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Lambertsen

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[54] **DUAL MODE MIXED GAS BREATHING APPARATUS**

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[52] **U.S. Cl.** **128/142.2**
[51] **Int. Cl.** **A62b 7/04**
[58] **Field of Search** 128/142.2, 142.3, 142, 140, 128/142.4, 147

[56] **References Cited**

UNITED STATES PATENTS

3,508,542	4/1970	Browner	128/142.2

FOREIGN PATENTS OR APPLICATIONS

1,130,272	2/1957	France	128/142
969,272	9/1964	Great Britain	128/147

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[57] **ABSTRACT**

Breathing apparatus, including provisions for carbon dioxide scrubbing and rebreathing, wherein basic resting oxygen supply is maintained by constant mass flow of an oxygen-containing gas, and oxygen in a ventilating gas in excess of the basic requirement is provided, in each inhalation cycle, by a demand valve actuated by collapse of a flexible gas storage chamber, the expansion of which is limited to normal exhalation volume for a predetermined level of physical exertion and means for dumping the exhalation volume in excess of that amount and sub-assemblies of such apparatus. By utilizing, as the demand supplied gas, a gas leaner in oxygen than that supplied at a constant mass flow rate, the tendency to oxygen toxicity during periods of exertion is reduced. Preferably, the system includes a flow-responsive, fail-safe valve to inactivate the rebreather circuit upon failure of the constant mass flow supply.

7 Claims, 5 Drawing Figures

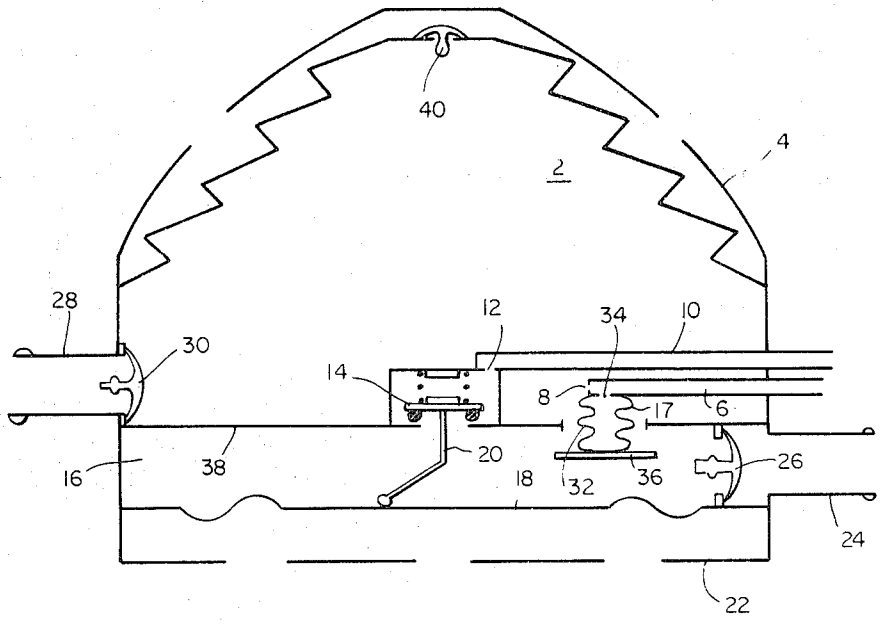
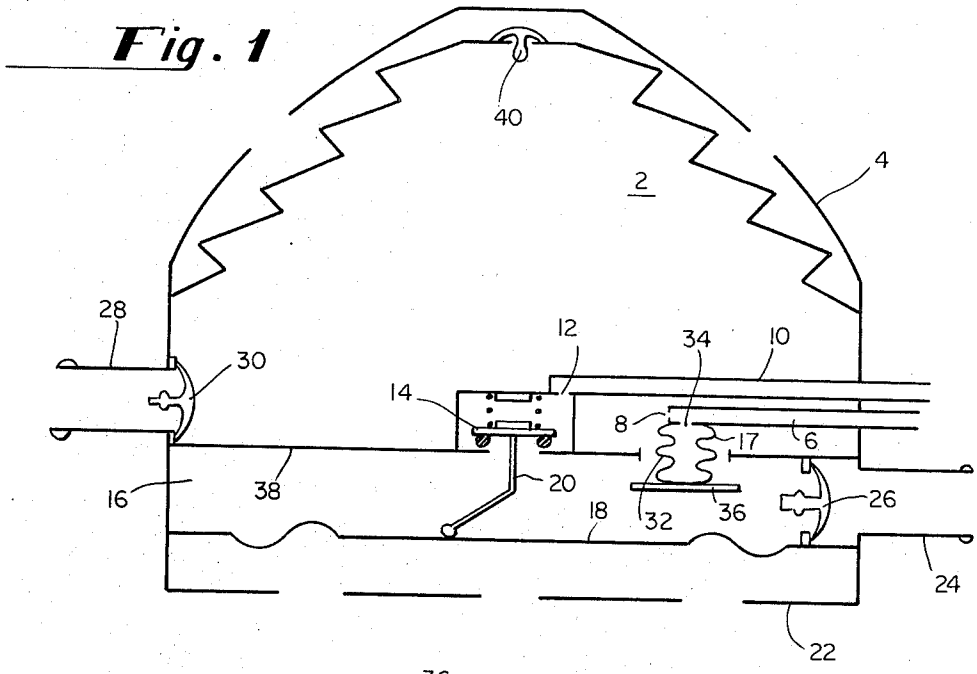


