Dec. 14, 1948. D. S. MARTIN, JR., ET AL 2,456,606

INERT GAS ELIMINATOR FOR HIGH ALTITUDE OXYGEN APPARATUS

Filed Aug. 10, 1944

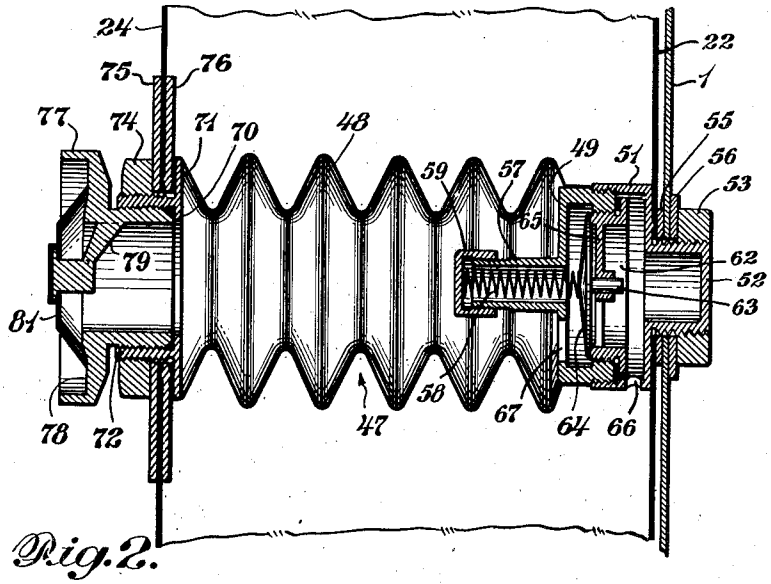


Fig. 2.

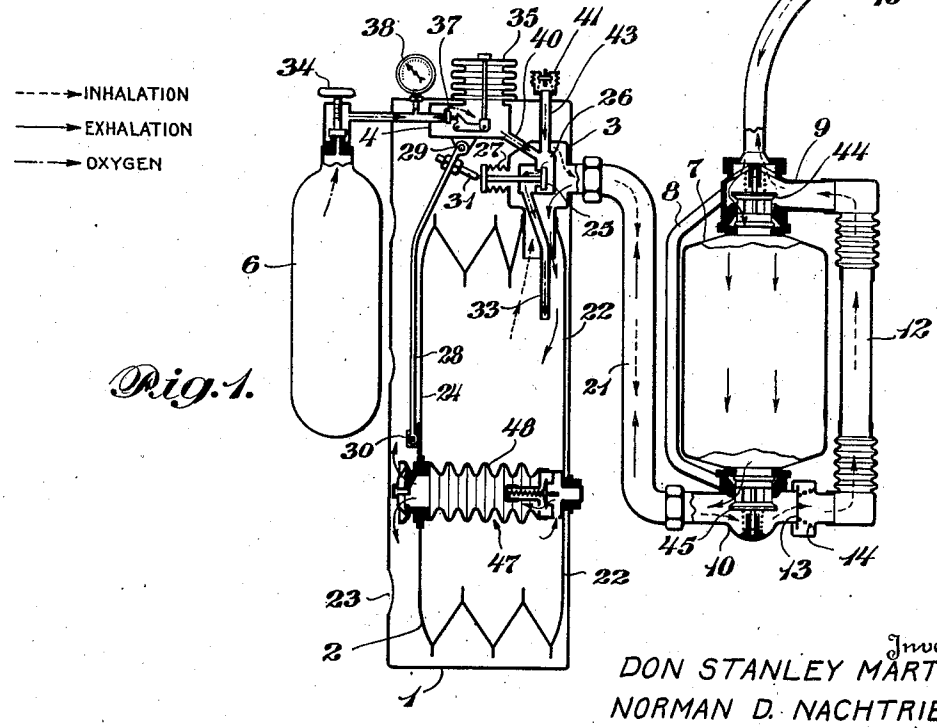


Fig. 1.

Inventors

DON STANLEY MARTIN, JR.

