** and with a chamber **25** respectively.

The oxygen tank **4** is connected to the chamber **25** by way of a manually-operable needle-valve **26**, a conduit **27**, a valve generally designated **2**, and a jet orifice **18**. The valve **2** comprises gas-pressure operated system including a valve **28** controlled by a diaphragm **29**. One side of the diaphragm **29** is subjected to the combined action of the downstream gas pressure and a bias spring **30** which tend to urge the valve to its sealing position, while the other side of the diaphragm receives the action of the external pressure and an adjustable spring **31** urging the valve to open position. The spring **31** engages a stop **32** engaged by one end of a lever **33**. The other end of the lever is actuated by a barometric capsule or bellows **34** partially filled with liquid under pressure.

The chamber **25** may moreover be placed in communication with the tank **5** of neutral gas by way of a hand-operated needle-valve **35**, a conduit **36** and a check-valve which may be considered as an expansion valve mounted in inverted relation, and generally designated **37**. The valve includes a check-valve member **38** connected with a diaphragm **39**. One side of this diaphragm is acted upon by the pressure in chamber **25** acting to open the valve, while the other side of the diaphragm receives the combined action of the external pressure and a biassing spring **40** acting to close the valve.

When the diver is positioned at a given depth, oxygen flows at a constant rate into chamber **25** and, through conduit **24**, into the body **1**. Should the diving depth increase, the oxygen flow rate would tend to increase. However, the increase in external pressure due to the increase in depth will cause a collapse of the capsule **34** and hence a reduction in the compression stress of biassing spring **31**. This reduction in the compression of the spring offsets the effect of the increase in external pressure on the expansion valve, so that the delivery rate of oxygen can be maintained at a strictly constant value regardless of the external pressure by suitably dimensioning the barometric capsule **34**.

The valve **38** is normally maintained seated by spring **40** so that the delivery of neutral gas is cut off. As the outer pressure increases, the volume of gas within the false lung increases and, at a predetermined point in the operation, the wall of the lung engages the end of the conduit **24** towards the end of an inhaling action, so that the conduit is sealed off. Since oxygen continues to flow into chamber **25**, the pressure in the chamber rises, unseating valve **38** and thus resulting in a supply of make-up neutral gas into the respiratory circuit. It will be observed that, in contrast to what occurs in the embodiment of Fig. 1 the diver does not have to expend any additional muscular effort to open the valve, since the valve opening is produced pneumatically by the pressure obtaining in chamber **25**.

What I claim is:

1. In a diving device, a collapsible container having a flexible wall, means for connecting in a closed circuit said container with the respiratory organs of the user of said apparatus, means for delivering oxygen into said container at a substantially constant rate, and means for maintaining the volume of respirable mixture in said closed circuit substantially constant.

2. In a diving device, a collapsible container having a flexible wall, means for connecting said container with the respiratory organs of a diver in a closed circuit, means for delivering oxygen into said container at a substantially constant rate, means responsive to surrounding pressure and to said collapsible container for supplying neutral-gas into said container when said pressure increases and means coupled to said container for discharging excess respirable mixture from said container when said pressure decreases.

3. In a diving device, a collapsible container having a flexible wall, inhaling and exhaling conduits for connecting said container with the respiratory organs of a diver in a closed circuit, a tank of oxygen gas coupled to said container, a tank of neutral-gas, means connecting said neutral-gas tank with said container including a valve biassed to closing condition, actuating means connected with the valve and responsive to said collapsible container to open the valve and deliver neutral gas into said container, and relief valve means connecting said container with the exterior, whereby said closed circuit will contain at all times a substantially constant volume of respirable mixture.

4. The combination claimed in claim 3 comprising an expansion valve connected with said oxygen tank and a jet orifice connected with the expansion valve to deliver expanded oxygen at a substantially constant rate into said container.

5. The combination claimed in claim 4 comprising manual adjusting means for variably biassing said expansion valve.

6. The combination claimed in claim 5, wherein said actuating means comprises a mechanical linkage.

7. The combination claimed in claim 5, wherein said actuating means comprises a gas-pressure operated system.

8. The combination claimed in claim 5, wherein said actuating means comprises a chamber coupled to the first said means, a fluid passage between said chamber and said container and positioned to be engaged by said flexible wall to be sealed thereby, and means responsive to the pressure in said chamber for operating said expansion valve.

9. The combination claimed in claim 4 comprising adjustable spring bias means for the expansion valve, and an element responsive to external pressure and operative to adjust said bias means in accordance with said external pressure.

10. The combination claimed in claim 4, wherein said neutral-gas is selected from the group consisting of hydrogen and helium.

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