Fig. 1



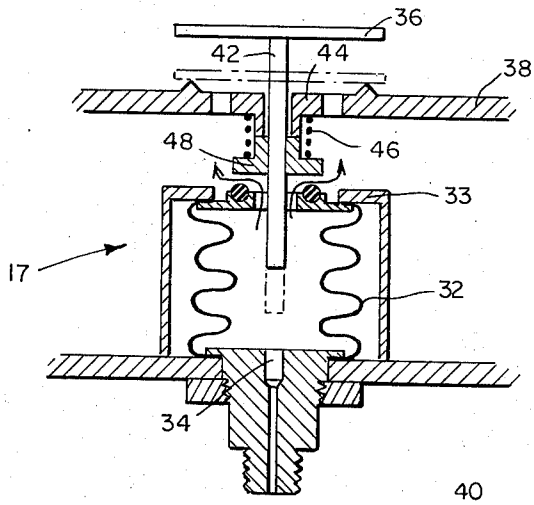


Fig. 2

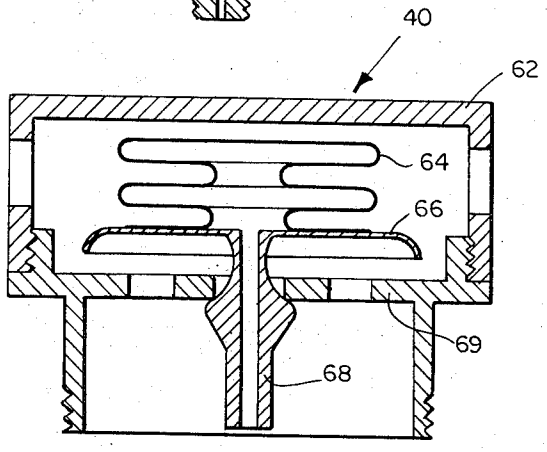


Fig. 4

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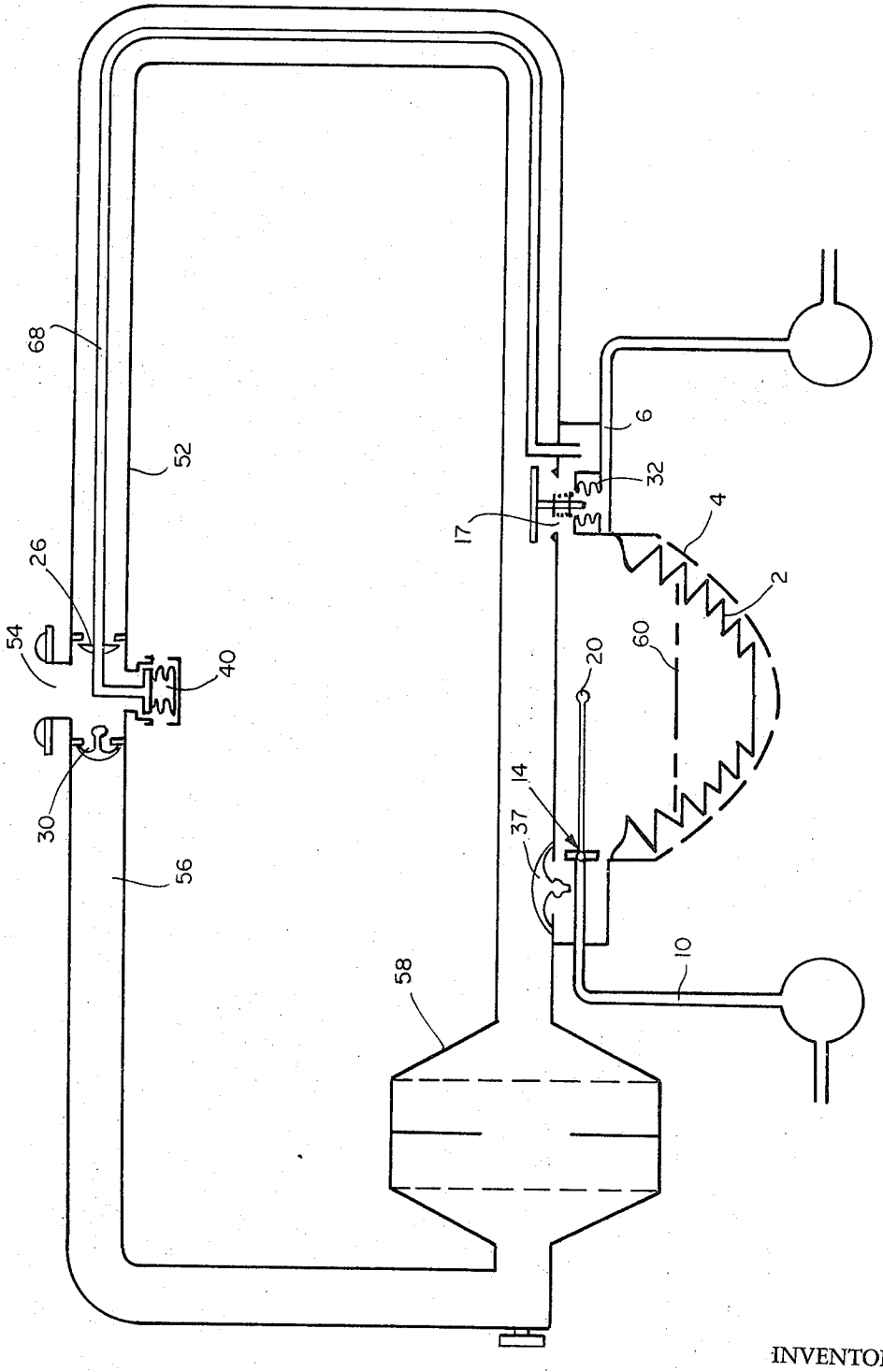