NORMAN D. NACHTRIEB

JARVIS EDWIN SEEGMILLER

By W. Glenn Jones

Attorney

Patented Dec. 14, 1948

2,456,606

UNITED STATES PATENT OFFICE

2,456,606

INERT GAS ELIMINATOR FOR HIGH ALTITUDE OXYGEN APPARATUS

Don Stanley Martin, Jr., Santa Fe, N. Mex., Norman D. Nachtrieb, Chicago, Ill., and Jarvis Edwin Seegmiller, Salt Lake City, Utah, assignors to the United States of America as represented by the Secretary of the Navy

Application August 10, 1944, Serial No. 548,882

7 Claims. (Cl. 128—191)

1

This invention relates to automatic nitrogen eliminating mechanism for high altitude oxygen rebreathing apparatus used by flying personnel.

High efficiency in the ultilization of oxygen and the consequent saving in weight are attractive features of the rebreather type oxygen apparatus for aviation use. The gases, still rich in oxygen, which are exhaled from the lungs, are not lost to the atmosphere; instead, they pass through a canister containing suitable chemicals and into a flexible rubber bag. The chemicals in the canister absorb carbon dioxide from the gas stream and may simultaneously generate oxygen. As oxygen is consumed from the system, it is replaced automatically from a small light-weight cylinder. Thus, with a satisfactory seal around the facepiece, the rebreather, together with the lungs and air passages of the person, forms a closed gas system from which oxygen can escape only into the blood stream of the body.

A serious disadvantage inherent in the use of rebreather type oxygen apparatus is the danger from inert gas which enters the system. Such gas consists chiefly of nitrogen and small amounts of the rare gases customarily designated only as nitrogen. The displacement of oxygen by any nitrogen in the closed rebreather system may result in serious or even fatal anoxia at high altitudes. The presence of nitrogen in the gases decreases the safe "ceiling" for the personnel. Even with the facepiece fitted satisfactorily and a tight rebreather system, nitrogen may enter the system from two sources. One source is the human body itself, which, in breathing air, dissolves throughout its tissues and fluids an amount of nitrogen of the order of one liter. When a person breathes oxygen, the dissolved gases leave the body by way of the lungs and when he is using the rebreather apparatus they enter into and remain in the closed system described above. Another source of nitrogen is the commercial breathing oxygen in the auxiliary cylinder which replaces oxygen used up in the rebreather system. A number of analyses have shown that such oxygen cylinders contain approximately 1% of inert gas. Thus the small cylinder used with this type of apparatus, which contains about 200 liters of gas at standard temperature and pressure, would contribute, upon being completely used, approximately 2 liters of nitrogen which would have accumulated in the closed rebreather system.

Prior to this invention it has been the necessary practice for the person using the rebreather apparatus to manually flush the system out after prescribed intervals, each time replacing the nitrogen-containing gases with cylinder oxygen. This, however, imposes an additional task upon the already busy flying personnel, and it is a task which is easily forgotten, resulting in anoxia and its consequences.

2

It is the primary object of this invention to provide automatic means for venting an oxygen rebreathing apparatus at a rate which will substantially eliminate the inert gases from the system without any attention from the personnel using the equipment. In the embodiment shown the venting means is essentially a small pump having valve means and operated by the breathing bag of the rebreathing apparatus during its pulsations. Other objects will become apparent as the description proceeds in connection with the drawings, in which:

Fig. 1 is a sectional view of a rebreathing apparatus incorporating the nitrogen eliminator, and illustrating the flow of the gases in the system; and

Fig. 2 is an enlarged sectional view of the nitrogen eliminator shown in Fig. 1, and showing the details of its construction.

The individual supply type oxygen rebreathing apparatus illustrated supplies flying personnel with respirable air that contains the high percentage of oxygen required for high altitude service. The apparatus operates independently of the external atmosphere; the wearer breathes oxygen in a closed circuit, inhaling from a flexible breathing bag and in turn exhaling through a chemical purifier back into the breathing bag, from which the unused oxygen is available for rebreathing. The chemical purifier, which may, for example, be potassium hydroxide, removes the carbon dioxide from the exhaled air. The oxygen supply that is available for breathing in the bag is continuously replenished in the same amount as that used by the body, in part by automatic admission of oxygen from the high pressure oxygen cylinder, and in part by reaction of the moisture in the exhaled air with the chemical purifier which may also include, for example, some sodium peroxide for that purpose. The rebreather system itself will be described first, and then the operation of the nitrogen eliminator, so that the operation of the combination will be clear.

