

[54] SELF-CONTAINED CLOSED CIRCUIT
BREATHING APPARATUS

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[22] Filed: Jan. 29, 1973

[21] Appl. No.: 327,769

[52] U.S. Cl. 128/142.2, 128/147
[51] Int. Cl. A62b 7/04
[58] Field of Search 128/142.2, 202, 140 R,
128/142, 142.3, 145-145.8, 142.4-142.7,
191 R, 147

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[57] ABSTRACT

The breathing apparatus provides a chemical canister, an expansible reservoir for positive pressure on the upstream side thereof, a contractible reservoir for negative pressure on the downstream side thereof, and suitable connecting conduits and a mouthpiece to provide a closed breathing circuit. The negative pressure reservoir comprises rigid top and bottom walls, a spacer extending from one to the other, and a rubber sleeve extending from one to the other so that it will be bowed in when air is withdrawn by inhalation. By enclosing the parts in a watertight enclosure and adding an oxygen bottle and suitable regulating valves, the apparatus can be adapted for underwater use.

8 Claims, 5 Drawing Figures

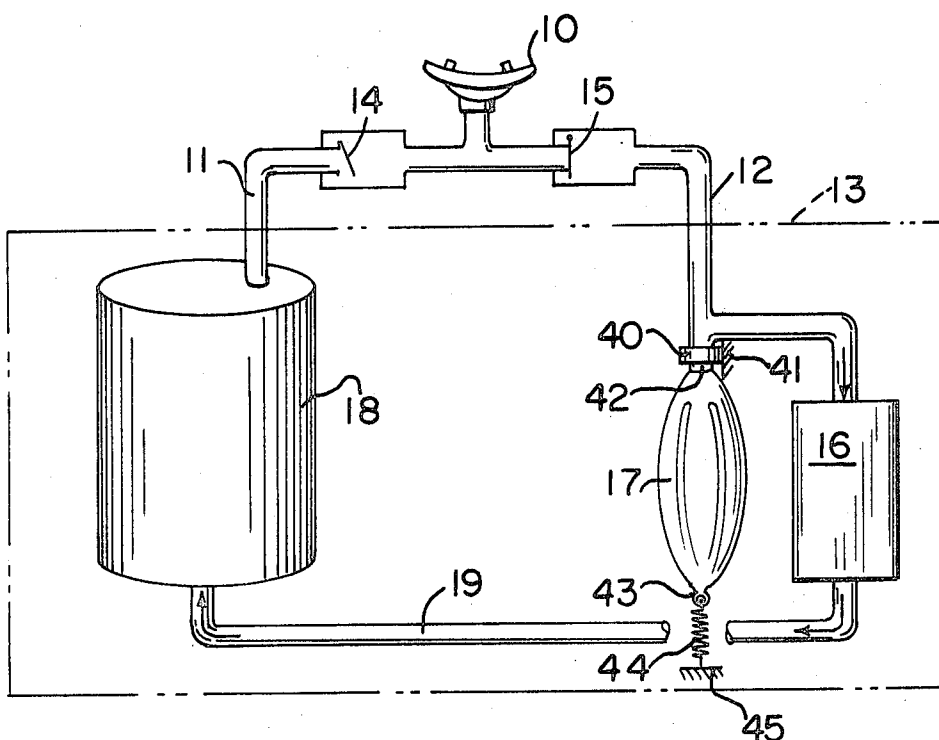


FIG. 1-

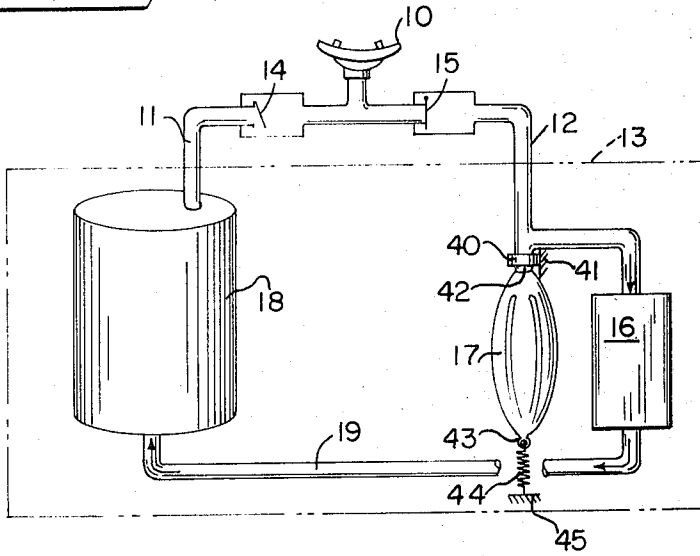


FIG. 3-

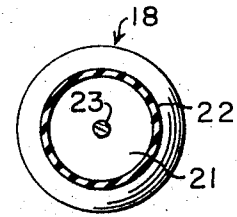


FIG. 2-

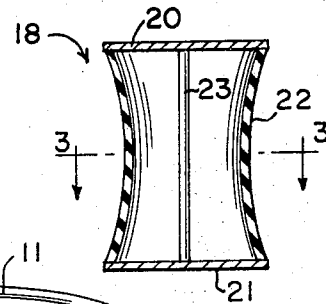
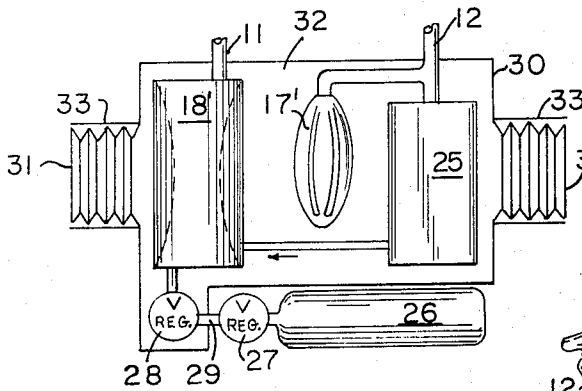


FIG. 4-

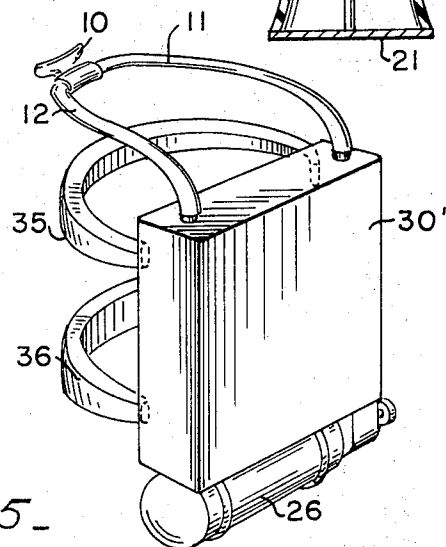


FIG. 5-

SELF-CONTAINED CLOSED CIRCUIT BREATHING APPARATUS

This invention relates to a self-contained closed circuit breathing apparatus. Such apparatus contains in the closed circuit a chemical canister which removes carbon dioxide and water vapor from the breathing gas. In one type the supplemental oxygen is generated chemically by the ingredients of the chemical canister, and in a second type, it is supplied by a bottle containing compressed or liquid oxygen. My invention is applicable to both the generating and bottle types of apparatus.