Fig. 3

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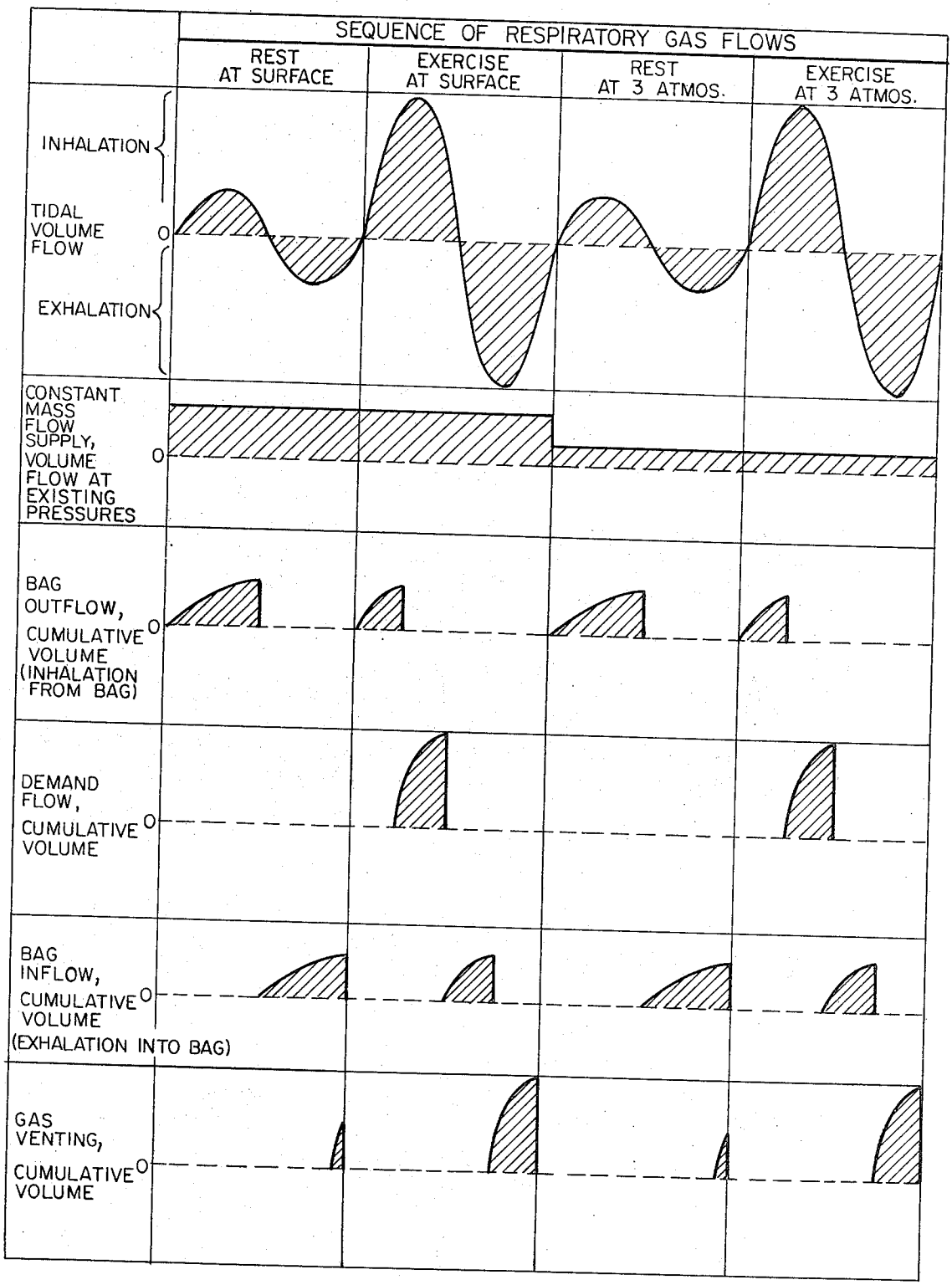


Fig. 5

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DUAL MODE MIXED GAS BREATHING APPARATUS

This invention pertains to breathing apparatus, usually used as a self-contained portable unit, useful to provide breathing gas in a hostile atmospheric environment, such as, under water, in heavy smoke, in noxious atmospheres, etc. More specifically, it relates to a system incorporating rebreather and selective dumping characteristics and inherently safer due to redundancy and automatic compensation for decreased oxygen tolerance during periods of physical exertion.