As shown in Fig. 1, an apparatus case 1 houses and supports a breathing bag 2, an admission valve housing 3, and an oxygen reducing valve 4. An oxygen cylinder 6 is attached to the apparatus case by means not shown. A canister 7 is also attached to the apparatus case by means not shown, the canister itself being held in a canister

holder 8 which holds both ends, the holder 8 being detachably mounted on the apparatus case 1. The canister holder 8 has fittings 9 and 10 respectively into which the passageways in the ends of the canister 7 fit. A flexible hose 12 connects at its two ends to the fittings 9 and 10, providing a by-pass around the canister during an inhalation by the person wearing the apparatus.

The fitting 10 has an inhalation check valve 13 which is held lightly against its seat by a spring 14, permitting passage of the air upwardly through the hose 12 during inhalation, but preventing the downward passage of the air during exhalation, thus requiring the exhaled air to pass through the canister 7 where it is chemically purified, the chemicals absorbing the exhaled carbon dioxide and also evolving oxygen upon contact with the moisture in the exhalations.

A flexible breathing tube 15 connects the upper fitting 9 to a facepiece 16, there being a facepiece valve 18 where the breathing tube connects to the facepiece. The valve 18 has an upper and a lower seat. The normal position of the valve 18 is the open position shown in Fig. 1, it being held in this position against its upper seat by a spring 19. When the valve is spring seated against the upper seat as shown in Fig. 1 the breathing air passes freely back and forth through the valve housing and into the facepiece from the breathing tube, or vice versa. When the wearer presses on the knob 20 to force the valve against the lower seat, it simultaneously uncovers the upper seat, thus closing communication between the breathing tube 15 and the facepiece 16, but opening communication between the facepiece and the outer atmosphere. The knob 20 is pressed in this manner only when the wearer intends to exhale directly to the atmosphere to eliminate nitrogen from the system as will be described.

The fitting 10 has open communication with the admission valve housing 3 through a flexible connecting tube 21, and the admission valve housing has open communication with the interior of the breathing bag 2 as shown in Fig. 1. The breathing bag is a stockinette-reinforced rubber storage reservoir for the breathing air and oxygen supply. It is of bellows design, permitting free contraction and extension with minimum resistance when the wearer breathes into and out of it through the aforementioned connections. At the end 22 into which the valve housing 3 extends, the breathing bag is relatively fixed with respect to the apparatus case. Its other end 24 is free to move towards and away from the fixed end 22 with the contraction and extension of the bag. The left side of the apparatus case is provided with large perforations 23 to vent the interior of the apparatus case to the atmosphere and prevent changes in pressure therein with contraction and extension of the breathing bag.

An oxygen admission valve 25 is held against its seat in the admission valve chamber 26 by means of a Sylphon spring 27. Oxygen is supplied to the admission valve chamber 26 at a pressure of approximately 7 pounds per square inch above the atmospheric pressure from either of two sources to be described. An admission valve lever 28 is pivotally attached at 29 at its upper end to the apparatus case and at 30 at its lower end to the moving end 24 of the breathing bag. Adjacent its upper end the valve lever 28 during its movement contacts the movable end of the Sylphon spring 27 to unseat the valve 25 and admit oxygen to the breathing bag via a tube 33. The

instant at which the valve 25 is unseated and seated again with relation to the cycles of movement of the breathing bag and the admission valve lever 28, is controlled and adjusted by means of an admission valve adjusting screw 31 which is threaded into the admission valve lever and engages the Sylphon spring 27 to unseat the admission valve 25.

One source of oxygen is the oxygen cylinder 6 which has a cylinder valve 34 to shut off or turn on the oxygen supply. From valve 34 the oxygen flows to the reducing valve 4 which is of the single stage expanding bellows type in which the oxygen pressure is reduced from the cylinder pressure of about 1800 pounds per square inch when the cylinder is full, to a pressure of not more than 7 pounds per square inch above the surrounding atmospheric pressure. As the pressure within the reducing valve builds up to the maximum pressure the expansion of the Sylphon 35 forces the valve 37 against its seat, as will be understood by those skilled in the art. A gauge 38 measures the pressure of the oxygen in the cylinder 6 when the valve 34 is open.

From the reducing valve 4 the oxygen flows through a passage 40 to the interior of the admission valve chamber 26, and thence, under the control of admission valve 25 to the interior of the breathing bag through the tube 33. A check valve connection 41, located at the top of the apparatus case 1, is provided in the event that it is desired or required that the apparatus be operated from an auxiliary or central oxygen supply in place of the individual oxygen cylinder 6 mounted on the side of the apparatus case. A passage 43 extends from the check valve connection 41 to the interior of the admission valve chamber 26. When the auxiliary oxygen supply is used instead of the cylinder 6, this cylinder may be disconnected, and the Sylphon 35 will close the valve 37 against its seat to prevent the loss of oxygen through the reducing valve.