Breathing apparatus of these types are frequently used in mines where an undesirable gas is in the atmosphere, and also in some instances, in fire fighting. With suitable modification the apparatus can be used as an underwater breathing apparatus.

One of the defects in breathing apparatus presently available on the market is that the chemical canister provides an undesirably great resistance to the flow of the breathing gas. In one type of rebreather apparatus, a breathing bag is located downstream of the chemical canister, the breathing bag serving as a reservoir for the breathing gas. When the user exhales, the gas is forced directly, and consequently at a high flow rate through the chemical canister and into the breathing bag, and the latter expands and serves as a reservoir for the inhalation half of the cycle.

The United States Bureau of Mines has set a limit, effective Mar., 1974, of plus or minus 2.0 inches of pressure, water gauge, for the breathing resistance of all self-contained breathing apparatus, when operated on a certain "standard" type breathing machine.

However, the apparatus described above and presently available does not meet this standard.

According to my invention, I provide two gas reservoirs, one being a positive pressure reservoir which is upstream of the chemical canister, and the other being a negative pressure reservoir which is downstream thereof. Thus, during the exhalation portion of the cycle, a positive pressure will be built up in the positive pressure reservoir, whereas during the inhalation half of the cycle, a negative pressure will be created in the negative pressure reservoir. As the pressure in the two reservoirs tends to equalize itself by flowing through the canister, it will be seen that the flow can take place throughout the complete breathing cycle. This means that for a given volume of gas to pass through the canister, the available time is at least twice as long as in the prior art device with the result that a lesser pressure is required.