Various types of breathing apparatus systems, particularly portable breathing apparatus carried in a backpack by underwater swimmers, fire fighters, etc., have been developed. Each of these systems has certain characteristic disadvantages. For example, one such system supplies gas in response to the demand of the user, based on the negative pressure in the system produced by inhalation. This type of system is typically open circuit, i.e., the entire volume of exhalation gas is simply vented from the system. Therefore a large volume of breathing gas must be carried in the portable apparatus.

In other prior art systems, a constant flow of breathing gas is supplied, and exhalation gas is either partially or fully recycled. Recycled exhalation gas must, of course, have the carbon dioxide removed therefrom and this is typically done by contact with CO_2 absorbent material. It is also known that the last part of the exhalation gas is that which is highest in CO_2 content, and selective dumping of this part of the exhalation gas conserves breathing gas by permitting recycle of exhalation gas substantially lower in CO_2 content and from which less CO_2 must therefore be removed.

Constant supply systems necessarily involve a tradeoff as to volume of gas and oxygen content of gas supplied. In order to reduce the total volume of the portable supply, it is desirable that a high oxygen concentration in the supply gas be maintained. However, high oxygen concentration in the gas breathed is undesirable under certain conditions particularly at high ambient pressures such as at some depth under water and during periods of physical exertion at high ambient pressures when the user is predisposed to oxygen toxicity. Moreover, the constant supply must necessarily be sufficient to provide for the oxygen requirements of a user during periods of physical exertion, in which case the supply is in excess of that needed during periods of rest.

In still other types of breathing apparatus, a closed circuit is used, i.e., breathing gases are continually recycled, and oxygen is added to the system only as necessary to maintain some predetermined oxygen level in the breathing gases. The disadvantages of this type of system are the inherent difficulties in sensing and maintaining proper oxygen concentration and the inconvenience of varying the oxygen content, depending on whether the user is at rest or in a period of physical exertion. Failure to take this variable into account also may lead to excessive oxygen concentration during a period of physicial exertion at high ambient pressure and predisposition to oxygen toxicity as a result.

It is therefore an object of the present invention to provide a hybrid breathing system wherein the various disadvantages are eliminated.

Another object of this invention is to provide a portable breathing apparatus which is inherently efficient with respect to the volume of gases used.

Still another object of this invention is to provide a breathing gas system wherein the oxygen level is automatically physiologically controlled to compensate for the decreased oxygen tolerance of a user during periods of physical exertion at increased ambient pressure.

These and other objects, which will be apparent in the course of the subsequent description, are met by a breathing apparatus which includes means for supplying two separate breathing gases, one of which has a higher oxygen content, or partial pressure, than its counterpart. That gas having the higher oxygen content is supplied at a constant mass flow rate through a collapsible gas storage chamber, the expansion of which is limited to a predetermined volume generally corresponding to the exhalation volume of a user at rest or during a period of limited physical exertion. The collapsible gas storage chamber also includes means, such as a rigid portion engaging a valve operator, to permit gas to flow, in response to the collapse of the collapsible storage chamber, from that gas supply having a lower oxygen content. The gases thus supplied are then delivered through an outlet line in the collapsible gas storage chamber, to the user. Typically, the user would receive the breathing gases thus supplied through a closed breathing chamber adapted to communicate with the breathing passages of the user and also communicating, through an inhalation valve, with the gas supply line. Preferably, this closed breathing chamber comprises a mouthpiece or mask of conventional design, also including an exhalation valve through which the mouthpiece or mask communicates with a recycle line by which exhalation gas is delivered through a carbon dioxide removing means, such as a chemical CO_2 scrubber, back to the collapsible gas storage chamber. After the collapsible gas storage chamber has been fully expanded by the exhalation gas, any excess exhalation gas is vented by an overpressure or dumping valve provided for that purpose.

By limiting the volume of the collapsible gas storage chamber to the volume of a normal inhalation of a resting individual the hazard of failure of gas flow is limited by the physiological tendency to take deeper breaths when a gas is partially rebreathed to the point of lowering the inspired oxygen concentration. Such deeper inhalation draws new gas from the demand supply system on emptying the collapsible reservoir then, on exhalation, conserves the oxygen in the last portion of the inhalation (the "dead-space" oxygen) by exhaling it into the collapsible storage container and selectively discharging the gas with lower oxygen concentration from the last portion of the exhalation. Preferably, a flow-sensitive valve, which closes in response to a failure of the constant mass flow gas supply, prevents passage of any exhalation gas back to the collapsible gas storage chamber in the event of such failure, thereby converting the system to a straight demand-supply system and preventing rebreathing of oxygen-depleted gas.