When the apparatus is in use, the canister 7 must be replaced from time to time. Means are provided whereby the system operates as a demand type during the time that the spent canister is removed and a new one is being inserted. Fittings 9 and 10 have valves 44 and 45 respectively which are spring pressed towards the canister and seal the openings from the fittings 9 and 10 to the canister when the canister is removed. The valves 44 and 45 are unseated by the canister itself when a canister is inserted in the holder and between the fittings 9 and 10, thus reestablishing communication between the fittings by way of the canister.

The above described elements comprise a rebreather type apparatus without the instant invention applied thereto, and its operation is as follows. Oxygen from the cylinder 6 passes to the reducing valve 4 where the pressure is reduced to approximately 4, and a maximum of 7 pounds per square inch. When the breathing bag 2 is deflated during an inhalation, movement of the admission valve lever 28 causes the admission valve adjusting screw 31 to bear against the Sylphon spring 27 and depress it, thus unseating the admission valve 25 from its seat. This allows oxygen to flow from the admission valve chamber 26, through tube 33, and into the breathing bag. The flow of oxygen into the breathing bag inflates it to the point where the admission valve lever 28 is raised and closes the valve 25 against its seat. The flow of respirable air in the apparatus is as follows: Upon inhalation air is drawn from the

breathing bag 2 through the flexible connecting tube 21, then through the inhalation check valve 13, the flexible hose 12, fitting 9, breathing tube 15, valve 18 and into the facepiece 16. Exhaled air passes from the facepiece, through the valve 18, back through the breathing tube 15 and into fitting 9. The passage of exhaled air back through the flexible hose 12 is prevented by the inhalation check valve 13, so from fitting 9 the exhalations pass through the unseated valve 44 and into the canister 7, thence through the unseated valve 45 in fitting 10, through the flexible connecting tube 21 and into the breathing bag, which is thereby extended.

When it becomes necessary to replace the canister 7 while the apparatus is in use, the apparatus functions as a demand type during the time that the canister is removed. The valves 44 and 45 are automatically spring pressed to closed position when the canister is removed and inhaled air passes from the breathing bag to the facepiece in the normal manner. Upon exhalation, however, the inhalation check valve 13 prevents the return of the breath to the breathing bag, and the exhaled air must be forced out around the edges of the facepiece to the outside atmosphere by increased exhalation pressure. Insertion of a new canister unseats valves 44 and 45 and the apparatus functions again as a rebreather.

In order to prevent the accumulation of inert nitrogen in the system during use, the facepiece valve 18 is brought into operation to flush out the system. This is accomplished as follows. After taking a full inhalation, it is held by the wearer until the valve 18 is pressed against its lower seat by pressure upon the knob 20. This uncovers the upper seat in the facepiece valve. The wearer now exhales, the breath exhausing into the atmosphere through the uncovered upper seat in valve 18. After exhaling, the knob 20 is released, thus closing the upper seat again and uncovering the lower seat. The wearer then inhales again in the normal manner, holds his breath while depressing knob 20 again, and exhales into the atmosphere again as before. In order to completely flush the system of the inert gas three full breaths should be exhaled to the atmosphere in this manner, after which normal use can be resumed. This flushing operation should be done when the apparatus is first donned, and then 5, 10, 15 and 30 minutes after the apparatus is first placed in operation, and at half hour intervals thereafter. Since no breath is returned to the breathing bag during the flushing operations, the breathing bag is not inflated beyond the point where valve 25 becomes closed, and during an inhalation the valve 25 will become opened again at the beginning of the inhalation in order to provide the wearer with a sufficient volume of gas.

The automatic nitrogen eliminator designated generally by the reference numeral 47 in Fig. 1 and shown in detailed enlargement in Fig. 2 does away with the necessity of performing the above described flushing out operations. The eliminator is essentially a small pump operated by the movements of the breathing bag. With each operating cycle of the breathing bag the pump meters a small amount of gas from the breathing bag out to the surrounding air.