Although the positive and negative pressure reservoirs can be in the form of rigid wall chambers in which the pressure developed is a function of the volume of the chamber, they would have to be of fairly large dimensions in order to accommodate a full breath without developing a back pressure corresponding to a breathing resistance of more than the proposed limit of 2.0 inches of water gauge. Thus the apparatus would not be suitable for portable apparatus due to bulkiness and weight.

Therefore, according to this aspect of my invention I provide positive and negative pressure reservoirs in the form of an expansible (or contractible) chamber which include elastic or resilient means for imparting

a positive (or negative) pressure loading on the gas contained therein.

The positive pressure reservoir after being inflated by an exhalation thus tends to restore itself to its original volume and forces air through the chemical canister. The negative pressure reservoir after being contracted by an inhalation thus restores itself to its original volume and draws air through said chemical canister.

Other objects, features and advantages will become apparent as the description proceeds.

In the drawings:

FIG. 1 is a diagrammatic representation of a preferred embodiment of my invention;

FIG. 2 is a vertical sectional elevation of the negative pressure reservoir;

FIG. 3 is a horizontal section taken along line 3—3 of FIG. 2;

FIG. 4 is a diagram showing a modification of my invention; and

FIG. 5 is a modification of a portion of the FIG. 4 apparatus.

In FIG. 1, the apparatus comprises a mouthpiece 10 which communicates with inhalation conduit 11 and an exhalation conduit 12 which lead to apparatus contained in an enclosure 13. A check valve 14 is provided in the inhalation conduit 11 and a check valve 15 in the exhalation conduit 12. The check valves and the mouthpiece often comprise a single piece of equipment, i.e., an integral component. The conduits 11 and 12 are flexible conduits. A face mask is sometimes used in place of the mouthpiece 10, both being referred to generically as a "mouth connection."

The exhalation conduit 12 leads to a chemical canister 16 which contains materials which remove the carbon dioxide and add chemically generated oxygen to the breathing gas. A positive pressure reservoir 17 communicates with the exhalation conduit 12 and is in the form of an elongate flexible wall bag of a capacity to accommodate at least a full breath. Such bag is known as a "breathing bag" and is made of rubber.

The neck 42 of the bag 17 is held in a collar 40 attached to a portion 41 of the frame (not shown) of the apparatus. There is a loop 43 at the bottom of the bag and a tensioned coil spring 44 extends between the loop 43 and another part 45 of the frame.

The tension exerted by the spring 44 urges the walls of the bag 17 toward each other into a position of minimum volume. As air is forced into the bag 17 by the lungs, the walls of the bag 17 expand, thus shortening the bag and tensioning the spring. The spring is designed so that the bag 17 then develops a positive pressure of not more than 2 inches water gauge for expulsion of its contents through the canister 16.

The inhalation conduit 11 leads from a negative pressure reservoir 18 to the check valve 14 and mouthpiece 10. A suitable conduit 19 extends from the canister 16 to the negative pressure reservoir and functions as an extension of conduit 11. In the alternative, conduit 19 can extend to the inhalation conduit 11 through a T-connection, with the reservoir 18 connected as in the case of the reservoir 17.

As shown in FIGS. 2 and 3, the negative pressure reservoir preferably comprises a rigid top wall 20, a rigid bottom wall 21, and elastic side walls in the form of a sleeve of elastic material, such as rubber. The side walls 22 are secured to the top and bottom walls 20 and 21 by a suitable adhesive, and may also have mechanical

interlocking means similar to a hose clamp. One or more spacers 23 extend between the top and bottom walls 20 and 21. Thus, when gas is removed from the negative pressure reservoir 18, as during inhalation, the ambient atmospheric pressure urges the walls inwardly, as shown in FIG. 2. However, due to the elasticity of the side walls, there is a slight loading on the contents of the reservoir 18 which develops a negative pressure. The dimensions of the reservoir 18, and the thickness and composition of the side walls 22 is such that the negative pressure developed at a full breath is not more negative than -2.0 inches water gauge.

Thus the canister 16 is disposed between a source of positive pressure and a source of negative pressure with the result that the gas will continue to flow through the canister throughout the major portion of the complete breathing cycle. Since the two reservoirs are alternately charged, whereas the discharge is substantially continuous, the operation of the two reservoirs are not in exact phase relationship, but neither are they 180° out of phase due to the fact that the flow of a given volume takes a certain amount of time.