This invention may be better understood by reference to the following detailed description, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic assembly view of a breathing apparatus subassembly embodying the basic features of the present invention;

FIG. 2 is a cross-sectional detail view of a fail-safe valve which may be incorporated in a breathing apparatus of the type taught herein;

FIG. 3 is a schematic assembly view of a breathing apparatus in accordance with the present invention, in which a subassembly slightly different than that shown in FIG. 1 is utilized;

FIG. 4 is a cross-sectional detail view of an overpressure valve shown in the assembly view of FIG. 3;

FIG. 5 is a series of graphical illustrations of gas flows in a system of the type shown in FIG. 3.

Referring more specifically to FIG. 1, there is shown a schematic illustration of a subassembly incorporating the basic features of the present invention. More specifically, a collapsible gas storage chamber 2, housed in a perforated rigid enclosure 4 which limits its volumetric expansion, but exposes it to ambient pressure, communicates with gas inlet line 6 adapted to receive breathing gas with a relatively high conventration of oxygen delivered through a constant mass-flow metering device, all of which is not shown in FIG. 1. Line 6 delivers breathing gas through orifice 8 to chamber 2. A second gas inlet line, namely, demand flow gas inlet line 10, is adapted to receive breathing gas of relatively low oxygen concentration from a source thereof and through a pressure reducer such that gas is delivered through inlet line 10, at a predetermined pressure increment above ambient, through orifice 12 and demand valve 14 (shown in a closed position in FIG. 1), to a lower section 16 of chamber 2. Lower section 16 of chamber 2 communicates with the main part of chamber 2 through fail-safe valve 17 and is closed at its opposite end by diaphragm 18, which operatively engages demand valve actuator 20 so that demand valve 14 is opened in response to collapse of diaphragm 18. Diaphragm 18 is also protected from and exposed to ambient pressure by a rigid perforated housing 22. Collapsible gas storage chamber 2 together with the lower section thereof 16 also include a gas outlet line 24 adapted to be connected to a breathing chamber or breathing mask or mouthpiece through an inhalation valve 26, which opens in response to the negative pressure produced by inhalation. Inhalation valve 26 may be located in the breathing apparatus subassembly shown in FIG. 1 or alternatively may be located in the breathing chamber, mask, mouthpiece, etc. Similarly, collapsible gas storage chamber 2 communicates with a gas inlet line 28 adapted to communicate, through an exhalation valve 30, with the breathing chamber, or breathing mask, or breathing mouthpiece, which in turn is in communication with the breathing passages of a user of the apparatus.

Collapsible gas storage chamber 2 communicates with lower section thereof 16 through fail-safe valve 17, which is maintained in the open position by bellows 32 under the pressure of the constant mass supply gas with which bellows 32 is in communication through orifice 34. Valve member 36 is seated against separator 38, which separates the upper part of collapsible gas storage chamber 2 from the lower part 16 thereof, in response to a drop in the pressure of the constant mass gas supply. This closes the rebreather circuit in the event of failure or exhaustion of the constant mass gas supply converting the system to an open circuit demand system and preventing rebreathing of oxygen-depleted gas. Valve 14 then becomes operative to supply gas, directly from the demand supply.

In the operation of a breathing apparatus incorporating the subassembly shown in FIG. 1, a constant mass flow of gas with a relatively high oxygen content, calculated to satisfy, for example, the basic metabolic needs of a user at rest and under other given conditions, is introduced through inlet line 6. Breathing gas in collapsible gas storage chamber 2 is exhausted to the user on inhalation through inhalation valve 26 and outlet line 24. During exhalation, the exhalation gas is returned to collapsible gas storage chamber 2 through inlet line 28 and exhalation valve 30 after passing through a carbon dioxide removal means, not shown. By use of high mass flow of gas with a small volume for the collapsible gas storage chamber the requirement for a carbon dioxide removal means can be eliminated. An overpressure valve 40 may be used to vent excessive pressure in storage chamber 2, although such an overpressure valve is preferably located, as described more fully hereinafter, at or near the breathing mask or breathing chamber upstream of the carbon dioxide removal means.

In the event the breathing gas needs of the user exceed that provided by the constant mass flow supply line, such as in periods of physical exertion, the volume of gas in storage chamber 2 and provided contemporaneously with inhalation by constant mass supply line 6 will be inadequate. The negative pressure of inhalation then causes collapse of diaphragm 18 thereby opening demand valve 14 through actuation of demand valve actuator 20 and thus providing for the delivery of additional breathing gas, as required, to the breather through inhalation valve 26.