The pumping element is a flexible rubber bellows 48, disposed with its axis parallel to the axis of the breathing bag, the bellows being extended and contracted by the breathing bag in its movements. At one end the bellows is mounted on and

sealed to the outer wall of an inlet valve housing 49. A cap 51 has threaded engagement with the outer wall of the housing 49. At its central portion the cap 51 has a hollow stud portion 52 which projects through aligned openings in the fixed end wall 22 of the breathing bag and the side wall of the apparatus case 1. A nut 53 is threaded onto the threaded portion of the stud 52 and clamps the wall 22 and the wall of the apparatus case between the cap 51 and the nut. Thus one end of the bellows 48 is fixedly connected and mounted on the wall of the apparatus case together with the fixed end 22 of the breathing bag. A sealing and spacing washer 55 on the stud 52 separates wall 22 and the apparatus case wall and assists in providing an airtight seal where the stud passes through them. A washer 56 under the nut 53 prevents marring of the apparatus case when tightening the nut, and may have a sealing washer similar to 55 between it and the wall of the case.

The inlet valve housing 49 has a hollow stud portion 57 which houses a valve spring 58. The end of the stud is closed by a cap 59 which is removable for adjustment or replacement of the spring. The housing 49 has internal threads into which a valve seat guide and bushing 62 is threaded, and its left side, as appears in Fig. 2, is the valve seat. In its center the bushing has a valve stem guide for the stem 63 of a valve 64. The guide is attached to the bushing by a strut or spider 65 so that the passage of gases through the bushing is substantially unobstructed. The spring 58 keeps the valve against its seat until it is lifted therefrom by the pressure of the gas when the breathing bag is being contracted. A series of openings 66 in the wall of the cap 51 provide passageways for the gas in the breathing bag to the underside of valve 64. When the valve is unseated the air passing through it exits into the interior of the bellows 48 through one or more openings 67 in the inlet valve housing 49.

The other end of the bellows 48 is attached to and moves with the movable end 24 of the breathing bag, and the valve which discharges the air from the bellows is attached to the movable end of the bellows. A fitting 70 has a central passageway therethrough, a radial flange 71 which fits within the last convolution of the bellows, and a cylindrical flange portion 72 having both internal and external threads. The cylindrical portion 72 projects through an opening in the movable end 24 of the breathing bag and a nut 74 clamps the wall of the bag against the radial flange 71, there being sealing washers 75 and 76 on either side of the bag and between the nut 74 and flange 71. A check valve body 77 having a central passageway therethrough, has threaded engagement with the internal threads of the fitting 70. The valve body has a radial flange portion which provides a valve seat 78. A strut or spider 79 extends into the central passageway of the valve body, and at its end it has a radial flange which supports a flexible valve member 81 at its center. The valve member 81 is of rubber or the like and its edge portions are substantially conical, with the edge resting against the valve seat 78 with a slight pressure due to the resilience of the valve material. This provides a check valve which permits the gases to exhaust under a slight pressure from the interior of the bellows, through the passageway in the valve body 77 and from under the edge of the valve member 81 into the outer atmosphere, but prevents the

entrance of atmospheric air into the bellows when the pressure therein is reduced under the atmospheric air pressure. This type of check valve is known as an "Acushnet" valve.

The left wall of the apparatus case of Fig. 1, which has the large perforations 23 therein, is removable by means not shown. With this wall removed, the check valve body 77 may be removed to inspect the interior of the bellows. The spring 58 may then be inspected or replaced by removing the cap 59.

In operation the bellows 43 is contracted and extended together with the breathing bag in its movements. During an inhalation by the wearer the bellows is therefore contracted, and since the pressure of any gas therein will be increased, the gas will escape from the bellows by passing under the edges of the check valve 81. As the breathing bag is extended during an exhalation by the wearer the bellows will similarly extend and the lower pressure therein will allow the valve 64 to become unseated and some of the gases from the breathing bag will pass into the interior of the bellows. Thus with every cycle of movements of the breathing bag the action of the nitrogen eliminator will be to remove a portion of the gases from the breathing bag and exhaust them to the atmosphere. This continuous discharge of a portion of the gases from the breathing bag prevents the accumulation of inert gases in the rebreather system and the manual flushing method described above is no longer necessary.

The venting rate achieved by the eliminator is dependent on the diameter of the rubber bellows and also on the depth and rate of breathing, so that as the wearer breathes faster and deeper the eliminator vents at a higher rate. With this particular mechanism the venting rate also depends on the degree of distention of the bellows. For this reason it is possible to adjust the venting rate within certain limits by changing the position of the oxygen admission valve adjusting screw 31. This adjustment determines the minimum degree of inflation of the breathing bag below which oxygen will be admitted from the cylinder 6. When oxygen is admitted before the breathing bag is fully deflated, the rubber bellows operates in a more distended condition and pumps out more gas per stroke.