The above described apparatus will meet the breathing resistance requirements of Rules and Regulations, paragraph 11.85-5a and 5c, and paragraph 11.85-6e of the United States Bureau of Mines, published in Federal Register Vol. 37 No. 59, Mar. 25, 1972; namely, exhalation resistance not to exceed two inches water-column height, and inhalation resistance not to exceed the difference between the exhalation resistance (2 inches of water) and four inches water-column height.

In a practical example, the capacity of the bag 17 is such that it will accommodate 2.0 liters of breathing gas. when thus expanded, the spring 44 causes the bag to exert a positive pressure of 0.7 inches water gauge. The negative pressure reservoir 18 is in the form of a cylinder 6 inches in diameter and ten inches high having a volume of four and one-half liters when in relaxed position. When exhausted to the extent of 2 liters, the negative pressure developed was 0.7 inches water gauge.

The positive pressure reservoir may alternatively be an elastic side wall chamber with spaced rigid top and bottom walls substantially identical to the structure 20, 21, 22, 23, shown in FIGS. 2 and 3. However, here the elastic walls 22 would bulge outwardly when inflated. This structure provides a somewhat closer control of the pressure volume relationship than the bag and spring arrangement 17 of FIG. 1.

When the invention is applied to a bottle type of breather apparatus, as shown in FIG. 4, the chemical canister 16 is replaced by a different type of chemical canister 25 which removes carbon dioxide and water vapor but does not replace the oxygen. The oxygen is supplied by an oxygen bottle 26 which communicates with the negative pressure reservoir 18' through pressure regulating valves 27 and 28 and connecting passageway 29. The regulating valve 27 maintains a supply pressure in the connecting passageway 29 that is 3 lbs. per square inch above ambient pressure, acting to reduce the bottle pressure.

Valve 28 is a demand regulator which senses the pressure within the negative pressure reservoir 18, and supplies oxygen to the system when the difference between the pressure within the reservoir 18 and the air surrounding same exceeds in the negative direction

more than a certain amount, such as -0.7 inches water gauge. As the carbon dioxide is removed by the chemical canister 25 from the breathing gas, the pressure within the breathing circuit will become reduced with the result that the demand valve 28 is operative to introduce additional oxygen into the breathing circuit.

It will be understood that in the FIG. 4 arrangement, the bag 17' is tensioned by a spring, the same as in FIG. 1. In the alternative, an elastic side wall chamber 20, 21, 22, 23, may be substituted for the tensioned bag as described in connection with FIG. 1.

The FIG. 4 arrangement may be used as an underwater breathing apparatus by enclosing same in a waterproof enclosure 30 having expansible wall portions 31 located within open ended guide collars 33 so that the ambient air pressure within the enclosed space 32 of the enclosure 30 is equalized with the water pressure. Preferably there are several expansible wall portions 31 located at different elevations irrespective of the attitude of the diver so that the pressure within the space 32 is an average of the water pressures at all extreme portions of the enclosure 30; that is, the same as the water pressure surrounding the diver's chest area.

In this arrangement, the negative pressure reservoir 18' can be of rectangular cross-section, and the other components may be proportioned such that the volume of the enclosed space 32, excluding the volume of the components 17', 18' and 25, is sufficiently small that the expansible wall portions 31 are effective for equalizing the ambient air pressure with the water pressure up to the desired maximum depth of operation, such as 15 feet. The expansible wall portions 31 also accommodate the periodic air displacements between the breathing apparatus and the diver's lungs.

At any depth within the operating range, the demand regulator 28 is effective to sense a pressure difference which exceeds in the negative direction the regulator setting, such as -0.7 inches water gauge.

The depth operating range can be shifted by bleeding air from passageway 29 into the space 32 by a suitable bypass valve, not shown, or by venting air out of the space 32 by a suitable vent valve, not shown.

FIG. 5 shows a modified enclosure 30' suitable for underwater use in which the water pressure equalizing portions are in the form of elastic tubes 35 and 36 which can be secured to the chest belts which hold the enclosure 30' to the user's back. Since each end of each tube communicates with the enclosure 30' at one of the four corners of the enclosure, it is possible to obtain a pressure within the space 32 which is an average of the water pressure surrounding the diver's chest area, irrespective of his attitude in the water.

Although only preferred embodiments of my invention have been shown and illustrated herein, it will be understood that various modifications and changes can be made in the constructions shown without departing from the spirit of my invention as pointed out in the appended claims.