To prevent rebreathing of breathing gases exhausted of their necessary oxygen content, fail-safe valve 17 closes upon exhaustion of the constant mass flow gas supply or a drop in pressure thereof. Obviously, various other types of sensing means, such as pressure sensors, rotometers, etc. may also be used to sense a failure of the constant mass flow. Thereafter, the rebreathing circuit is closed and the apparatus operates as a pure demand system with valve 37 closing and opening, respectively on exhalation and inhalation. As in any demand system, the user is warned of approaching supply exhaustion by difficulty in inhalation due to pressure drop in the supply. Similarly, if the demand supply fails, the volume of the collapsible gas storage chamber 2 is too small for full inhalation in even moderate exertion, providing immediate warning of failure of the demand supply. The volume of constant mass flow supply will ordinarily be inadequate to meet a user's needs for inhalation in periods of physical exertion, thereby also making inhalation difficult. In either event, therefore, the user is warned of system failure. If the demand system gas supply fails and physical exertion is continued the limitation of inhalation volume is accompanied by a progressive decline in inspired oxygen concentration from the rebreathed gas in the collapsible gas storage chamber, due to metabolic consumption of oxygen. At rest the inspired oxygen concentration will not fall.

Because the additional gas needed for breathing during periods of physical exertion is provided by the demand supply which is of a lower oxygen concentration or partial pressure, the danger of oxygen toxicity caused by breathing of high oxygen content gas during periods of physical exertion is inherently minimized in the hybrid breathing system of the present invention.

Turning now to FIG. 2, there is shown in detail an improved form of fail-safe valve 17, in which constant

mass flow gas supply passes through orifice 34 into bellows 32 and thence, when valve 17 is open, out of bellows 32 and through separator 38. In this embodiment of valve 17, valve member 36, valve stem 42, and valve operator 48 are moved via valve guide 44 into the open position by the constant mass flow gas stream. Bellows 32 encounters stop 33 preventing its further expansion when valve 17 is open. Failure of this constant mass flow stream permits relaxation of valve spring 46 and the collapse of bellows 32, in turn causing valve member 36 to seat on separator 38.

In FIG. 3, a somewhat different form of breathing apparatus subassembly (than that shown in FIG. 1) is shown as is an overall breathing apparatus in which it is incorporated. Using like numbers to refer to members previously described, collapsible gas storage chamber 2, the volumetric expansion of which is limited by perforated rigid enclosure 4 (through which collapsible gas storage chamber 2 is exposed to ambient pressure) communicates through fail-safe valve 17 (of the type shown in FIG. 2) with the inhalation tube 52 of a breathing mask or mouthpiece 54, in which is included inhalation valve 26 and exhalation valve 30. Through exhalation valve 30, breathing mask 54 communicates with exhalation tube 56 through which exhalation gases are passed to a carbon dioxide cannister or scrubber 58 (conventionally a housing containing a chemical absorbent for carbon dioxide) and thence back through fail-safe valve 17 to collapsible gas storage chamber 2. Relatively high oxygen concentration breathing gas is supplied through a constant mass flow metering device, not shown, inlet line 6 and bellows 32 of fail-safe valve 17 to collapsible storage chamber 2. When gas from line 6 and from the rebreathing circuit is inadequate, such as in periods of physical exertion, perforated plate 60 in collapsible gas storage chamber 2 operates demand actuator 20 to open demand valve 14 and thereby provide additional breathing gas, of lower oxygen concentration for reasons described above, from demand gas flow inlet line 10.

On exhaustion of or other failure of the mass flow gas supply and consequent closure of the fail-safe valve 17, inhalation of gas released into storage chamber 2 from demand valve 14 occurs via one-way valve 37, the opening of which is assisted by the negative pressure in the inhalation tube 52 operating on the downstream side of the valve 37 which is responsive to a pressure difference across its face.

Overpressure, exhaust or dump valve or vent 40 in this embodiment of the invention is located near or in the breathing mask or mouthpiece 54. As shown in FIG. 4, the exhaust valve here utilized comprises a rigid perforated enclosure 62 with bellows 64 tending to hold valve member 66 in its closed position seated against separator 69. Bellows 64 communicates with pressure-compensating tube 68 by which valve member 66 is biased into the closed position with a pressure equal to that in the breathing gas storage chamber 2, which is in turn balanced against ambient pressure by virtue of its exposure to ambient through perforated enclosure 4.

Thus upon exhalation, the exhalation gas is delivered preferentially through the CO_2 scrubber to the collapsible gas storage chamber 2. Preferably the volume of that chamber in its fully expanded condition is a predetermined volume related to the expected exhalation volume of the user under some preset condition such as a user at rest. In that case, the system will effectively be a total rebreather system. However, when the exhalation volume exceeds this amount, such as in periods of physical exertion, the exhalation will produce a pressure build-up such that the pressure on valve member 66 will exceed by some predetermined increment that in collapsible gas storage chamber 2 and force valve member 66 to open, thus venting the remainder of the exhalation gas. Since it is well known that the last part of an exhalation is substantially higher in carbon dioxide content, particularly during periods of physical exertion, than those portions of the exhalation which precede it, location of dump valve 40 upstream of CO_2 scrubber 58 causes dumping of that gas containing a maximum of CO_2 thereby prolonging the life of the CO_2 scrubber chemical by reducing the amount of CO_2 which it must remove.