Preferably, the constant of spring 58 is so adjusted that valve 64 will be opened by a differential pressure of approximately 40 millimeters of water between the interior of the breathing bag and the interior of the bellows. This pressure will cause nearly the maximum distention of the breathing bag. Thus when the breathing bag is filled, if the pressure therein becomes too great, the valve 64 will open and gas will be permitted to escape from the system by blowing through the valves 64 and 81. This feature permits excess oxygen, which may be formed by over production of the chemical in the canister or may result from the adjustment of the admission valve adjusting screw 31, to be removed automatically from the system without discomfort for the person using the rebreathing apparatus.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is, therefore, to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are, therefore, intended to be embraced therein.

We claim:

1. In an oxygen apparatus comprising a flexible breathing bag which expands and contracts with the entrance and exit of gases therefrom; a face mask; means forming passageways by which the wearer breathes from and into said breathing bag; means by which oxygen is supplied to make up for the loss of oxygen in the apparatus; and automatic means operated by said breathing bag in its movements and operable to discharge a portion of the gases from the aparatus to prevent an accumulation of inert gases therein, a pump having inlet valve means communicating with the breathing bag and outlet valve means exhausting to the atmosphere.

2. In an oxygen apparatus comprising a flexible breathing bag which expands and contracts with the entrance and exit of gases therefrom; a face mask; means forming passageways by which the wearer breathes from and into said breathing bag; means by which oxygen is supplied to make up for the loss of oxygen in the apparatus; and automatic means operated by said breathing bag in its movements and operable to discharge a portion of the gases from the apparatus to prevent an accumulation of inert gases therein, a flexible bellows type pump having inlet valve means communicating with the breathing bag and outlet valve means exhausting to the atmosphere.

3. In an oxygen apparatus comprising a flexible breathing bag which expands and contracts with the entrance and exit of gases therefrom; a face mask; means forming passageways by which the wearer breathes from and into said breathing bag; means by which oxygen is supplied to make up for the loss of oxygen in the apparatus; and automatic means operated by said breathing bag in its movements and operable to discharge a portion of the gases from the apparatus to prevent an accumulation of inert gases therein, a pump having inlet valve means communicating with the breathing bag and outlet valve means exhausting to the atmosphere, both of said valve means being of the check valve type operable by differential gas pressures.

4. In an oxygen apparatus comprising a flexible breathing bag which expands and contracts with the entrance and exit of gases therefrom; a face mask; means forming passageways by which the wearer breathes from and into said breathing bag; means by which oxygen is supplied to make up for the loss of oxygen in the apparatus; and automatic means operated by said breathing bag in its movements and operable to discharge a portion of the gases from the apparatus to prevent an accumulation of inert gases therein, a bellows within said breathing bag, the bellows contracting and extending with said breathing bag in its movements; a valve inlet means from said breathing bag to said bellows; and valve outlet means from said bellows to the atmosphere.

5. An inert gas eliminator for an oxygen apparatus wherein the wearer exhales into and inhales from a breathing bag, comprising a bellows adapted to fit into the breathing bag and operable to be extended and contracted by the breathing bag in its movements; first valve means at one end of said bellows operable to admit gas from the breathing bag to said bellows; and second valve means at the other end of said bellows operable to exhaust gas from said bellows to the atmosphere.

6. The device described in claim 5 wherein said first and second valve means are check valves which open by differential pressure but prevent the passage of gas therethrough into the breathing bag.

7. The device in claim 5 wherein said first and second valve means are check valves which open by differential pressure, the opening pressure of said first valve being adjustable and said second valve being removable whereby said first valve may be reached for adjustment.

DON STANLEY MARTIN, JR.
NORMAN D. NACHTRIEB.
J. EDWIN SEEGMILLER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
795,679	Bamberger et al.	July 25, 1905
1,225,269	Paul et al.	May 8, 1917
1,472,117	Drager II	Oct. 30, 1923
1,564,835	Drager I	Dec. 8, 1925
2,217,575	Von Hoff	Oct. 8, 1940
2,268,145	Weltz	Dec. 30, 1941
2,269,500	Wildhack	Jan. 13, 1942