I claim:

1. A self-contained, closed circuit breathing apparatus comprising an inhalation conduit and an exhalation conduit, a mouth connection communicating with said conduits for making connection with the mouth of the operator, an inhalation check valve and an exhalation check valve on either side of said mouth connection providing unidirectional flow through said inhalation and exhalation conduits respectively, a chemical canis-

ter connected across said inhalation and exhalation conduits, a positive pressure reservoir communicating with said exhalation conduit at a point between said chemical canister and said exhalation check valve, and a negative pressure reservoir communicating with said inhalation conduit at a point between said chemical canister and said inhalation check valve, said positive pressure reservoir comprising an expansible container having flexible wall means incorporating resilient means providing a positive pressure loading on the gas within said container when said container is expanded by an exhalation, and said negative pressure reservoir comprising a contractible chamber having flexible wall means incorporating resilient means providing a negative pressure loading on the gas within said chamber when said chamber is contracted by an inhalation.

2. Breathing apparatus as claimed in claim 1 in which said contractible chamber includes rigid top and bottom walls, means securing said top and bottom walls in a fixed spaced relationship to each other, and flexible side wall means connecting said top and bottom walls and being secured thereto in air tight relationship, said flexible side wall means being formed of elastic sheet material and constituting said resilient means.

3. Breathing apparatus as claimed in claim 1 in which said expansible container comprises an elongate bag having flexible walls, and in which said resilient means comprises means tensioning said bag in the longitudinal direction to urge said flexible walls toward each other into a small volume position, and providing a resilient loading on said walls when said bag is expanded by said exhalation.

4. Breathing apparatus as claimed in claim 1 in which said flexible wall means of said expansible container comprises an elastic wall portion, said elastic wall portion also constituting said resilient means.

5. Breathing apparatus as claimed in claim 1 which includes an oxygen bottle, a regulating valve connected thereto providing a constant supply pressure, a demand regulating valve connected between said negative pressure reservoir and said first-mentioned regulating valve for supplying oxygen to the closed breathing circuit of said breathing apparatus when the difference between the pressure within said negative pressure reservoir and ambient pressure exceed in the negative direction a predetermined negative pressure.

6. Breathing apparatus as claimed in claim 5 which includes a water tight enclosure surrounding said positive and negative pressure reservoirs to permit immersion of said apparatus, and means for substantially equalizing the ambient air pressure within said enclosure with the water pressure surrounding same.

7. A self-contained, closed circuit breathing apparatus comprising an inhalation conduit and an exhalation conduit, a mouth connection communicating with said conduits for making connection with the mouth of the

operator, an inhalation check valve and an exhalation check valve on either side of said mouth connection providing unidirectional flow through said inhalation and exhalation conduits respectively, a chemical canister connected across said inhalation and exhalation conduits, a positive pressure reservoir communicating with said exhalation conduit at a point between said chemical canister and said exhalation check valve, and a negative pressure reservoir communicating with said inhalation conduit at a point between said chemical canister and said inhalation check valve, said positive and negative pressure reservoirs each comprising a chamber having rigid top and bottom walls in a fixed spaced relationship to each other, and side wall means connecting said top and bottom walls and being secured thereto in air tight relationship, said side wall means being formed of elastic sheet material, the relationship of the volume of said reservoir, the quantity of gas contained in a full exhalation or inhalation, and the elasticity of said side wall means being such that said positive pressure loading will be less than 2.0 inches water gauge, and said negative pressure loading will be not more negative than -2.0 inches water gauge.

8. A self-contained, closed circuit breathing apparatus comprising an inhalation conduit and an exhalation conduit, a mouth connection communicating with said conduits for making connection with the mouth of the operator, a chemical canister connected across said inhalation and exhalation conduits, a positive pressure reservoir communicating with said exhalation conduit at a point between said chemical canister and said mouth connection, a negative pressure reservoir communicating with said inhalation conduit at a point between said chemical canister and said mouth connection, said positive pressure reservoir being designed to accommodate a full exhalation with a positive pressure loading, and said negative pressure reservoir being designed to accommodate a full inhalation with a negative pressure loading, an oxygen bottle, a regulating valve connected thereto providing a constant supply pressure, a demand regulating valve connected between said negative pressure reservoir and said first-mentioned regulating valve for supplying oxygen to the closed breathing circuit of said breathing apparatus when the difference between the pressure within said negative pressure reservoir and ambient pressure exceed in the negative direction a predetermined negative pressure, a water tight enclosure surrounding said positive and negative pressure reservoirs to permit immersion of said apparatus, and means for substantially equalizing the ambient air pressure within said enclosure with the water pressure surrounding same, said pressure equalizing means comprising elastic tubes communicating with said enclosure and adapted to surround the chest of the user.

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