The function of the breathing apparatus of the present invention may best be illustrated by the graphical analysis of various gas flows into and from the system and within the system shown in FIG. 5. As the graph titles in FIG. 5 indicate, gas flow is illustrated for four sets of conditions, namely, with the user at rest in an ambient pressure of 1 atm., with the user in a period of physical exertion at an ambient pressure of 1 atm., with the user at rest in an ambient pressure of 3 atm., and with the user in a period of physcial exertion in an ambient pressure of 3 atm. The first horizontal set of curves illustrate tidal volumetric flow to and from the user. It will be noted that volumetric flow is roughly the same at rest regardless of whether the user is at an ambient pressure of 1 atm. or 3 atm., but substantially higher during periods of physical exertion at the two ambient pressures illustrated.

The second horizontal set of graphs illustrate that the volumetric flow rate of the constant mass flow supply is constant regardless of the physical state of the user, but is substantially reduced when the ambient, and therefore the system, pressure increases to 3 atm. The cumulative volume flow as the bag is emptied and as it is filled is shown in the next two horizontal sets of charts, and in both of these cases it will be noted that the bag is substantially emptied and substantially filled in phase with inhalation and exhalation when the user is at rest. During periods of physical exertion, however, the bag is emptied and filled, respectively, much faster and the remaining inhalation gas is provided, as shown in the horizontal set of graphs titled Demand Flow, by the demand supply which takes over after the bag is completely emptied. Similarly, the remaining exhalation gas after the first part of the exhalation has filled the bag, is vented to the ambient environment as shown in the bottom horizontal set of graphs. Finally, also in the bottom horizontal set of graphs, entitled Gas Venting Cumulative Volume, a relatively small quantity of gas is shown to be vented in each breathing cycle even when the user is at rest. This corresponds roughly to the volume of diluent gas introduced into the system along with the constant mass flow supply when that supply utilizes a breathing gas with an oxygen content of less that 100 percent.

The graphical analyses as shown in FIG. 5 are not drawn to scale and are based on estimated relative proportions rather than tests or numerical calculations.

In Table 1 (below) there is shown a summary of various gas flows and volumes, as well as gas concentrations, for various conditions of collapsible chamber

storage volume, user's physical state (at rest or in a period of exertion) and for various constant mass flow rates in a system of the type shown in FIG. 3. It will be noted that two values of CO_2 concentration are given, the first of which is the CO_2 content of the exhaled gases at the end of the inhalation cycle, and the second is the average in the total exhalation. The values for breathing volumes and concentrations are all based on physiological tests. The gas flow rates and concentrations within the system are based on calculations for these various sets of conditions. Nevertheless, Table 1 illustrates, inter alia, that with a constant mass flow supply of 100 percent oxygen, as may be tolerated by user at rest at one atmosphere of ambient pressure, the percentage of oxygen in the breathing gas decreases substantially, to on the order of 20 percent (comparable to ordinary air) under conditions of exercise. Table 1 also shows various interrelationships between collapsible chamber volume, constant mass flow rates, oxygen and CO_2 concentrations, and physical state of user which permits the design and adjustment of a system tailored to the particular needs of any user.

Other advantages of the breathing apparatus of the present invention include minimization of the resistance to breathing by providing peak inspiratory flow from a "fractional breathing bag" (collapsible chamber less than breathing volume for each cycle) in parallel with the demand unit. By selection of the appropriate small volume for the "fractional breathing bag," the overall apparatus weight required to accomplish neutral buoyancy for underwater use is reduced.

Extension of the gas-saver principle, previously patented by the inventor herein, see U. S. Pat. No. 2,871,854, Lambertsen, retains the feature of selective dumping of the last part of each exhalation, with increasing efficiency of CO_2 dumping as the degree of physical exercise increases.

As mentioned above, employment of dual gases provides for automatic compensation for the decreased oxygen tolerance of exercise.

While this invention has been described with reference to particular embodiments thereof, it should be understood that numerous other embodiments and various modifications of all of these embodiments may be made within the true spirit and scope of the present invention. The appended claims are intended to cover all such embodiments and modifications as would be obvious to one skilled in the art.

TABLE 1.—GAS UTILIZATION SUMMARY

Activity	Collapsible gas chamber volume, l.	O_2 used, l./min.	CO_2 formed, l./min.	Volume breathed per min.	Breath frequency per min.	Volume per breath, l.	Peak CO_2, percent	Av. CO_2, percent	Mass flow, l./min.	Demand flow, l./breath	O_2 insp., percent	CO_2 dischg., l./min.	CO_2 fraction dischg.	CO_2 fraction absorbed
Rest	.500	.260	.200	6.7	14	.50	5.5	2.99	.500	0	100	.013	.06	.94
	.600									0	100	.013	.06	.94
	.700									0	100	.013	.06	.94
	.800									0	100	.013	.06	.94
	.900									0	100	.013	.06	.94
	1.000									0	100	.013	.06	.94
	.500	.260	.200	6.7	14	.50	5.5	2.99	.750	0	100	.027	.14	.86
	.600									0	100	.027	.14	.86
	.700									0	100	.027	.14	.86
	.800									0	100	.027	.14	.86
	.900									0	100	.027	.14	.86
	1.000									0	100	.027	.14	.86
	.500	.260	.200	6.7	14	.50	5.5	2.99	1.000	0	100	0.41	.20	.80
	.600									0	100	0.41	.20	.80
	.700									0	100	0.41	.20	.80
	.800									0	100	0.41	.20	.80
	.900									0	100	0.41	.20	.80
	1.000									0	100	0.41	.20	.80
Moderate Exercise	.500	1.000	.800	29.0	24	1.20	5.5	2.76	.500	.700	22.0	.46	.58	.42
	.600									.600	21.0	.40	.50	.50
	.700									.500	20.1	.33	.41	.59
	.800									.400	18.9	.24	.30	.70
	.900									.300	17.2	.20	.25	.75
	1.000									.200	13.9	.13	.16	.84
	.500	1.000	.800	29.0	24	1.20	5.5	2.76	.750	.700	24.7	.46	.58	.42
	.600									.600	23.7	.40	.50	.50
	.700									.500	22.9	.33	.41	.59
	.800									.400	22.0	.24	.30	.70
	.900									.300	21.0	.20	.25	.75
	1.000									.200	19.2	.13	.16	.84
	.500	1.000	.800	29.0	24	1.20	5.5	2.76	1.000	.700	27.7	.46	.58	.42
	.600									.600	26.6	.40	.50	.50
	.700									.500	25.8	.33	.41	.59
	.800									.400	25.2	.24	.30	.70
	.900									.300	24.8	.20	.25	.75
	1.000									.200	24.6	.13	.16	.84
Strenuous Exercise	.500	2.000	1.600	65.0	34	1.90	5.5	2.46	.500	1.40	20.9	1.17	.73	.27
	.600									1.30	20.3	1.09	.68	.32
	.700									1.20	19.8	1.00	.63	.37
	.800									1.10	19.3	.92	.58	.42
	.900									1.00	18.8	.84	.53	.47
	1.000									.90	18.2	.75	.47	.53
	.500	2.000	1.600	65.0	34	1.90	5.5	2.46	.750	1.40	22.4	1.17	.73	.27
	.600									1.30	21.7	1.00	.68	.32
	.700									1.20	21.1	1.00	.63	.37
	.800									1.10	20.5	.92	.58	.42
	.900									1.00	20.0	.84	.53	.47
	1.000									.90	19.5	.75	.47	.53
	.500	2.000	1.600	65.0	34	1.90	5.5	2.46	1.000	1.40	24.0	1.17	.73	.27
	.600									1.30	23.1	1.09	.68	.32
	.700									1.20	22.4	1.00	.63	.37
	.800									1.10	21.8	.92	.58	.42
	.900									1.00	21.2	.84	.53	.47
	1.000									.90	20.7	.75	.47	.53

I claim:

1. Dual mode breathing apparatus comprising

a. first and second gas source inlet lines connected to high pressure sources of a first and a second oxygen-containing breathing gas, respectively, said first gas having a higher partial pressure of oxygen than said second gas,

b. a collapsible gas storage chamber with gas storage chamber inlet and gas outlet lines, said chamber having a first positive means to permit gas to flow, upon collapse of said chamber, from said second gas source inlet line to said gas storage chamber outlet line, and a second positive means to limit the volumetric expansion of said chamber to no more than one liter,

c. means for delivering said first gas from said first gas source inlet line at a constant mass flow rate to said collapsible gas storage chamber and further including a closed breathing chamber adapted to communicate with the breathing passages of a user of said apparatus, said breathing chamber also communicating with said gas outlet line from said collapsible gas storage chamber through an inhalation valve means and with said gas inlet line to said collapsible gas storage chamber through an exhalation valve means.

2. Breathing apparatus, as recited in claim 1, further including means for removing carbon dioxide from gas flowing in said gas inlet line of said collapsible storage chamber.

3. Breathing apparatus, as recited in claim 1, further including a dump valve means for releasing gas from said collapsible chamber to the environment surrounding said apparatus in response to said collapsible chamber reaching its fully expanded state and the pressure in said chamber exceeding that in said environment by some predetermined increment.

4. Breathing apparatus, as recited in claim 3, and further including a means, downstream of said dump valve, for removing carbon dioxide from gas flowing in said gas inlet line of said collapsible storage chamber.

5. Breathing apparatus, as recited in claim 1, wherein said breathing chamber comprises a mouthpiece adapted to engage the mouth area of a user of said apparatus.

6. Breathing apparatus, as recited in claim 1, wherein said collapsible gas storage chamber comprises a flexible enclosure housed in a rigid supporting member having openings therein, said flexible enclosure including a rigid portion adapted, upon collapse of said enclosure, to engage a valve operator which together with its associated valve comprises said first positive means recited in part (b) of claim 1.

7. Breathing apparatus, as recited in claim 1, further including a sensing means for sensing a failure in said constant mass flow and for interrupting gas flow from said storage gas chamber inlet to said breathing chamber in response thereto.

* * * * *